Breakthroughs and Emerging Insights from Ongoing Design Science Projects

Research-in-progress papers and poster presentations from the 11th International Conference on Design Science Research in Information Systems and Technology (DESRIST) 2016

St. John, Newfoundland, Canada, May 23-25

Edited by

Jeffrey Parsons
Tuure Tuunanen
John Venable
Markus Helfert
Brian Donnellan
Jim Kenneally

Preface

This volume contains selected research-in-progress papers and poster presentations from DESRIST 2016 - the 11th International Conference on Design Science Research in Information Systems and Technology held during 24-25 May 2016 at St. John's, Newfoundland, Canada.

DESRIST provides a platform for researchers and practitioners to present and discuss Design Science research. The 11th DESRIST built on the foundation of ten prior highly successful international conferences held in Claremont, Pasadena, Atlanta, Philadelphia, St. Gallen, Milwaukee, Las Vegas, Helsinki, Miami, and Dublin. This year's conference places a special emphasis on using Design Science to engage with the growing challenges that face society, including (but not limited to) demands on health care systems, climate change, and security. With these challenges in mind, individuals from academia and industry came together to discuss important ongoing work and to share emerging knowledge and ideas.

Design Science projects often involve multiple sub-problems, meaning there may be a delay before the final set of findings can be laid out. Hence, this volume "Breakthroughs and Observations from Ongoing Design Science Projects" presents preliminary findings from studies that are still underway. Completed research from DESRIST 2016 is presented in a separate volume entitled 'Tackling Society's Grand Challenges with Design Science', which is published by Springer International Publishing, Switzerland.

The final set of accepted papers in this volume reflects those presented at DESRIST 2016, including 11 research-in-progress papers and 4 abstracts for poster presentations. Each research-in-progress paper and each poster abstract was reviewed by a minimum of two referees.

We would like to thank the authors who submitted their research-in-progress papers and poster presentations to DESRIST 2016, the referees who took the time to construct detailed and constructive reviews, and the Program Committee who made the event possible. Furthermore we thank the sponsoring organisations, in particular Maynooth University, Claremont Graduate University, and Memorial University of Newfoundland, for their financial support.

We believe the research described in this volume addresses some of the most topical and interesting design challenges facing the field of information systems. We hope that readers find the insights provided by authors as valuable and thought-provoking as we have, and that the discussion of such early findings can help to maximise their impact.

May 2016

Jeffrey Parsons,
Tuure Tuunanen,
John Venable,
Brian Donnellan,
Markus Helfert,
Jim Kenneally (Eds.)

Contents

Research in Progress

Poster Presentations

Programme Committee:

Tero Päivärinta, Luleå University of Technology
Helmut Krcmar, Technische Universitt Munchen
Frederik Ahlemann, University of Duisburg-Essen
Marlon Dumas, University of Tartu
Oliver Thomas, University of Osnabrueck
Markus Helfert, Dublin City University
Thant Syn, Texas A&M International University
Akhilesh Bajaj, University of Tulsa
Bjoern Niehaves, University of Siegen
Samuli Pekkola, Tampere University of Technology
Tamara Babaian, Bentley University
Debra Vander Meer, Florida International University
Huimin Zhao, University of Wisconsin-Milwaukee
Sven Carlsson, Lund University
Roel Wieringa, University of Twente
Karthikeyan Umapathy, University of North Florida
Michael Schermann, Technische Universität München
Dimitris Karagiannis, University of Vienna
Henk Sol, University of Groingen
Volker Nissen, Technical University of Ilmenau
Oliver Müller, University of Liechtenstein
Subodha Kumar Texas A&M University
Shirley Gregor, The Australian National University
Marcus Rothenberger University of Nevada Las Vegas
George Widmeyer, Fort Lewis College
Victoria Yoon, Virginia Commonwealth University
Jae Choi, University of Wisconsin-Milwaukee
Alan Hevner, University of South Florida
Jörg Becker, European Reseach Center for IS
Alexander Simons, University of Liechtenstein
Bill Kuechler, University of Nevada, Reno
Gerhard Schwabe, Universität Zürich
Robert Winter, University of St. Gallen
George Wyner, Boston College
Michael Rosemann, Queensland University of Technology
Roger Chiang, University of Cincinnati
Paul Ralph, University of Auckland
Karlheinz Kautz, University of Wollongong
Matti Rossi, Aalto University
Sandeep Purao, Bentley University
Kalle Lyytinen, Case Western Reserve University
Ahmed Abbasi, University of Virginia
Sudha Ram, University of Arizona
Susanne Leist, University of Regensburg
Raj Sharman, SUNY, Buffalo
Jinsoo Park, Seoul National University
Brian Donnellan, Maynooth University
Stephan Aier, University of St. Gallen

Balaji Padmanabhan, University of South Florida
Hemant Jain, University of Wisconsin-Milwaukee
Anindya Datta, National University of Singapore

Additional Reviewers

Jannis Beese
Michael Blaschke
Dominik Bork
Kevin Clees
Yating Feng
David Hoffmann
Xingzhi Jia
Markus Lang
Rakesh Mallipeddi
Prabu Ramachandran
Josef-Michael Schwaiger
Michael Walch
Seokjun Youn

General Chairs

Markus Helfert
Brian Donnellan
Jim Kenneally

Program Chairs

Jeffrey Parsons
Tuure Tuunanen
John Venable

Products and Prototypes Chair

Paul Ralph

Proceedings Chair:

Rob Gleasure

Panel Chairs

Monica Chiarini Tremblay
Carson Woo

Doctoral Consortium Chairs

Joerg Evermann
Matti Rossi

Website and Review System Coordinator

Roman Lukyanenko

A Four-Cycle Model of IS Design Science Research: Capturing the Dynamic Nature of IS Artifact Design

Andreas Drechsler[1] and Alan Hevner[2]

[1] University of Duisburg-Essen, Essen, Germany
andreas.drechsler@icb.uni-due.de
[2] University of South Florida, Tampa, FL
ahevner@usf.edu

Abstract. *We propose to extend the well-known three-cycle view for design science research (DSR) with a fourth cycle (change and impact cycle) that captures the dynamic nature of IS artifact design for volatile environments. The appropriation of innovative designs results in organizational changes that happen outside the new artifacts' immediate application contexts. The intention behind introducing the fourth cycle is to integrate recent advances in the DSR discourse conceptually within the DSR cycle model. We critically review such recent advances and integrate them into an extended model. We show how this change and impact (CI) cycle adds an important facet to DSR to cope with dynamic application contexts as well as artifact-induced organizational change and the resulting need for follow-up design efforts. Iterations of the CI cycle represent the continuous design evolution required to keep up with changing organizational environments.*

Keywords: design science research; DSR cycle model; rigor cycle; relevance cycle; design cycle; change and impact cycle

Introduction

In recent years, design science research (DSR) has become an established research paradigm in the IS field [4]. A widely cited model visualizing the paradigm's foundations is Hevner's three cycle view of DSR [6], comprising a rigor, a design, and a relevance cycle. While this three-cycle view comprehensively conceptualizes the critical aspects of a DSR project, it lacks a key dynamic perspective on how the DSR project relates to the organizational context with which it is embedded. Due to the strong link to a real-world problem or situation, the design researcher is, unlike in other research paradigms, not necessarily controlling the DSR project's progress speed. For instance, rapidly changing environmental conditions may require quick and short design cycles to maintain artifact utility. In turn, quick design cycles may leave only limited opportunities to draw on and grow extant theoretical knowledge bases in the rigor cycle [4]. Recent advances in the DSR discourse – such as emergent design science [10] or agile design science [1] – have proposed additional measures for the DSR process to cope with dynamics and time-related aspects in DSR. The root sources for these dynamics often lie in the wider environment outside the artifacts' immediate application context or environment and therefore outside the three cycles of the original model [6].

Against this backdrop, we propose to extend the three-cycle view on DSR with a fourth cycle that covers exactly this wider application context and integrates this source of contextual change and dynamics into the conceptual cycle model of DSR. The extended four-cycle view thus treats dealing with these dynamic aspects not as an exception that a DSR process needs to mitigate or manage outside the research scope. Instead, the four-cycle view elevates these dynamic issues to the same level as refining the artifact in the design cycle or ensuring a research contribution in the rigor cycle. In turn, the four-cycle view allows the DSR paradigm to integrate the proposed individual measures from the literature on how to deal with dynamics in DSR into a comprehensive knowledge base. Further, the four-cycle view allows us to extend our perspective on artifact design beyond its immediate uses to the artifacts' longer-term impacts on their wider organizational or societal environments. Lastly, we propose to extend the underlying cycle metaphor to consider dynamic and different cycle turning speeds. This extension represents design science researchers' needs to consider and synchronize the cycle speeds during a research project to achieve and to take – depending on the extent of friction they experience between different cycles – explicit measures to increase the traction between the cycles so that they keep turning synchronously.

We organize our research-in-progress paper as follows. In the second section, we briefly summarize the three-cycle view and review selected recent advances to the DSR discourse that cover more dynamic DSR aspects. In Section 3, we introduce our proposal for a four-cycle view and show how it integrates dynamic DSR process aspects discussed in the previously reviewed literature. In the fourth section, we draw conclusions and outline further research avenues to build upon our proposed model.

The DSR Three Cycle Model and Proposed Extensions

This section briefly introduces the extant three-cycle view of design science research and outlines recent proposed extensions.

The Established Three-Cycle View

Figure 1 shows a graphical representation of the three cycles: the rigor cycle, the relevance cycle, and, in between, the design cycle. The relevance cycle provides the research problem or opportunity, the requirements, and the acceptance criteria for the artifact's utility in the field [6]. This cycle links the environment to the artifact that we view – in-line with Simon [11] – as a coherent human-made entity that constitutes an interface between its inner workings and the elements of its environment as they are represented in Figure 1: people, organizational systems, and technical systems within a particular application domain (e.g., business, healthcare IT, smart cities). The rigor cycle covers how the artifact design is grounded in extant knowledge bases that include, but are not limited to, scientific theories, but also experience and expertise. Simultaneously, artifact evaluation should rigorously contribute to these knowledge bases in capturing what works, what does not work, and how the evaluation findings fit with and extend the extant theories and experiences. The central design cycle supports the actual artifact design/redesign and the corresponding artifact evaluation. Artifact evaluation can take place within the design cycle in artificial settings (e.g., thought or laboratory experiments) or in real-world contexts [12]. The latter evaluation type comprises field tests that become part of the relevance cycle.

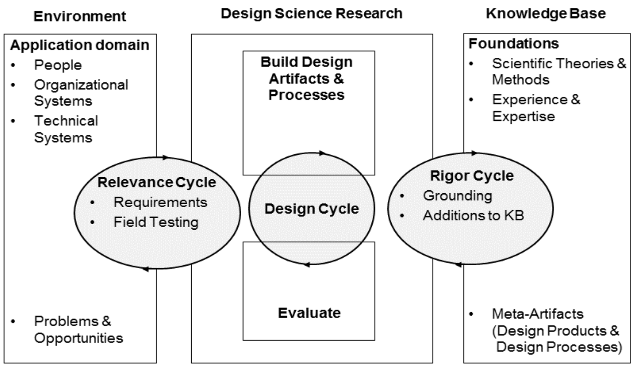


Fig. 1. The Three Cycle View of Design Science Research (From Hevner [6])

Overall, the three-cycle view captures the DSR idea to refine the artifact design iteratively through several interconnected design, relevance, and rigor cycles. This refinement is to increase both the artifact's effectiveness to address the real-world problem as well as its knowledge contributions over several iterations.

Beyond the Three Cycle Model - Extensions

We briefly review several recent contributions to the DSR literature that cover issues that lie beyond the three cycles. We acknowledge that the limited scope and size of this paper does not allow us to conduct a systematic and comprehensive literature review. Despite this, we think that even a few selected sources make a sufficient case for the viability of the four-cycle model that we present in the following section.

Pirkkalainen [10] highlights the emergent nature of many design research projects. Often, DSR projects take place in complex settings with many stakeholders from research and practice communities driving the project. Such projects also often have large-scale overarching objectives beyond just the development of a single artifact. A key initial part of these projects is locating and agreeing on issues that warrant the design of a novel DSR artifact in the first place. Likewise, Mullarkey and Hevner [7] highlight the challenge of defining and agreeing on a design problem to start DSR or Action Design Research (ADR) processes, especially in "wicked" environments. Here, it is pointed out that the three-cycle view does not explicitly contain the starting point or problem trigger that initially sets the cycles in motion.

Conboy, Gleasure, and Cullina [1] speak of complex and changing contexts of DSR projects and propose to adopt an agile metaphor to DSR. The overall objective is broken down into sub-objectives, which are to be reached in shorter iteration cycles in the form of "sprints". Each sprint comprises (re)designs and subsequent evaluations, and may lead to a problem redefinition and corresponding new solution requirements. In contrast, the three-cycle view lacks the notion of a dynamic environment beyond the artifact's immediate application context. There is also no conceptualization of the factor time and iteration speed in the original three-cycle view.

Further, Gill and Hevner [3] propose to consider artifact fitness in addition to artifact utility. In essence, they distinguish two artifact fitness types: 1) Fitness as maximizing an economic utility function focusing on goodness of fit in a design context and 2) Fitness as biological reproduction focusing on sustained design utility over changing 'generational' contexts. In the three-cycle view, the former type of fitness can be placed at the bridge between the design and the relevance cycle. However, since the three-cycle view does not cover changing contexts, there is no place to integrate the latter fitness type into the model.

Lastly, Pandza and Thorpe [8] highlight that one should not treat an artifact's introduction into a context as an engineering-like installation. Instead, introducing an artifact into an organizational context triggers subsequent organizational (or social) change that (hopefully) contributes toward reaching the overarching goal or addressing the problem that served as DSR project trigger. The eventual outcome of such an organizational/societal change process cannot be predicted with certainty, however. We concur and have proposed to conceptualize such a change process not as causation-oriented, but as effectuation-oriented [2], borrowing a model from entrepreneurship research. In contrast, the term "field testing" in the three-cycle view implies that one should just examine whether the artifact manages to cause the intended effects or solution and evaluate its utility accordingly. Again, the idea of having an artifact leading to deliberate larger-scale organizational or societal transformations as well as emergent changes in its contexts, is explicitly absent from the three-cycle view.

Proposing a Four Cycle View of Design Science Research

Here, we propose an extension to the three-cycle view of Figure 1 that allows us to place the advances reviewed in Section 2.2 within the same cycle metaphor and, thus, make sense of them in the greater DSR context.

To better capture the dynamic nature of artifact design for dynamic real-world contexts, we include a fourth cycle in the DSR model as shown in Figure 2. This new cycle is termed the *Change and Impact* (CI) cycle. The newly introduced cycle covers the design artifacts' second-order impacts to their wider organizational and societal contexts. We therefore propose to distinguish an artifact's immediate application context – that covers the direct artifact user(s) within their environment – from the encompassing socio-technical system within which the immediate application context is a subsystem.

For instance, for an information system that is to be used within a particular business process, this business process would be the immediate application context. In contrast, the entire business process chain, the respective business function(s), the encompassing enterprise or even an entire supply chain would form the wider context. Likewise, for a mobile healthcare IT app, the app itself, the mobile device(s), and the doctors and/or patients that use the app would be the immediate application context, while the more encompassing healthcare system and, in an even grander scale, the corresponding country's society in need of improved health care would constitute the wider context.

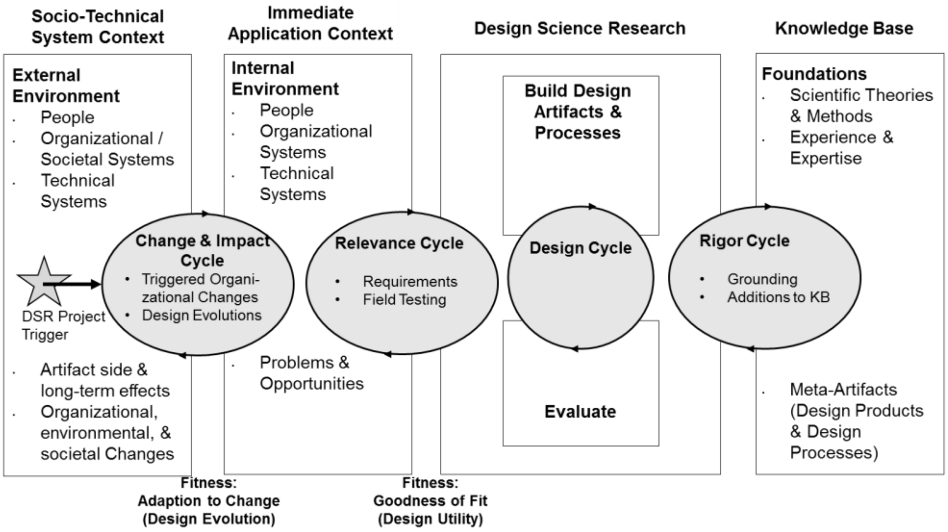


Fig. 2. A Four Cycle View of Design Science Research

We recognize that the delineation between these two contexts can change depending on the design researchers' interests and initial DSR project goals. Thus, in the second example above, is the mobile app itself the "unit of design" that is of key interest and is its intended utility defined as its immediate effects on the patients, or is the mobile app just a part of a more comprehensive healthcare system research project to increase patient care quality for an entire city or region? This delineation may even shift during the project when additional artifact effects within the wider contexts are to be found relevant as part of the immediate artifact's evaluation.
To aid the initial delineation between the immediate and the wider application contexts, we propose to consider the direct trigger for the DSR project as being "just" outside the immediate application context. By this we mean that the objectives of many DSR projects are typically driven by factors in the external environment within which the designed artifacts are to be embedded. Viewed from a stakeholders' perspective within this external environment, the goals of a DSR project are not simply the building and evaluation of artifacts as such but to provide broader impacts to stakeholder communities in organizations and/or society. Simultaneously, there may be DSR projects, such the ones with a design/artifact-centric starting point [9], without an external environment where a CI cycle could take place. Therefore, we do not consider iterations through the CI cycle as necessarily mandatory for DSR.

Benefits and Implications of the CI Cycle

In a static perspective, the additional CI cycle allows researchers to explicitly distinguish the immediate artifact effects or impacts from those it may have indirectly on the wider context, i.e. parts of the research setting that are initially outside the DSR project's scope. Such indirect effects may include long-term effects, but also unintended side-effects a traditional artifact utility evaluation may not be designed to capture. We posit that artifacts especially in complex research settings (such as today's enterprises or societies) will almost invariably trigger such indirect effects. The added notion of societal systems in the extended model also formally reflects the extended role of IS research nowadays that impacts society in domains such as healthcare IT or smart cities compared to traditionally being limited to business organization settings.

In a dynamic perspective, the CI cycle provides a lens for researchers to become more aware of dynamics in the wider organizational or societal context and to make sense of and cope with these dynamics within a research project's scope. Today's organizations and societies are consistently changing (through deliberate efforts as well as due to emergence from within) and, thus, serve as major source for dynamics outside a DSR project's scope. Such external dynamics highlight that goals, rationales, and requirements for DSR projects may change as well over the duration of a research project. Even for purely technical IS artifacts changes in the wider context (such as mergers between enterprises or new legislation) may impact an artifact's viability and utility. A particular change in the wider context may also create a problem that has not existed (or perceived) before and thus constitute the trigger for the entire DSR project. In turn, the artifact's introduction to its immediate application context may likewise serve as trigger for additional changes in the wider environment that will lead to new or changed requirements for the artifact, therefore to new subsequent iterations through the cycles, or, in the worst case, even may make the artifact not viable anymore.

An extended dynamic perspective also enables us to consider the factor of time in DSR in a more differentiated way. First, in DSR projects it is often not the researcher that controls the project's execution speed. Especially when being closely embedded in volatile environments, the pace of environmental change and key stakeholders' urgent needs may demand quick results in form of artifacts that address these needs. Thus, we can regard the CI cycle as often being the "driving axle" for the entire DSR project right from the start when researchers address a particular real-world problem. The CI cycle may also start turning more quickly after the artifact's first incarnation has been placed in the real-world setting and it becomes evident during the evaluation that it requires comprehensive redesigns for immediate utility. In any case, a high rotation speed CI cycle consequently calls for equivalent speeds for the other cycles.

However, depending on the CI cycle turning speed, it may not be possible or feasible to arrive at sufficiently quick artifact redesigns or contributions to the knowledge base, depending on the artifact's constitution or the extant landscape of theories or knowledge bases (or rather, the respective design researchers' knowledge about them). Such a situation carries the danger of the researchers over-emphasizing artifact utility without considering issues such as artifact generalizability or theoretical contributions, in order to satisfy real-world demands.

Following the metaphor of turning cycles even further, we arrive at the notions of *traction* and *friction* between each cycle. Traction exists when the researchers are able to cope with a DSR project's speed when moving back and forth between cycles. Friction occurs when one cycle turns too quickly so that researchers cannot keep up with the needs of the subsequent cycle in time. For instance, in dynamic and unpredictable contexts agile DSR states a goal of achieving quicker turning speeds (short iteration cycles) of the leftmost three cycles (cf. Section 2.2). The enhanced model in Figure 2 highlights this possibility and may help design science researchers to be aware of such dangers and to prepare for such situations beforehand. For instance, by initially reviewing literature more comprehensively including knowledge that may or may not be needed later, researchers can keep the rigor cycle turning more quickly throughout a research project. Alternatively, they can prepare to gather and store data systematically while coping with quick relevance and CI cycles and conduct a single more comprehensive but still thorough rigor cycle that covers several iterations through the design, relevance, and CI cycles after the “dust has settled”.

Further, the four-cycle view allows us to integrate both artifact fitness criteria mentioned in Section 2.2. The “goodness of fit” aspect is covered at the bridge between the design and relevance cycle as it addresses the challenge of successfully adapting an artifact initially to its application context. In contrast, the evolutionary aspect of artifact fitness that covers long-term artifact adaptability rather calls for coverage between the relevance and the newly introduced CI cycle as it is usually the change in the wider contexts that drives long-term artifact fitness requirements for sustained utility. Again, a more dynamic and volatile wider context may require rapid new design generations. This will require the initial design cycles to focus greater attention on sustainable design features such as decomposability, openness, and elegance [3]. Such dynamic notions of artifact fitness also highlight the importance of design theory elements such as artifact mutability [5]. Here, the four-cycle view can help to put the rationale to consider artifact fitness in addition to artifact utility in DSR more front and center than current models.

Lastly, the four-cycle model allows the integration of the extant partial recommendations reviewed in section 2.2 more comprehensively into the underlying DSR foundations. Such integrated meta-design knowledge about DSR processes and products that can cope with high and differing turning speeds allows further research projects in volatile environments to design more useful and sustainably useful artifacts and to further grow this meta-design knowledge base.

Conclusion and Outlook

In this paper, we propose extending the established three-cycle DSR model with a fourth cycle that supports an improved understanding of change and impact (CI) on organizations or society that are triggered by a design artifact upon introduction into its immediate application context. Our goal is to contribute an extension to the conceptual DSR foundations to adequately reflect today’s more ambitious and complex IS DSR projects. The model thus contributes to a maturing discipline that tackles current organizational and societal issues that occur in highly dynamic and volatile environments. We conceptualize the CI cycle as the driving axle of the other three cycles and, thus, the entire DSR process. We posit that most DSR projects start due to changes in the wider environment that lead to a particular (class of) trigger(s) that, in turn, create(s) the need for a novel artifact to address a particular (class of) issue(s).

Based on the initial model proposed in this paper, we see several avenues for further research. First, research is needed to more systematically review and comprehensively integrate extant research that incorporates ‘soft’, organizational, or socio-technical aspects in design. Moreover, we see potential in expanding the notion of traction and friction between the cycles by likewise reviewing and integrating extant research that covers how to bridge the interfaces between any two cycles – for instance, how to deal with inherent artifact complexity and volatility. Such research furthers our overall goals of equipping design researchers for future ambitious and impactful IS DSR projects to cope with grander scopes and dynamic contexts within and outside the projects.

References

1. Conboy, K. et al.: Agile Design Science Research. In: Donnellan, B. et al. (eds.) New Horizons in Design Science: Broadening the Research Agenda. pp. 168–180 Springer International Publishing (2015).
2. Drechsler, A., Hevner, A.: Effectuation and Its Implications for Socio-Technical Design Science Research in Information Systems. In: Donnellan, B. et al. (eds.) At the Vanguard of Design Science: First Impressions and Early Findings from Ongoing Research. pp. 77–84 DESRIST, Dublin, Ireland (2015).
3. Gill, T.G., Hevner, A.R.: A Fitness-Utility Model for Design Science Research. ACM Trans. Manag. Inf. Syst. 4, 2, 5:1–5:24 (2013).
4. Gregor, S., Hevner, A.R.: Positioning and Presenting Design Science Research for Maximum Impact. MIS Q. 37, 2, 337-A6 (2013).
5. Gregor, S., Jones, D.: The Anatomy of a Design Theory. J. Assoc. Inf. Syst. 8, 5, 312–335 (2007).
6. Hevner, A.: A Three Cycle View of Design Science Research. Scand. J. Inf. Syst. 19, 2, 87–92 (2007).
7. Mullarkey, M.T., Hevner, A.R.: Entering Action Design Research. In: Donnellan, B. et al. (eds.) New Horizons in Design Science: Broadening the Research Agenda. pp. 121–134 Springer International Publishing (2015).
8. Pandza, K., Thorpe, R.: Management as Design, but What Kind of Design? An Appraisal of the Design Science Analogy for Management. Br. J. Manag. 21, 1, 171–186 (2010).
9. Peffers, K. et al.: A Design Science Research Methodology for Information Systems Research. J. Manag. Inf. Syst. 24, 3, 45–77 (2007).
10. Pirkkalainen, H.: Dealing With Emergent Design Science Research Projects in IS. In: Donnellan, B. et al. (eds.) At the Vanguard of Design Science: First Impressions and Early Findings from Ongoing Research. pp. 61–68 DESRIST, Dublin, Ireland (2015).
11. Simon, H.A.: The Sciences of the Artificial. MIT Press, Cambridge, Massachusetts (1996).
12. Venable, J. et al.: FEDS: a Framework for Evaluation in Design Science Research. Eur. J. Inf. Syst. (2014).

1. Exploring the workload balance effects of including continuity-based factors in nurse-patient assignments

Haoqiang Jiang, Juanjuan Li, and Debra Vander Meer
Florida International University
hjian006@fiu.edu, jli071@fiu.edu, vanderd@fiu.edu

Abstract. *Workload balance in nurse-patient assignments is important for ensuring quality in patient care. Unbalanced workloads can lead to high levels of nursing stress, medical errors, lower-quality outcomes, and higher costs. Studies have proposed assignment strategies based on patient acuity, location, and characteristics of specialized units. These methods do not address the part of workload associated with continuity in care coordination, and the potential benefits associated with continuity-based assignments. We present the results of a pilot simulation study comparing an acuity-oriented method to a continuity-based approach, using acuity as a measure of workload. Our results suggest that a purely continuity-based approach can result in skewed workloads when measured by patient acuity. In future work, we plan to consider hybrid methods, which may be able to provide the benefits of both continuity and acuity based methods.*

Keywords: nurse-patient assignment, balanced workload, acuity-based assignment, continuity-based assignment

Introduction

- Nurse-patient assignment is an important routine task for patient care delivery and hospital operation. These assignments determine how the patient care workload is distributed among the available nurses to provide care in a work shift [5]. Unbalanced nurse-patient assignments may occur. In such scenarios, patients requiring more difficult and time-consuming care may be assigned to one nurse in a shift, compared to the workloads assigned to other nurses in the shift. These imbalances can lead to increased nursing working pressures, missed care, or medical errors, which can result in lower-quality health outcomes for patients and increased health care costs [2]. Balanced-workload nurse-patient assignments can help to avoid these negative outcomes.

Many hospital units use manual methods to assign nurses to patients. These strategies can vary based on a unit's working norms [1]. For example, a unit might allow nurses select their own patients, or make assignments via a round-robin method, or a charge nurse might set up assignments based on the walking distance between patient rooms, or from a patient room to the nursing station or storage locations [11]. Interesting interdisciplinary work has emerged from collaborations between nursing and engineering researchers, where scholars have proposed mathematical solutions to solve the nurse-patient assignment problem. These approaches consider patient acuity as a metric, and assign nurses to patients using optimization and heuristic methods [5] [9].

Clearly, there is value in balancing workloads using measures such as acuity and walking distance. However, continuity in patient care is also important. Information sharing for care coordination is critical for care delivery [10], but the time and effort related to this are not represented in measures of acuity [12] [13]. For example, grouping a set of patients as a care group, and transferring the group as a set to another nurse at shift change time can reduce communication barriers. Similarly, assigning nurses to patients that they have cared for in previous shifts can result in a reduced learning curve in meeting a patient's needs. Such continuity-based approaches methods can reduce transmission costs in care coordination [14].

While acuity-only approaches can miss opportunities afforded by methods that promote continuity, we suspect that a pure-continuity assignment approach would come with a high cost in terms of acuity balance. In this research-in-progress, we seek to demonstrate this cost with a simulation experiment, showing the potential extent of workload imbalance using a pure-continuity approach for nurse-patient assignment. In next steps in this research effort, we plan to explore hybrid methods that can deliver a combination of the workload-balancing benefits of acuity-only methods, as well as the information transmission benefits of continuity-based approaches.

Related work

Work in nurse-patient assignments has considered both general-setting inpatient care as well as specialty settings. For general inpatient settings, patient acuity and walking distance are two major factors considered in the literature. Acuity-based decision-making approaches consider factors such length of stay, diagnosis, and nurse specialty [9], while distance-based approaches consider measured distances between important locations or recorded time spent walking [11]. Other research considers acuity in specialty settings. In a neonatal intensive care unit, a nurse can be assigned to only a small number of babies, and cannot be assigned to patients in more than one zone [6] [7]. Research has also applied optimization for scheduling nursing assignments in an outpatient chemotherapy setting, aimed at more balanced workloads across the available nursing resources and scheduling windows [5]. These strategies are designed to work within the constraints and norms of specialty settings, and cannot be applied in general inpatient settings.

While there are studies that report on the benefits of reducing transmission costs [14], to our knowledge, there are few systematic studies that consider the impact of continuity-based assignment on workload balance. Our work aims to begin to address this gap in the literature, with the goal of developing hybrid approaches that can take advantage of the benefits of both acuity-based and continuity-based approaches.

Overview

Studies have demonstrated the value of acuity as a metric for generating balance in workload assignments. However, not all of a nurse's time is spent on acuity-driven activities. One example of this is care coordination. Studies have demonstrated that current Electronic Health Record (EHR) implementations do not provide sufficient support for care coordination [12], even though such information transfers are critically important, especially for managing fragile patients, or those with chronic conditions [8]. Absent automated support for information transfers, nurses must initiate in-person communication for knowledge transfers. This generates logistical challenges, for example, in finding the person to or from whom a nurse must transfer information. Studies suggest that continuity-based assignments could help overcome care coordination challenges [10] [14].

Acuity-based and continuity-based assignment methods differ significantly in their bases for decision-making. Acuity metrics are typically based on a quantification of the count and difficulty of the interventions that a patient requires. In contrast, continuity-based assignment methods seek to improve communication and information transfer by removing logistical challenges or reducing required learning curve at knowledge-transfer time [11]. These methods do not consider acuity in assignment.

While there is value in the goals of continuity-based assignment, a purely continuity-based approach would likely result insignificant workload imbalances, when the workload is measured by acuity balance across assignments. We seek to demonstrate these effects in this research-in-process paper. We plan to develop hybrid approaches that incorporate both acuity and continuity as our work continues.

Method and Pilot Study

We seek to compare the variation of workload balance for acuity-based and continuity-based approaches using variation from average acuity for a shift as a metric of imbalance. In a simulation study, we compare four assignment approaches: an acuity-based approach, a continuity-based approach, and assignment methods using random and round-robin approaches. We first define a simple metric for acuity based on nursing workload. We then describe the assignment methods for comparison. Since random allocation and round-robin are generally well-understood, to save space, we describe only the acuity-based and continuity-based approaches, and provide a running example to show how each method assigns nurses to patients. We then present a brief pilot study showing the workload balance impacts of each of these methods.

– Nursing Workload and Patient Acuity

Acuity-based workload assignments typically characterize nursing workload in terms of patient care requirements for workload balancing purposes [5][7][9], i.e., patients with more acute conditions will, on average, require more work in terms of patient care. A nursing shift consists of a number of different care activities, each representing a different portion of a nurse's workload. A study of 767 nurses in 36 hospitals identified five categories of care activities and the associated portion of an average nursing shift accounted for by each category: documentation (35.3%), care coordination (20.6%), patient care activities (19.3%), medication administration (17.2%), and patient assessment (7.2%) [3].

We model patient acuity as a function of these percentage allocations for direct patient care. Our model assumes that the time required for direct care would be similarly allocated, in relative terms, to the average time allocations over the course of a shift. Of the five categories, only three account for variation in acuity across a set of patients: patient care activities, medication administration, and patient assessment activities. Documentation varies roughly directly with overall care activities. Intuitively, this makes sense: each care activity must be documented, so the more care a patient requires, the more documentation that patient will require. Care coordination involves the logistics of communication among healthcare providers at care transfer points, where the specifics of a patient's needs must be clearly conveyed from one caregiver to another [10]. This generally does not vary with acuity; rather, it varies more with the number and scope of obstacles and logistical challenges associated with arranging face-to-face communication in a busy inpatient setting. The time associated with care coordination is therefore associated with continuity, which is the focus of our study.

We model acuity as a weighted function t, shown in Expression (1), of expected effort across three aspects of nursing workload for a patient: medication (denoted d), care assessment (denoted r) and care activities (denoted a). The weights for d, r, and a are based on the percentages of expected effort [3] normalized to sum to 1.0, i.e., overall acuity for a patient will fall in the range [0,1]. The input values for d, r, and a can come from a variety of possible sources, including manual estimation and acuity assessments provided by an EHR. In this work, we assume a simple estimation of patient acuity for each of the three dimensions on a 1-5 Likert scale (where 1 refers to low acuity for a dimension, and 5 refers to high acuity) at the beginning of each shift. Division by 5 ensures that patient overall acuity scores fall in the range [0,1].

$$\mathrm{t} = (0.39\mathrm{d} + 0.44\mathrm{r} + 0.17\mathrm{a})/5 \tag{1}$$

– Method

As a part of the larger research project, we generated a set of simulated shift sequences. While this work is not yet complete, we used a portion of one of our shift sequences in our study here. The overall data set contains 1,700 simulated patients, where each patient stays for between four and twelve shifts distributed normally around a mean of 7. A patient's acuity score varies on a per-dimension and per-shift basis; acuity for a dimension (d, r, and a) for a patient-shift is drawn from a normal distribution over the integers in the range [1,5] with a mean of 3, and the overall acuity for a patient in a shift is calculated based on Expression (1). The shift schedule has two 12-hour shifts per day. Nurses are assigned to either the day or night shift, and typically work four days a week.

We describe the acuity-based and continuity-based methods that form the focus of our research here, and illustrate each approach using a sample shift from our simulated shift sequences. We model a nursing shift as follows. A set of nurses is scheduled to work in shift c. Each nurse h_j is assigned to a working package w, where a working package consists of a set of patients. Each patient p_i is represented in shift c with a tuple (p_i, e, t_{p_i},) that represents the patient's status in shift c, where p_i is the patient ID, e represents the count of shifts the patient has been in the unit as of shift c (e.g., a new admission would have a value of e=1), and t_{p_i} holds the patient's acuity in shift c. We summarize our notation in Table 1.

Table 1. Notation

Parameter	Description
t_{p_i}	acuity for p_i
p_i	patient with ID i
e	patient shift in stay
d	medication time
r	care activity time
a	assessment time
c	current working shift
h_j	nurse with ID j
w	working package

The continuity-based approach requires references to the set of working packages in the previous working shift, so we selected a sample shift c from mid-shift-sequence. In shift c, we have 4 nurses and 23 patients; the nurse patient ratio is 1:5.8, which is representative of real-world nurse-patient ratios [4]. The four nurses in shift c are h_1, h_3, h_4, and h_5. The patients in shift c are (p_{108}, 3, 0.844), (p_{110}, 2, 0.766), (p_{15}, 3, 0.746), (p_{48}, 3, 0.742), (p_{14}, 5, 0.732), (p_{25}, 2, 0.722), (p_{53}, 3, 0.698), (p_{26}, 3, 0.688), (p_{38}, 3, 0.68), (p_{115}, 2, 0.678), (p_{63}, 3, 0.62), (p_{59}, 3, 0.60), (p_{89}, 3, 0.59), (p_{74}, 3, 0.58), (p_{36}, 3, 0.532), (p_{75}, 3, 0.512), (p_{65}, 3, 0.492), (p_{51}, 2, 0.458), (p_{34}, 3, 0.444), (p_{90}, 1, 0.442), (p_{77}, 3, 0.39), (p_{96}, 1, 0.312), and (p_{91}, 3, 0.278).

– Acuity-based assignment

The acuity-based approach attempts to balance workload across nurses in a shift by minimizing the deviation from average acuity in nursing workload. We allocate one w per available nurse. We sort patients by descending acuity t_{p_i}, and assign the top acuity patients will be assigned to a working package w. We calculate the total acuity for each w. We sort the working packages by ascending acuity, and the remaining unassigned patients by descending acuity. We assign the highest-acuity patient to the lowest-acuity working package in the round, and continue the sort-assign process until all patients have been assigned to working packages. Once all patients have been assigned to working packages, we assign each working package to a nurse.

We illustrate the acuity-based assignment approach using the sample shift as an example. Since these assignments are based on the patient acuities, we omit e the patient information tuple. There are 23 patients and four nurses, so there will be 6 sort-assign rounds. In the round 1, we used the arrangement as below: w_1:[(p_{108}, 0.844)], w_2:[(p_{110}, 0.766)], w_3:[(p_{15}, 0.746)], w_4:[(p_{48}, 0.742)]. In round 2, the arrangements were: w_4:[(p_{48}, 0.742), (p_{14}, 0.732)], w_3:[(p_{15}, 0.746), (p_{25}, 0.722)], w_2:[(p_{110}, 0.766), (p_{53}, 0.698)], and w_1:[(p_{108}, 0.844), (p_{26}, 0.688)]. In round 3, the acuity totals are 1.464, 1.468, 1.474, and 1.532 for working package w_2, w_3, w_4, and w_1, respectively, before assignment. Round 3 assignments were: w_2:[(p_{110}, 0.766), (p_{53}, 0.698), (p_{38}, 0.68)];

w_3:[(p_{15}, 0.746), (p_{25}, 0.722), (p_{115}, 0.678)]; w_4:[(p_{48}, 0.742), (p_{14}, 0.732), (p_{63}, 0.62)]; and w_1:[(p_{108}, 0.844), (p_{26}, 0.688), (p_{59}, 0.60)].

In the final round, the total acuities of each working packages are 3.15, 3.43, 3.45, and 3.52 for w_1, w_2, w_3, and w_4, respectively, and the final assignments are: w_1:[(p_{108}, 0.844), (p_{26}, 0.688), (p_{59}, 0.60), (p_{74}, 0.58), (p_{90}, 0.442)], w_2:[(p_{110}, 0.766), (p_{53}, 0.698), (p_{38}, 0.68), (p_{36}, 0.532), (p_{51}, 0.458), (p_{96}, 0.312)], w_3:[(p_{15}, 0.746), (p_{25}, 0.722), (p_{115}, 0.678), (p_{75}, 0.512), (p_{65}, 0.492), (p_{91}, 0.278)], and w_4:[(p_{48}, 0.742), (p_{14}, 0.732), (p_{63}, 0.62), (p_{89}, 0.59), (p_{34}, 0.444), (p_{77}, 0.39)]. We assigned w_3 to h_1, w_2 to h_3, w_1 to h_4, and w_4 to h_5.

− **Continuity-based assignment**

In the continuity-based assignment approach, we attempt to reduce the time and effort associated with care coordination and improve continuity of care by transferring working packages intact from one shift to the next. If the set of patients and the number of nurses do not change between shifts, then the assignment strategy is a simple matter of assigning a nurse to each working package. However, we need to account for scenarios where the number of nurses changes from shift to shift, as well as patient admissions and releases. Thus, we introduce the concept of average nurse-patient ratio (denotes as *n-p* ratio) to balance patients across working packages in a shift. Intuitively, the *n-p* ratio describes the desired number of patients per working package when the patient count across working packages is balanced. In all scenarios described below, the patient allocation to a working package or selection for transfer to a different working package is based on a random selection; i.e., the continuity-based method does not consider acuity in decision-making.

If the nurse count in c is the same as the nurse count in shift c-1, but the number of patients in any working package w is bigger than the average *n-p* ratio, we will assign patients to other working packages that do not reach the average *n-p* ratio. If the nurse count in c is greater than the nurse count in c-1, we create new working packages for each additional nurse. Based on the *n-p* ratio in the current shift, we transfer patients from the previous shift's working packages (which exceed the *n-p* ratio) to the new working packages. If the nurse count in c is less than the nurse count in c-1, we need to assign patients to a smaller number of working packages, so we designate one or more working packages for disassembly. Patients in these working packages are transferred to existing working packages based on the *n-p* ratio. In all cases, newly-admitted patients are assigned to working packages based on the *n-p* ratio.

We illustrate the continuity-based approach using the sample shift and the data for the prior shift (c-1) in our simulated shift sequence. This method does not consider acuity in decision-making; therefore, the patient acuity t_{p_i} is not shown in the patient information. In shift c-1, there were five working packages: w_1:[(p_{74}, 2), (p_{75}, 2), (p_{65}, 2), (p_{91}, 2)], w_2:[(p_{15}, 2), (p_{14}, 4), (p_{25}, 1), (p_{63}, 2), (p_{59}, 2)], w_3:[(p_{48}, 2), (p_{53}, 2), (p_{36}, 2), (p_{51}, 1)], w_4:[(p_{110}, 1), (p_{38}, 2), (p_{89}, 2), (p_{34}, 2)], and w_5:[(p_{108}, 2), (p_{26}, 2), (p_{115}, 1), (p_{77}, 2)]. The input for working packages in c is the same working package with incremented patient shift numbers: w_1:[(p_{74}, 3), (p_{75}, 3), (p_{65}, 3), (p_{91}, 3)], w_2:[(p_{15}, 3), (p_{14}, 5), (p_{25}, 2), (p_{63}, 3), (p_{59}, 3)], w_3:[(p_{48}, 3), (p_{53}, 3), (p_{36}, 3), (p_{51}, 2)], w_4:[(p_{110}, 2), (p_{38}, 3), (p_{89}, 3), (p_{34}, 3)], and w_5:[(p_{108}, 3), (p_{26}, 3), (p_{115}, 2), (p_{77}, 3)]. In addition, there are two new admissions in c: (p_{90}, 1) and (p_{96}, 1). The *n-p* ratio in this shift is 1:5.8.

There were five nurses in c-1, but only four in c; therefore, we delete one working package w_1:[(p_{74}, 3), (p_{75}, 3), (p_{65}, 3), (p_{91}, 3)] in c. These patients, as well as the newly admitted patients, are transferred to the intact working packages from c-1 based on n-p ratio. After all transfers and assignments, the working package assignments for c are as follows: w_2:[(p_{15}, 3), (p_{14}, 5), (p_{25}, 2), (p_{63}, 3), (p_{59}, 3), (p_{91}, 3)], w_3:[(p_{48}, 3), (p_{53}, 3), (p_{36}, 3), (p_{51}, 2), (p_{90}, 1), (p_{96}, 1)], w_4:[(p_{110}, 2), (p_{38}, 3), (p_{89}, 3), (p_{34}, 3), (p_{65}, 3), (p_{75}, 3)], and w_5:[(p_{108}, 3), (p_{26}, 3), (p_{115}, 2), (p_{74}, 3), (p_{77}, 3)]. The total acuities of each working packages are: w_2: 3.698, w_3: 3.184, w_4: 3.484, and w_5: 3.18. We assigned w_2 to h_1, w_3 to h_3, w_4 to h_4, and w_5 to h_5.

The final patients' acuities for random assignments are: h_1: 2.594, h_3: 3.796, h_4: 3.552, and h_5: 3.604. And the final patients' acuities for round robin algorithm are: h_1: 3.56, h_3: 3.764, h_4: 3.47, and h_5: 2.752.

The average patients' sum of acuity per nurse is 3.387. We used the standard deviation (denoted as SD) of workload acuity as a metric to the variation of workload acuity across different assignment methods, where SD shows how far each method deviates from the average workload acuity in the shift. In our example shift, SD for the acuity-based method is 0.138, the SD for the random method is 0.466, the SD for the round robin method is 0.382, and the SD for the continuity-based method is 0.218.

Pilot study and discussion

A single shift experimental test is not sufficient to explore the differences among the four approaches, so we performed a pilot study using a 26-shift sequence from one of our simulated shift sequences, and ran each method for each approach. Table 2 shows the average SD across the sequence of shifts for each method studied.

Table 2. Pilot Test Results

	Acuity	Random	Round robin	Same Working Package
Std. Deviation	0.125	0.379	0.308	0.323

As we suspected, we found that the acuity-based method provided the best overall balance of workload acuity, the continuity-based approach delivered workload acuity imbalances in the same range as that provided by Random and Round Robin methods. In future work, we intend to explore the potential for hybrid methods incorporating both continuity and acuity in nursing assignments, with the goal of capturing a balance of the benefits of each assignment technique.

References

Bosek, M. S. D., & Savage, T. A. (2007). *The ethical component of nursing education: Integrating ethics into clinical experience*. Lippincott Williams & Wilkins.

Blackman, I., Henderson, J., Willis, E., Hamilton, P., Toffoli, L., Verrall, C., Elizabeth, A., & Harvey, C. (2015). Factors influencing why nursing care is missed.Journal of clinical nursing, 24(1-2), 47-56.

Hendrich, A., Chow, M. P., Skierczynski, B. A., & Lu, Z. (2008). A 36-hospital time and motion study: how do medical-surgical nurses spend their time?.The Permanente Journal, 12(3), 25.

Lang, T. A., Hodge, M., Olson, V., Romano, P. S., & Kravitz, R. L. (2004). Nurse–patient ratios: a systematic review on the effects of nurse staffing on patient, nurse employee, and hospital outcomes. *Journal of Nursing Administration*, *34*(7-8), 326-337.

Liang, B., & Turkcan, A. (2015). Acuity-based nurse assignment and patient scheduling in oncology clinics. *Health care management science*, 1-20.

Mullinax, C., & Lawley, M. (2002). Assigning patients to nurses in neonatal intensive care. *Journal of the Operational Research Society*, 25-35.

Schaus, P., Van Hentenryck, P., & Régin, J. C. (2009). Scalable load balancing in nurse to patient assignment problems. In Integration of AI and OR Techniques in Constraint Programming for Combinatorial Optimization Problems (pp. 248-262). *Springer Berlin Heidelberg*.

Bates, D. W. (2010). Getting in step: electronic health records and their role in care coordination. *Journal of general internal medicine*, *25*(3), 174-176.

Sundaramoorthi, D., Chen, V. C., Rosenberger, J. M., Kim, S. B., & Buckley-Behan, D. F. (2010). A data-integrated simulation-based optimization for assigning nurses to patient admissions. *Health care management science*, *13(3)*, 210-221.

McDonald, K. M., Sundaram, V., Bravata, D. M., Lewis, R., Lin, N., Kraft, S., McKinnon.M., Paguntalan.H., & Owens, D. K. (2007). Closing the quality gap: a critical analysis of quality improvement strategies, (*Vol. 7: Care Coordination*).

Wolf, L. D., Potter, P., Sledge, J. A., Boxerman, S. B., Grayson, D., & Evanoff, B. (2006). Describing nurses' work: combining quantitative and qualitative analysis. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 48(1)*, 5-14.

Séroussi, B., Jaulent, M. C., & Lehmann, C. U. (2015). Health information technology challenges to support patient-centered care coordination. *Yearbook of medical informatics*, *10*(1), 8.

Jones, C. D., Vu, M. B., O'Donnell, C. M., Anderson, M. E., Patel, S., Wald, H. L., Coleman,E.A., & DeWalt, D. A. (2015). A failure to communicate: a qualitative exploration of care coordination between hospitalists and primary care providers around patient hospitalizations. *Journal of general internal medicine, 30*(4), 417-424.

Austin, D. J., Bonten, M. J., Weinstein, R. A., Slaughter, S., & Anderson, R. M. (1999). Vancomycin-resistant enterococci in intensive-care hospital settings: transmission dynamics, persistence, and the impact of infection control programs. *Proceedings of the National Academy of Sciences, 96*(12), 6908-6913.

2. Designing Location-based Educational Services for School Students at Cultural Institutions: The case of the National Portrait Gallery of Australia

James Steele[1], Shirley Gregor[1], John Campbell[1], Robert Fitzgerald[2], and Byron Keating[1]

[1] Australian National University, Canberra, Australia
{james.steele, shirley.gregor, john.campbell, byron.keating}@anu.edu.au
[2] University of Canberra, Canberra, Australia
robert.fitzgerald@canberra.edu.au

Abstract. *Cultural institutions provide important benefits for society and for the visitors who come to them. Their staff need to understand how information technology can augment the visitor experience, and how to engage with their visitors to design programs that will meet visitors' expectations for greater interaction. Using an iterative, design science based approach, coupled with design thinking workshops bringing stakeholders together, we showed how location-based educational services coupled with mobile apps on handheld devices could be designed to enrich the experience for school students visiting the National Portrait Gallery of Australia.*

Keywords: museum design, design thinking, patterns, pattern language, beacons, positioning, location-based technology

1 Introduction

Cultural institutions such as Australia's National Portrait Gallery provide important benefits to society and to the visitors who come to experience them. Due to resource constraints, many visitors tour the galleries without the benefit of expert guidance that would help to fulfil the Gallery's purpose: "to increase the understanding and appreciation of the Australian people … through portraiture." [1, p. 14]. This is especially true for school students visiting the Gallery. While 11,000 of the 18,500 school students who visited the National Portrait Gallery in 2013-14 participated in facilitated programs [1], the other 7,500 students went on self-guided tours with only an orientation session and the help of a simple app on a supplied handheld device. Our research sought to solve the problem of how to engage those students on self-guided tours using location-based educational services: enriching experiences that could be delivered to students depending on their location within the Gallery and their proximity to particular works.

The community invests heavily in cultural institutions, their collections and staff. Funding pressure from government requires institutions to show value for their activities, something that is currently addressed mainly through quantitative metrics like visitor numbers and the quantified results of exit surveys. While a large scale visitor experience survey was done in the past [3], the Gallery has no formal means to gather qualitative data from visiting school groups to help it design experiences that suit the purpose of the institution and the interests of the visitors. Our process seeks to provide staff at cultural institutions with the skills and techniques to include input from visitors in the design and development of the programs provided by the institutions.

Prior studies have looked at the effectiveness of museum visits for promoting learning [2, 3, 4], but little research has been done on designing information technology-based solutions, particularly those using location-based technologies or social networking techniques, to assist self-guided groups of school students visiting museums [5]. Many cultural institutions have developed mobile apps to augment their visitors' experience [6, 7, 8, 9, 10]. By and large, these apps provide visitors with written, visual and auditory information to supplement what is available in the galleries and exhibitions. Missing from these apps are layers of active engagement and cocreation that educational theory tells us [11, 12, 13] are important for learning to take place.

Learning is a social experience [11], [13]. In *Designing Social Interfaces* [14], Crumlish and Malone provide us with a theory of patterns, principles and practices judged to be 'best practice' in designing social experiences. We used their work as a foundation to design and develop a social experience using location-based technologies to assist the Gallery to better serve visiting self-guided school groups. By abstracting from observation to theory and then developing practical solutions [15], we refined and extended Crumlish and Malone's patterns to support collaborative student leaning.

This paper presents the design of *You2*: a mobile app that guides the experience for school students visiting the National Portrait Gallery of Australia. The team sought to answer two questions in its action research project: how can location-based educational services engage students visiting the Gallery in more meaningful ways when compared with existing arrangements; and how can the Gallery design visitor experiences that take into account the perspectives of all stakeholders?

The paper's theoretical significance is twofold: in the recording of previously unreported design patterns for social interaction to improve the user experience; and in the methods introduced to museum stakeholders to help them include visitors in the design of better visitor experiences.

2 Method

As a research methodology, design is defined as the development of "incrementally effective applicable problem solutions" [16, p. 47]. The project partners investigated the problem of engaging school students visiting the National Portrait Gallery on self-guided visits using an iterative process involving design thinking workshops, observations, discussions, prototyping, video recording and revisions of a 'problem solution': the *You2* app. The workshop design was also refined each time one was held.

Workshop 1. We surveyed the ideas of those involved using a design thinking workshop [17] with 25 representatives of cultural institutions, the researchers, teachers and developers. Design thinking is a process where people from a range of backgrounds all actively work together, even competitively, to address design issues [18]. Participants were taken through a design thinking process and completed worksheets based originally on IDEO's Design Thinking for Educators [19] and Strategyzer's Business Model Canvas [20].

Observations. 450 11-13 year-old students from 10 schools were observed visiting the Gallery on organised visits. Each group was given an introductory briefing and iPad tablet containing the *Reading Portraits* app. *Reading Portraits* is a simple app developed by the Gallery staff to provide groups of up to 15 students with some directions to engage them with the Gallery's collection.

Workshop 2. A second design thinking workshop was held with Gallery staff from a range of disciplines, along with museum researchers, educators, developers and members of the research team. The workshop was briefed on the outcome of the observations and tasked with coming up with ideas for the design of a suitable experience for visiting students.

Software Requirements Specification. The suggestions from these workshops, observations, and discussions with stakeholders were mapped to patterns from Crumlish and Malone' *Designing Social Interfaces* [14] to see how the suggestions fit with established practices, identify best practice solutions, and to see where existing theory was lacking. A Software Requirements Specification (SRS) for a location-based educational services app, *You2*, was developed.

Prototype. An initial prototype *You2* app was developed in Evernote to demonstrate the solution proposed in the SRS. The prototype was evaluated with 15 11-13 year-old students from a local school by observation and video recording of their use of the prototype during a one-hour tour of the Gallery. Each group of three students shared one tablet containing the prototype app. The prototype directed each group to specific galleries, and contained detailed instructions on their tasks. Students entered their responses to the tasks in the prototype itself in text, audio recordings, and with photos. The prototype also contained a survey for the students to complete at the end of their tour of the Gallery. The student responses to the tasks and the survey were collected and analysed after their visit.

Student Design Thinking Workshop. After their tour of the Gallery, the students then participated in a two-hour design thinking workshop based on Institute of Design Stanford's *Gift-Giving Project* [21]. The aims of the workshop were to get their feedback on the experience of using the *You2* prototype and to give them the opportunity to design their own experience of visiting the Gallery. This workshop was video recorded and observed by Gallery staff, the researchers and teachers.

The Final You2 app. The Software Requirement Specification was revised following reflection on the outcomes of the observations of the students using the initial prototype in the Gallery, and their contributions through the design thinking workshop. Further evaluation by observation and survey with students visiting the Gallery will be made once the next iteration of the app is ready.

3 Outcomes

Workshop One. Pattern analysis of transcripts of presentations and content of workshop sheets from the initial workshop using AntConc (text analysis toolkit), TagAnt (part-of-speech tagger), and Wordle (an online word cloud visualisation tool) [22, 23, 24] showed that the participants felt the need for an experience for *groups* visiting the *gallery* that was a *journey* (*tour, trail*) through the space *interacting* with *augmented works* and *creating* a response. The analysis also showed workshop participants agreed that visitors should *experience works* in the *galleries* and *exhibitions*; had access to a *map*, *stories*, and *history*; could *find* out more about *people* (*subjects* and *artists*) and *music* related to them; complete a *quiz*; *connect* with each other; take a *selfie*; *compile* their responses and *send* them to or *exchange* them with other people through the Gallery *website*; and *review* what they themselves and others have done.

Observations at the National Portrait Gallery. Observations of school students visiting the Gallery on self-guided tours showed that both the students and accompanying adults enjoyed their experiences, even though most of them were tired; not prepared; and did not understand what they would experience. The large groups of up to 15 students meant that most students made no contribution to discussions raised as a result of using the *Reading Portraits* app. There was also scope to *prepare students (and accompanying adults) so that they better understood how to behave in a gallery*.

Workshop Two. Participants in the second design thinking workshop agreed that the focus of the experience should be on the *students* rather than *teachers* or *accompanying adults*. To overcome the students' and teachers' weariness, lack of preparation and understanding seen during the observations, it was agreed that visiting groups should be offered programs that would *energise, motivate, engage* and *entertain* them quickly and without assuming that they had done any preparation for the visit.

Software Requirements Specification. Functions in the SRS for the *You2* app were mapped to Crumlish and Malone's framework to look for patterns of best practice for user experience to help with the development of the app. During this process a number of patterns that were not readily apparent in the framework were identified. These new patterns were:

Production	User creates content (audio, photos, text) and selects media for Saving and Displaying
Photographing	User accesses their device's camera through the app to capture full-view and close-up images of selected works, editing and cropping if necessary. The user can choose from the shots taken those to be saved, shared and displayed.

Selfies	User accesses their device's camera through the app to create, choose and edit a selfie to share.
Audio Recording	User uses their device's microphone through the app to create, edit and choose audio to share.
Writing	User adds text to their exhibition to save and display.
Presentation	User organises, saves and exports the materials they have created, and presents them to an audience.

The initial draft SRS defined an experience for the *students* working in *groups* that *actively engaged* them in *tasks* requiring them to *look closely at portraits* and to *record their responses*.

Evernote prototype app. Direct observation and analysis of video recording of students using the prototype showed that the *You2* design worked well. The students enjoyed the experience and carried out the tasks with competence. It was, however, thought that the experience could be simplified a little to reduce the number of separate steps required; and that when making an audio recording of their responses, students should be able to see and review their notes. The students' response to the experience can be best summed up with the following quote from one of the students:

> … The experience we had at the National Portrait Gallery was really excellent. We had loads of fun and we got to look at loads of different portraits, and it was really interesting to look at all the different styles, the way people did them. (Year 6 student after using the prototype *You2* app, September, 2015)

Student Design Thinking workshop. In the student design thinking workshop, the students provided valuable feedback on the prototype and came up with a number of their own ideas for augmenting a visit to the Gallery. Social networking features were high on their list of suggestions, especially more sharing options, and tagging and rating portraits. The students also suggested that there be details of the portraits included in the app.

Revised Software Requirements Specification. Only minor revisions were made to the SRS after reflecting on the experience of the students using the prototype and their feedback via the survey and workshop. The main change was that rather than repeating the same process for two portraits, it was streamlined for the second portrait so the students had a novel experience the second time around. The final SRS included the Scope and Functions for the *You2* app as follows:

Scope. The *You2* app should: enhance the level of engagement from self-guided groups; help users understand how to read a portrait; be enjoyable to use, and motivate users to complete the experience; be accessible to visiting students of diverse ages and abilities; and function regardless of the current hang in the gallery.

Functions. During a 45 minute to one-hour tour of the Gallery, the *You2* mobile app will help small groups of students create their own short audio tour of several portraits.

The app will ask the students a series of questions and collect their responses (as selections, text input, photos, and audio recordings). The students' responses can be played on the device or emailed to them.

4 Discussion

The success of the *You2* app for students is reflected in their response to the experience as evidenced by observation, video recording, survey results, and feedback from teachers and Gallery staff. The students expected that the experience would not be engaging, but they loved it and were happy to encourage other students to visit the Gallery in the future. It was clear that the shared experiential learning model was successful. More students were engaged actively compared with the case where students visited the Gallery in larger groups facilitated by the *Reading Portraits* mobile app.

For teachers, success is measured immediately by their observations that the students are more engaged when using the *You2* app when compared with the alternatives (no app or using the *Reading Portraits* app). For the Gallery, success is measured by their observations that the students learned to look closely at the works and came up with their own interpretations of the artists' intentions. For the researchers, validation of the process of developing the experience was demonstrated by the positive responses of the Gallery staff to the input provided by the students and teachers when given the opportunity to test prototypes and workshop their own ideas.

We questioned whether any of Crumlish and Malone' 126 patterns gave us guidance on what constitutes best practice for the media production and presentation aspects of the *You2* app. While most of the functions proposed for the app can be matched to Crumlish and Malone's patterns, there are no specific principles or patterns for taking photographs (including selfies); recording audio; typing in text (apart from in a blog); and creating and giving presentations, even though these things are common activities in social apps. We believe the *You2* app demonstrates effective user experiences for these patterns that will be useful to other developers that seeks to engage users in a social experience, such as support for informal learning in museums and galleries.

It could be argued that Crumlish and Malone's Broadcasting/Publishing and Communication patterns cover the required functions. There is, however, a sufficient difference between what Crumlish and Malone saw as constituting Broadcasting/Publishing and Communication, and what was required for the *You2* app.

5 Conclusion

Emerging communication devices and embedded technologies that provide location and proximity services give us new opportunities to enrich the experience of visitors to galleries and museums. These services not only help institutions to communicate with visitors in ways not previously possible – potentially satisfying demand for greater and more active engagement with institutional staff – they also provide opportunities for visitors to communicate among themselves and with their families, fellow students, teachers and friends. We set out to improve the design process for the experiences visitors – particularly school groups – had when they visited the National Portrait Gallery. The *You2* app differs from most other museum apps by actively engaging visitors rather than just providing information. By introducing the Gallery staff to design thinking workshops, particularly those involving the customers themselves – school students – in the design of the experiences they wanted to have when they visited the Gallery, we showed Gallery staff how working together on problems with other stakeholders (particularly the students themselves) helped them to come up with better solutions, and to see the issues they were dealing with from a number of perspectives. The process helped them to understand they could use a common language to describe the experiences they wanted to deliver, based on established 'best practice' frameworks with extensions to accommodate their circumstances.

The new design patterns that we have proposed here are applicable to a broader range of social interfaces beyond apps to support school students visiting cultural institutions. These design patterns differentiate the user experience from one where the user is a passive receiver of information to one where the user is a contributor of nuanced artefacts (audio, text and photo). They should therefore be important considerations for any experience where developers want to engage with their users to cocreate materials and encourage users to actively participate in the development and interpretation of shared media, from transitory virtual objects through to canonical works of art. What these design patterns add to the corpus are references to techniques that actively engage users in ways that help them to learn more from their involvement by doing something other than just hearing or seeing information or responding to existing interpretations. Examples might include application environments for shared proposals to develop community space; for school field-trip social and scientific data acquisition, sharing and interpretation; or for gathering indigenous knowledge of place through collecting and embedding stories in particular locations.

References

3. National Portrait Gallery of Australia, "National Portrait Gallery of Australia Annual Report 13/14," NPGA, Canberra, 2014.
4. J. H. Falk and L. D. Dierking, *Public institutions for personal learning: establishing a research agenda*. Washington: American Association of Museums, 1995.
5. J. H. Falk and L. D. Dierking, "School field trips: assessing their long-term impact," *Curator Mus. J.*, vol. 40, no. 3, pp. 211–218, 1997.
6. L. Kelly, "Student Learning in Museums: what do we know?," Sovereign Hill Museums Association, Jun. 2011.
7. T. Roppola, *Designing for the museum visitor experience.* New York: Routledge, 2014.
8. Museum of Modern Art, "MoMA | The MoMA iPhone App." [Online]. Available: http://www.moma.org/explore/mobile/iphoneapp. [Accessed: 27-Jan-2016].
9. Guggenheim Museum, "Guggenheim App Adds Feature to Highlight Artworks Near Users," 15-Dec-2015. [Online]. Available: http://www.guggenheim.org/new-york/press-room/news/6707-guggenheim-app-adds-feature-to-highlight-artworks-near-users?utm_source=hootsuite&utm_medium=social&utm_campaign=srgm-twitter. [Accessed: 27-Jan-2016].
10. Canadian Museum for Human Rights, "Mobile app," 27-Feb-2015. [Online]. Available: https://humanrights.ca/visit/tours/mobile-app. [Accessed: 27-Jan-2016].

11. Museum of Old and New Art, “Mona » The O.” [Online]. Available: https://www.mona.net.au/theo. [Accessed: 27-Jan-2016].
12. Apple, Inc, “Art Gallery of New South Wales Apps on the App Store,” *iTunes*. [Online]. Available: https://itunes.apple.com/au/developer/art-gallery-of-new-south-wales/id459345055. [Accessed: 27-Jan-2016].
13. C. H. Crouch and E. Mazur, “Peer Instruction: Ten years of experience and results,” *Am. J. Phys.*, vol. 69, no. 9, p. 970, 2001.
14. D. A. Kolb, *Experiential learning: experience as the source of learning and development*. Englewood Cliffs, N.J.: Prentice-Hall, 1984.
15. D. A. Kolb, R. E. Boyatzis, and C. Mainemelis, “Experiential Learning Theory: Previous Research and New Directions,” in *Perspectives on cognitive, learning, and thinking styles*, R. Sternberg and L. Zhang, Eds. New Jersey: Lawrence Erlbaum, 2000.
16. C. Crumlish and E. Malone, *Designing Social Interfaces: Principles, Patterns, and Practices for Improving the User Experience*, 2nd ed. Sebastopol, CA: O’Reilly Media, 2015.
17. J. S. Lee, J. Pries-Heje, and R. Baskerville, “Theorizing in design science research,” in *Service-Oriented Perspectives in Design Science Research*, Springer, 2011, pp. 1–16.
18. K. Peffers, T. Tuunanen, M. A. Rothenberger, and S. Chatterjee, “A Design Science Research Methodology for Information Systems Research,” *J. Manag. Inf. Syst.*, vol. 24, no. 3, pp. 45–77, 2008.
19. D. Munnerley, M. Bacon, R. Fitzgerald, A. Wilson, J. Hedberg, and J. Steele, “Augmented Reality: application in Higher Education,” Office for Learning and Teaching, 2015.
20. T. Brown and B. Katz, *Change by design: how design thinking transforms organizations and inspires innovation*, 1st ed. New York: Harper Business, 2009.
21. IDEO, “Design Thinking for Educators,” 2013. [Online]. Available: http://designthinkingforeducators.com/. [Accessed: 19-Feb-2014].
22. Strategyzer, “Value Propositions & Business Models,” 2016. [Online]. Available: https://strategyzer.com/. [Accessed: 23-Apr-2016].
23. H. Plattner, “The Gift-Giving Project,” 2015. [Online]. Available: https://dschool.stanford.edu/groups/designresources/wiki/ed894/The_GiftGiving_Project.html. [Accessed: 24-Apr-2016].
24. L. Anthony, *AntConc*. Tokyo, Japan: Waseda University, 2014.
25. L. Anthony, *TagAnt*. Tokyo, Japan: Waseda University, 2014.
26. J. Feinberg, “Wordle – Beautiful Word Clouds,” 2014. [Online]. Available: http://www.wordle.net/. [Accessed: 23-Apr-2016].

Toward Improving Adverse Drug Reactions Reporting from Twitter

Salem Alghamdi and Osama Mujallid

Claremont Graduate University, Claremont, California

{Salem.Alghamdi, Osama.Mujallid}@cgu.edu

Abstract. *Adverse Drug Reaction (ADR) has become a central concern for many healthcare providers [15]. It is well-known that adverse reactions to drugs are a reason for several health problems. According to the Food and Drug Administration (FDA) estimation, ADRs are the 4th leading cause of death [15]. The prevalence of ADRs necessitates the establishment of a simple ADR reporting process. The ADR reporting process involves many stakeholders such as the FDA, the patient, and the health professional. The research uncovered a significant lack of communication among the stakeholders, thus the research goal is to improve this lack in communication. This research focuses on how to improve ADR reporting based on patients' posts on Twitter and also what solution can be provided to improve the communication between the patient and the doctor during the ADR reporting process. Therefore, this study proposes a solution to enhance such the communication between the stakeholders.*

Keywords: Health Informatics · Design Science Research (DSR) · Media Richness Theory (MRT) · Adverse Drug Reactions (ADRs) · Social Network · Twitter

Introduction

As Adverse Drug Reactions (ADRs) are considered one of the leading causes of death in health care [15]. Medical researchers have become increasingly interested in studying ADR due to its importance as a significant public health problem that can be prevented [15]. In fact, Sloane stated that ADRs are considered one of the main causes of illness, hospitalization, and mortality [10]. As a consequence, the drug reactions have received a considerable amount of attention by drug scientists and health professionals.

Recently, a study found that 42% of the patients involved in social networks discuss their current health conditions online [18]. Thus, social networks become a potential vital source of information to monitor the effects of medical drugs after they have been licensed [10], yet there are different issues when it comes to report an ADR from online data sources. One issue is that patients post their drug reactions on different social networks, such as Twitter, which does not necessarily mean their doctors will receive it. Another issue is that there are criteria that need to be fulfilled in order for the report to be recognized by the Food and Drug Administration (FDA) [9].

The propose solution addresses three objectives. The first objective is to provide a reliable solution that works as a communication channel between patients and health professionals. A second objective is to provide a solution that help the patient to report ADRs to their health professionals. A third objective is to provide a solution for health professionals to report ADRs through Twitter while taking into consideration the FDA criteria. The research questions focus on how the (ADR) reporting can be improved based on patients' posts on Twitter and also what solution can be provided to improve the communication between the patient and the primary doctor during the ADR reporting process. This study provides a reliable tool called an Easy Reporting (EZ-R) that will allow users to report ADRs and aims to enhance such communication, which will eventually benefit all involved stakeholders. To enhance a rich communication among stakeholders during the reporting process, this study draws upon Media Richness Theory (MRT) [13]. Section 3, explain the MRT as the theoretical foundation for the propose solution.

Background and Related Work

An Adverse Drug Reaction is defined as any serious undesirable experience that a patient has associated with the use of a medical product [2]. ADRs make around 30% of hospital admissions in the US and costs up to 30.1 billion dollars per year [16]. ADRs can occur to any number of patients after a drug enters the market. This led to the establishment of the ADR reporting processes.

The current ADR process has a few limitations. The ADR process involves many stakeholders, two of which must be present to complete a report. The FDA is one stakeholder and they are responsible for protecting the public health, investigating drug complaints, and monitoring drug reactions [12]. Either the patient or the doctor may submit an ADR to the FDA. Moreover, a new study found that 86 % of Adverse Events (AEs) went unreported [17]. Even if a patient files an online complaint, the process often poses a big challenge because the current online process has many limitations; according to Ying et. al. [8]. One of those limitations is the dependence on volunteers to report ADRs. This makes it a passive system that is limited by latency and inconsistency, which resulted a significant lack of communication between healthcare providers and patients. Therefore, a solution is needed in order to prevent more ADR related to deaths and costs for the country.

Today, patients are increasingly turning to social networks as a source for health-related information, health and wellness advice, and to share experiences [1]. According to a recent study, 26% of adult that use Internet discuss their personal health problems online and 42% of them discussing current conditions on social network [18]. Twitter, one of the most popular social network websites, has around 320 million users monthly as of December 31, 2015 [14]. According to Ginn, R., et. al., [5], Twitter users generate more than 9000 tweets every 4 seconds. With this volume of data, healthcare providers and agencies tried to analyzing and predicting ADRs from the content of Twitter using data mining techniques [10]. Yet, this approach lack the FDA four criteria as a requirement to accept ADR reports based on social network data mining, specifically: 1. An identifiable patient which is the patient information that includes patient name, or patient identification number; 2. An identifiable reporter which is the person who is in charge of reporting to the FDA such as a family member, doctor, or pharmacist; 3. The drug name that causes the ADR; 4. An adverse event or fatal outcome that caused by the drug [4].

Theoretical Foundation

The theoretical foundation of this study draws upon Media Richness Theory (MRT), developed by Richard L. Daft and Robert H. Lengel in the 1980's [13]. MRT categorized different levels of communication media to carry information, ranging from low (or lean) richness to high (or full) richness [13]. For instance, within a hospital setting, a lower level communication media channel between doctor and patient would be letters, reports, and emails, while a higher richness level of communication that provides rapid response and feedback channels are vehicles such as face-to-face communications and videoconferencing [13].
The MRT provides a theoretical basis for the propose tool (EZ-R). In fact, in this study, the MRT inspired the researchers to build an artifact considering the communication aspect between the doctor and the patient. Such an artifact that will mediate the ADR reporting process and improve the current passive low richness method into a richer, and more active method. It also facilitates more instant feedback between the patient and the health professional. Therefore, MRT grounded this research and inspired the design process in applying features such as chat feature (instant messaging) and other features that allow bi-directionally real-time communication between the two parties to facilitate an immediate feedback capability.

Research Approach

This research follows the Design Science Research (DSR) approach, introduced by Hevner and Chatterjee [7], which includes a set of artifacts that solves a wicked problem. DSR is composed of three related cycles: "the relevance cycle, the rigor cycle, and the design cycle" [7]. The relevance cycle utilization is to connect the requirements from the environment related to the research. The rigor cycle provides the prior knowledge as a foundation to the research as well as helps to add a new knowledge from the research to the knowledge base. The design cycle contributes as the construction and evaluation phase of the artifacts. Moreover, the DSR artifact outcome can be one or more namely, *constructs* which include vocabulary and symbols; *models* which include abstractions or representations; *methods* which include algorithms or practices; *instantiations* which include implemented or prototype systems; or *design better theories* [7].

Therefore, based on the DSR approach, the goal of this research is to define the problem and develop an artifact that can provides a reliable solution as a communication channel between patients and health professionals, and ultimately improve ADR reporting. Thus, the outcome solution consists of three main artifacts:

a patient mobile application (instantiation), a doctor mobile application (instantiation), and an algorithm (method) that run in the backend of both applications.

Designing & Building the Artifacts

Technical Requirements

To develop the applications, android studio was used to implement both doctor and patient applications. The following tools were used during the development phase: android Software Development Kit (SDK), Java, Android Mobile OS, Twitter API, MySQL database, and JSON (JavaScript Object Notation).

Design & Build the Artifacts

From DSR perspectives, each of the artifacts designed to play a different role in reporting ADR namely, Dashboard (doctor's application), Mobile Application (patient's application), and an algorithm to looks up and detects side effects in patient tweets (both patients and doctor applications). The three artifacts have been designed and developed in iteration process. Both applications and algorithm have been constructed and tested to build the final artifacts. The source of the data was from Drugs.com and collected based on the top 20 drug names and the relevant 700 side effect terms, that being looked up on searches engines. This collected data have been stored on databased on the server. This sample have been used to test both applications and algorithm functionality.

The EZ-R works under two assumptions. First, the research team assumes that the doctor has a list of patients' Twitter usernames. Another assumption is that the patient agreed that all of their tweets will be monitored by the doctor. Each doctor will have an application that works as a dashboard. The next sections will describe both applications in detail.

Artifact 1: Doctor Dashboard Application (Instantiation)

In this dashboard, the home page contains the main functions which are "View Report", "Lookup for Patient on Twitter", "Chat with Patient", and "Send SMS to Patient". These functions empower doctors to help their patients to report the side effects. With taking into consideration of the previous assumptions, the doctor will use the "lookup for patients" function, which runs the algorithm to find out whether or not the patient's tweets contain mention of side effects. If the algorithm found that the patient's tweets contain a side effect, then the doctor's screen will shows this side effect. Next, the doctor can initially use "Send SMS" function to send an SMS to the patient to download the patient application on his/her smartphone. After the patient downloads the application, then the doctor will be able to use the following functions: the "View Report" function shows a list of reports or questions that are submitted by the patient. The "Chat with Patient" function enables the patient and doctor to communicate over messaging with each other. Thus, the doctor application can help doctors to monitor his/her patient on social network and empower them to help patients to report the side effects.

Artifact 2: Patient Mobile Application (Instantiation)

Initially, when the user runs the application for the first time, a login screen will be displayed. A username and password screen prompts for authentication. The user will provide unique username and password for the first time. If the username is correct, then the application will store the username on the server. If the patient tweeted about a drug side effect, the application gathers the tweet content using Twitter API. The API matches keywords in Tweets to those that are pre-stored on the server. If the tweet matches, then the application will automatically send a notification prompting the patient to report the side effect to the doctor. The patient can use the following three functions. One function is the "patient profile", which will allow the patient to enter and update his/her demographic information, address and medical record number. Another function is "send report" which helps patients report an ADR. In this function, the patient will be directed through workflow steps to complete an ADR report including patient identity, drug reactions, adverse drug event, drug name, and drug dosage. Last function is the "chat with a doctor" which allows doctors and patients to engage in a real-time transmission of text-based conversation. Thus, the patient can ask the doctor questions about completing the ADR report process, or how to avoid dangerous adverse drug reactions. Therefore, the patient application can help the patient communicate with his/her doctor any time, and to report the side effects easily.

Artifact 3: An algorithm to look up and detect side effects in patient tweets

The algorithm works in both the doctor dashboard application and the patient mobile application. The algorithm runs as a loop to detect patient tweets contains side effects that match the list of terms of side effect and drugs' names that stored previously on the server. The algorithm runs on the doctor application only when the doctor uses "lookup for patients". The following steps explain the algorithm:

(a) Algorithm Steps in Doctor Application.

(i) **Assumption:** It is assumed that the patient posted a tweet that has a side effect (Fig.2). For example, if a patient posts a tweet including this text: "I have chest pain for 2 days from using XYZ … etc.", then the application works according to the following algorithm description.

(ii) Algorithm description:

1. The doctor looks up the patient username (Fig.1 and Fig. 2).
2. The application checks if this username has tweeted about a side effect.
3. If yes, the application retrieves the tweet content using Twitter API.
4. The application compares the KeywordMatch with tweet content with side effects that are pre-stored in the server.

5. If keyword is matching, then a message is sent to the doctor about side effect (Fig.1 and Fig. 2).

6. The doctor sends SMS to patient to download the app.

(iii) **Pseudo code explain the algorithm in doctor application:**

```
{     SET         initial username
    IF (username == True) THEN { get Tweet_Content from
Twitter API
         IF (Tweet_Content == True))
 THEN   { KeywordMatch ==  Tweet_Content
            Run_Function (Send SMS)     }
         ELSE REPEAT }
  ELSE    END }
```

(b) **Algorithm Steps in Patient Application**.

(i) **Assumption:** It is assumed that the patient is using his/her Twitter account using Twitter on desktop, or Twitter app on a smart device.

(ii) Algorithm description:

1. After the user logs into the mobile application, the application checks the username. (The application stores the username on the server when the user uses the patient application for the first time).
2. The application monitors tweet content that is posted on the user account (Fig.1 and Fig. 2).
3. The application gets the patient tweet content using Twitter API. (Works as a repeated process each time of tweet).
4. The application compares keywords of tweet content to side effects that are pre-stored on server.
5. If KeywordMatch matches one of side effect that pre-stored on server.
6. Then automatically send a push notification to patient (Fig.1 and Fig. 2).
7. Patient will use the mobile app to report his/her side effect.
8. Doctor will receive the report (Fig.1 and Fig. 2).

(iii) **Pseudo code explain the algorithm in patient application:**

```
{
    Get username From Server
    IF (username == True) THEN { get Tweet_Content from
Twitter API
    IF (Tweet_Content == True)) THEN { KeywordMatch ==
Tweet_Content
Run_Function (Push_Notification)
IF Push_Notification == is_open
  {initiate_Patient_App
  }
      }
ELSE REPEAT
```

```
}
    ELSE      END
}
```

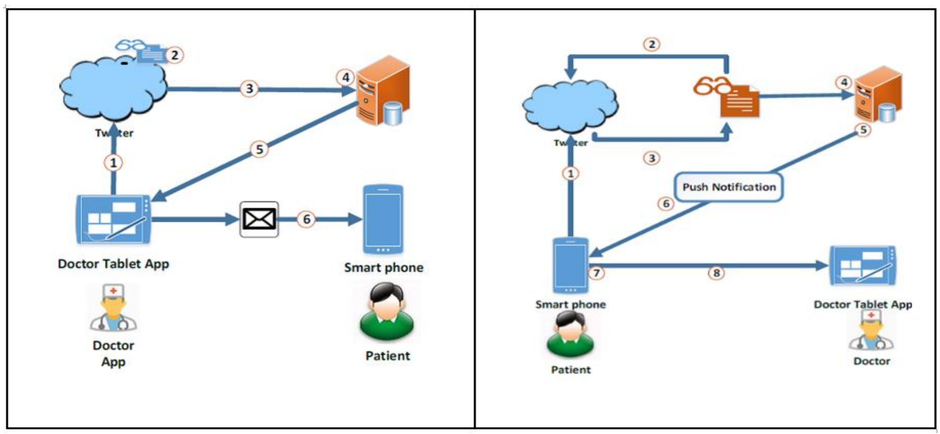


Fig. 3. Algorithm steps of both doctor application (left) and patient application (right).

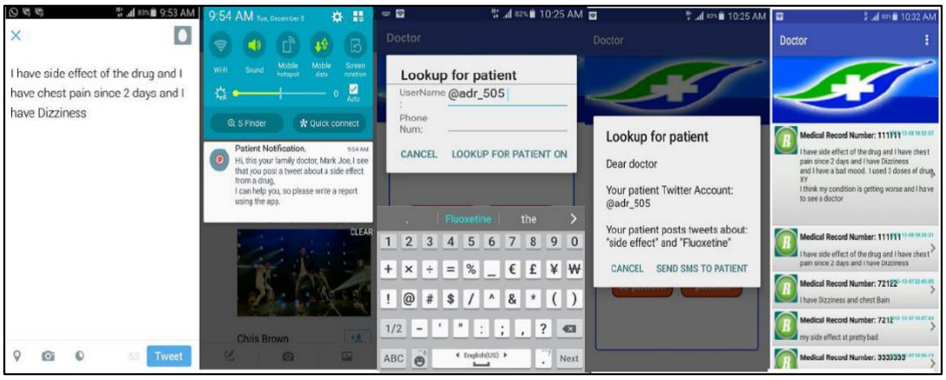


Fig. 2. Screenshot of both doctor and patient applications.

Novelty and Advantages

The artifact, EZ-R is a reporting application that will rely on Twitter and works as a mediating solution that will fulfills the FDA's criteria and helps alleviate the current process limitations. EZ-R helps the user to ADR reporting in real time after he/she posts a tweet. In addition to the uniqueness of using EZ-R application, it also has two advantages. These advantages are: first, it creates an active channel between the patient and his/her doctor. Second, obtains the four information to validate an ADR report assigned by the FDA. On the other hand, EZ-R is a different solution from the data mining or machine learning solutions because data mining and machine learning solutions are required a huge amount of data that need data cleansing which can be time-consuming, costly, and require special data analytical skills [10]. Moreover, data mining and machine learning solutions don't provide a communication tool between the patient and the health professionals in terms of reporting ADRs from Twitter.

Limitation and Challenges

For this pilot study, the researchers examined the functionality of the application, however, there were some challenges and limitations. First, the researchers were limited in detecting false-positives to detect synonyms of symptoms of the side effect that not stored. Second, there remains a limitation in regard of misspelled words, unknown keywords, or incorrect drug names submitted by patients and were not previously stored on the server.

Conclusion and Future Work

Recently, a large number of patients discuss their health issues and ADRs on different social networks [18], such as Twitter, which leave a large percentage of ADRs not reported to authorize health professionals or to the Food and Drug Administration (FDA) [18]. So far there is no reliable tool that might be used by health professionals to report an ADR based on their patient's tweets. This research provides a reliable solution that targeted patients whom discussing their current health condition on Twitter, and facilitates the submission of ADR by improving the communication with their health care professionals more easy and user-friendly.

Future enhancement should take into account the aforementioned limitations, as well as provide a sufficient sample size for the evaluation. Moreover, this solution might incorporate video conferencing within the application. More importantly, the application can be connected with the FDA database. Also, this solution could be integrated with other technologies, such as WordNet, to detect unknown symptoms or unidentifiable patients from different social networks. Lastly, a proper HIPPA and security procedures should be implemented to deal with patient's data privacy.

Acknowledgment

The authors would like to thanks professor Samir Chatterjee and the members of the IDEA Labs at CGU, Hamzah Ibrahim, Shaima Ewais, and Riad Alharbi for their help and guidance .The guidance helped the authors in developing the mobile application and provided helpful feedback during the implementation, iterative design and testing.

REFERENCES

27. Alabbasi,A. et al. (2014). Social Media Analytics for Smart Health. (2014). IEEE INTELLIGENT SYSTEMS, 1541-1672. Retrieved October 23, 2015, from www.computer.org/intelligent
28. Baniasadi, S., Fahimi, F., & Shalviri, G. (2008). Developing an Adverse Drug Reaction Reporting System at a Teaching Hospital. Basic & Clinical Pharmacology & Toxicology, 102(4). Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/j.1742-7843.2008.00217.x/abstract
29. C. Freifeld, C., S. Brownstein, J., M. Menone, C., Bao, W., Filice, R., Kass-Hout, T., & Dasgupta, N. (2014). Digital Drug Safety Surveillance: Monitoring Pharmaceutical Products in Twitter. Springerlink.
30. FDA Guideline for Industry Clinical Safety Data Management. (n.d.). In Definitions and Standards for Expedited Reporting (Vol. CH-E2A). Http://www.fda.gov/downloads/Drugs/.../Guidances/ucm073087.pdf
31. Ginn, R., Pimpalkhute, P., Nikfarjam, A., Patki, A., O'Connor, K., Sarker, A., . . . Gonzalez, G. (n.d). Mining Twitter for Adverse Drug Reaction Mentions: A Corpus and Classification Benchmark.
32. Hevner, A. 2007. "A Three Cycle View of Design Science Research," Scandinavian Journal of Information Systems (19:2) (available at http://aisel.aisnet.org/sjis/vol19/iss2/4).
33. Hevner, A., and Chatterjee, S. 2010. "Design Science Research in Information Systems," in Design Research in Information Systems Integrated Series in Information Systems, Springer US, pp. 9– 22 (available at http://link.springer.com/chapter/10.1007/978-1-4419-5653-8_2).
34. Ji, Y., Ying, H., Dews, P., Farber, M., Mansour, A., Tran, J., . . . Massanari, R. (2010). A fuzzy recognition-primed decision model-based causal association mining algorithm for detecting adverse drug reactions in postmarketing surveillance. International Conference on Fuzzy Systems
35. Preventable Adverse Drug Reactions: A Focus on Drug Interactions. (2014, June 18). Retrieved December 16, 2015
36. Sloane, R., Osanlou, O., Lewis, D., Bollegala, D., Maskell, S., & Pirmohamed, M. (2015). Social media and pharmacovigilance: A review of the opportunities and challenges. British Journal of Clinical Pharmacology Br J Clin Pharmacol, 910-920.
37. Reisman, M. (2012). The FDA's Social Media Guidelines Are Here ... Were They Worth the Wait? Vol. 37(No. 2).
38. Reinecke, K., and Bernstein, A. 2009. "Tell Me Where You've Lived, and I'll Tell You What You Like: Adapting Interfaces to Cultural Preferences," in Proceedings of the 17th International Conference on User Modeling, Adaptation, and Personalization, Trento, Italy, June 22-26, pp.185-196.
39. Warters, B. (2015). Media Richness Theory. Retrieved November 23, 2015, from http://campus-adr.net/ODRModule/index.htm
40. T. (2015, December 31). Https://about.twitter.com/company. Retrieved April 08, 2016, from https://about.twitter.com/company
41. U.S. Food and Drug Administration. (n.d.). Retrieved January 22, 2016, from http://www.fda.gov/drugs/developmentapprovalprocess/developmentresources/druginteractionslabeling/ucm110632.htm
42. Sultana, J., Cutroneo, P., & Trifirò, G. (2013). Clinical and economic burden of adverse drug reactions. Journal of Pharmacology and Pharmacotherapeutics J Pharmacol Pharmacother, 4(5), 73. doi:10.4103/0976-500x.120957
43. Freifeld, C. C., Brownstein, J. S., Menone, C. M., Bao, W., Filice, R., Kass-Hout, T., & Dasgupta, N. (2014). Erratum to: Digital Drug Safety Surveillance: Monitoring Pharmaceutical Products in Twitter. Drug Saf Drug Safety, 37(7), 555-555. doi:10.1007/s40264-014-0172-9

44. Sarker, A., Nikfarjam, A., & Gonzalez, G. (2015). Social Media Mining Shared Task Workshop. Biocomputing 2016. doi:10.1142/9789814749411_0054

45. Situating Requirements Engineering methods within Design Science Research

Okhaide Akhigbe
School of Electrical Engineering and Computer Science, University of Ottawa, Canada
okhaide@uottawa.ca

Lysanne Lessard
Telfer School of Management, University of Ottawa, Canada
Lysanne.Lessard@telfer.uottawa.ca

Abstract. *Design Science Research Methodologies (DSRM) are increasingly used to guide research in fields beyond Information Systems, in particular those of Requirements Engineering and Software Engineering (RE/SE). While a number of DSR methodologies have been developed by scholars in the RE/SE fields, there remains a certain level of confusion about the way in which the aim and scope of DSRM and those of methods typically used in RE/SE differ. This issue can be observed in graduate students' work as well as in published literature. In particular, the difference between the research orientation of DSRM and the solution orientation of RE/SE methods can be difficult to navigate. We propose to address this challenge by situating three RE/SE methodologies proposed in published literature within one common DSRM; doing so clarifies the scope of these methodologies and highlights ways in which the knowledge contributions of their results could be further enhanced. This effort is a first step towards providing better guidance to researchers who are new to design science research in order to ensure that recognized DSR principles are promoted and respected.*

Keywords: Design science research methodologies, engineering methods, design science research education

Introduction

Design Science Research (DSR) is a research paradigm that has become common ground in the field of Information Systems; it is also emerging as a legitimate approach in other fields such as computer science and software engineering [0, 0]. Indeed, its focus on the creation and validation of innovative artifacts able to solve human problems has made DSR attractive to researchers in these fields [0]. Advancements within DSR have helped to establish it as an approach that is both rigorous and relevant [0, 0, 0]. Their application and recommendations provide a basis for a systematic and adequate application of DSR principles.

Nevertheless, misunderstanding of DSR methods, concepts and outputs can still be observed among graduate students and researchers new to DSR. In fields such as Requirements Engineering and Software Engineering (RE/SE), such misunderstandings may arise from an understandable confusion between methods typically used by practitioners in these fields – or developed for them or related users

– and methodological guidelines provided by DSR methodologies. For example, a methodology is often described as the science of methods used in a particular area of study or activity [0, 0]. A methodology outlines the plan of action and process informing the choice and use of specific methods. It also connects the choice and use of the methods to desired outcomes. In relation to research, methodologies inform the choice and use of appropriate methods and the extent to which the methods are justified in the context of the purpose of the research [0, 0]. However, the term methodology can more generally refer to a set of methods used to solve a practical problem. This semantic ambiguity can make it difficult to understand, for example, how guidelines for performing Structured Analysis and Design [0] to create an application should be used within a research project using a Design Science Research (DSR) approach.

The objective of this research is to clarify the difference between a RE/SE – often practical – method and a DSR methodology in order to provide improved guidance to graduate students and researchers from those fields that are less familiar with DSR principles. To achieve this, we developed a framework that situates RE/SE methods and methodologies within a common DSR methodology. This framework could help RE/SE researchers improve, for example, their knowledge contributions. It could also prove useful in other fields, helping users with field-specific methods and methodologies to better articulate their research contributions. As a first step toward this objective, this research-in-progress analyzes a purposive sample of three RE/SE methodologies taken in extant literature and with which the authors of this paper are familiar. Each methodology is then placed within the well-known Design Science Research Methodology (DSRM) [0] in order to clarify its aims and scope. In addition, we highlight how using the DSRM might have helped the authors to enhance the knowledge contributions of their research.

The remainder of this paper is organized as follows: in Section 0 we describe the method used in our analysis; we then outline our analysis of three select RE/SE methodologies in Section 0. We discuss additional DSR methodologies and provide recommendations to improve the knowledge contributions of these methodologies in Section 0, and conclude with future work aiming to formalize this research-in-progress in Section 0.

Method

The Design Science Research Methodology (DSRM) offers conceptual principles, practice rules and a process for carrying out and presenting research in a manner that respects recognized principles of design science research [0]. As a methodology, the DSRM provides a template that can be used to present and evaluate research projects. The authors of the DSRM illustrate this by analyzing extant research projects in terms of the six iterative activities of the DSRM (problem identification and motivation; objective of the solution; design and development; demonstration; evaluation; communication), their entry point into the process, and their contribution [0]. However, this was mainly accomplished to evaluate the methodology itself rather than the projects serving as cases.

In this paper, we effectively follow on the authors' proposition and use the DSRM as a template to evaluate three research projects focused on the development of methodologies and tools in the field of RE/SE. This allows us to clarify the aims, scope and outputs of each methodology from a design science research perspective. We then draw on other methodologies proposed within the body of literature on design science research to propose ways in which each research project could further articulate its knowledge contributions [0, 0].

Overview and analysis of three RE/SE methodologies

In this section, a brief overview of each methodology is first presented in Sections 0, 0, and 0. An analysis of these methodologies using the DSRM [0] is then presented in Section 0.

The Regulatory Intelligence Methodology

The Regulatory Intelligence Methodology (RIM) has been proposed to improve regulators' decisions making when they enforce compliance [0]. Its development was motivated by the current shift from prescriptive to outcome-based regulations, which brings challenges in terms of evaluating if the requirements of a regulation are satisfied, and to what extent. To address this challenge, RIM uses goal modeling and analysis [0] to facilitate the transformation of prescriptive regulations into outcome-based regulations with goals that can be measured, analyzed and reported using Business Intelligence (BI) tools. In its application, the RIM assumes the regulator is committed to introducing an outcome-based approach for regulation writing; the methodology thus consists of seven iterative steps that regulators should follow in order to state and implement regulations in a manner conducive to their monitoring.

The Business Intelligence - Enabled Adaptive Enterprise Architecture

The Business Intelligence - Enabled Adaptive Enterprise Architecture (BIEAEA) has been proposed to anticipate and proactively support the adaptation and evolution of enterprise architectures [0]. Its development was motivated by challenges common in current dynamic business environments where Information Systems (IS) are not often aligned to business objectives they support. Operating on the premise that IS provide information that decision makers use to meet business objectives, the BIEAEA provides a goal-oriented modeling procedure that links IS to decisions and business objectives. In its application, the BIEAEA framework consists of a model, a methodology and tool; together, these elements support the exploitation of goal, process, and indicator modeling, and analysis in order to specify the relationships between an organization's business objectives and information systems.

Business Intelligence Modelling

Business intelligence modeling (BIM) is a modeling technique and accompanying methodology that supports the exploration and monitoring of business objectives and risks according to chosen performance measures [0]. It aims to present a business-friendly viewpoint of data collected by an organization for operational, analytical, or strategic objectives [0]. This is mainly achieved through the provision of constructs for modeling hierarchical goal structures, and the performance of individual goals through associated performance indicators [0]. The accompanying methodology focuses on procedures for reasoning with models in a manner that allows the exploration of scenarios and the identification of strategies to achieve business objectives.

Analysis of three methodologies

Table 1 presents the main components of the Design Science Research Methodology (DSRM) [0] in the left-hand column, and the application of these components to the three methodologies presented above. Analyzing the Regulatory Intelligence Methodology (RIM) [0], the Business Intelligence - Enabled Adaptive Enterprise Architecture (BIEAEA) [0], and Business intelligence modeling (BIM) [0] as they are reported in literature highlights a first key point about their nature: from the perspective of the DSRM, these methodologies are used to develop artifacts, the output of research projects, rather than to guide the research process itself.

While they can certainly be understood as methodologies in the sense of sets of methods peculiar to needs within a body of knowledge, their use by professionals (regulators or business users) will most likely take them outside the realm of research. Secondly, while they have all been developed in the context of research problems, their contributions are stated in practical terms, hence in terms of their usefulness for practitioners. While this shows their relevance, none of these methodologies have been evaluated and hence contribution to the knowledge base of RE/SE remains to be articulated.

Table 1. Analysis of three RE/SE methodologies [0, 0, 0] using DSRM [adapted from 0]

DSRM components	Application of DSRM to RIM, BIEAEA, and BIM
Entry point into the research process	**RIM, BIEAEA, BIM:** Goal-centered initiation.
Problem identification and Motivation	**RIM:** Difficulty of evaluating if the requirements of outcome-based regulation are satisfied and to what extent. **BIEAEA**: Challenges for businesses to adapt their enterprise architectures in the current dynamic business environment. **BIM**: Business intelligence systems and displays tend to be organized around data structures rather than business users concerns.
Objective of the solution	**RIM:** Provide practical means to transform regulations from prescriptive to outcome-based formats in a way that enables measurement, analysis, and reporting of their performance using BI tools. **BIEAEA**: A method to connect information systems to decisions and business objectives in an organization with means to explore and evaluate different kinds of change.

DSRM components	Application of DSRM to RIM, BIEAEA, and BIM
	BIM: Provide a modeling approach and methodology to bridge the business-level understanding of an enterprise with its representation in databases.
Design and development	**RIM:** Use of goal-oriented modeling and analysis to create outcome-based regulations and evaluation strategies that facilitate analysis and reporting using BI tools. **BIEAEA**: Use of goal-oriented modeling principles and tools to create a methodology, goal models and evaluation strategies for anticipating and supporting adaptation to change. **BIM:** Extension of goal-oriented modeling constructs and development of a methodology to analyze business objectives and risks according to chosen performance measures.
Demonstration	**RIM:** Proof-of-concept design was created, modified and applied to the needs of regulators in safety compliance and financial domains. **BIEAEA**: Proof of concept design along with “well-formedness rules” to ensure models and their assumptions are accurate, was demonstrated. Qualitative interviews were collected to assess the BIEAEA’s performance and limitations. **BIM:** The relevance of BIM has been shown through a number of case studies.
Evaluation	**RIM, BIEAEA, BIM:** Have not been evaluated.
Communication	**RIM:** Manuscript and test scenarios related to the RIM have been published in peer-reviewed publications [0, 0, 0]. **BIEAEA**: Manuscript and case study related to the BIEAEA have been published in conference proceedings [0, 0]. **BIM:** The concepts and use of BIM have been communicated through a number of papers and articles [0,0, 0].
Contribution	**RIM:** A procedure and supporting tool for using performance modelling to improve regulatory decision-making. **BIEAEA**: A procedure and supporting tool for using goal analysis to anticipate and manage evolution in an organization’s business objective and IS. **BIM:** A model-based approach to reasoning about an enterprise’s strategies in the context of its business environment, and in relation to its data and performance indicators.

Discussion

The methodologies presented in the previous section address tangible practical problems and leverage authors’ deep domain knowledge to propose convincing means to address them. The numerous peer-reviewed venues in which their concepts and demonstrations were published attest to their quality. Nevertheless, their analysis through the components of the Design Science Research Methodology (DSRM) [0] showed similar areas for improvement in terms of evaluation and contributions. In this section, we propose complementary design science research (DSR) methodologies that could have been used to further enhance the development and contributions of each methodology.

The research underlying each methodology addressed two complementary concerns, that of practical and knowledge problems. Their results in turn should then have practical and knowledge contributions. An appropriate methodology to address such nested problems relies on the regulative cycle [0]. This methodology provides a conceptual methodology for understanding the logic of practical problems. Using the regulative cycle, practical problems can be decomposed into knowledge subproblems and practical subproblems with useful guides for solving them. Whereas practical problems call for a change of the world so that it better agrees with given stakeholder goals, knowledge problems rather call for a change in our knowledge about the world [0]. In the context of the Regulatory Intelligence Methodology (RIM) [0], for example, practical problems include challenges in enforcing regulations in a manner that achieves the goals of the regulator; knowledge problems by contrast include the need to modify our knowledge about how regulated bodies respond to regulations. The former requires the development of a method and tool to evaluate regulations in regards to regulators' goals. The later requires evaluating proposed methods and tools in regards to their objective improvement of regulations enforcement.

As Table 1 shows, the authors of the three reviewed methodologies did not articulate such knowledge contributions. The knowledge contribution framework [41] could have been a tool to help them do so. According to this framework, reviewed methodologies fall in the category of "Exaptation", where existing solutions are adapted to solve new problem. This kind of solution can lead to both prescriptive and descriptive knowledge contributions [41]. Prescriptive contributions can happen at three levels: 1) Artifact implementation in specific contexts; 2) Operational principles such as constructs, methods, and models serving as a nascent design theory; and, 3) mid-range and grand theories about artifacts in context [41]. The three reviewed methodologies all show elements of knowledge contributions at levels 1 and 2, but not at level 3. Indeed, more advanced evaluations of each methodology would be required to arrive at well-developed design theories. More so, while the demonstrations provided for each methodology helps to answer value questions (knowing if the implemented artifacts satisfy stakeholder requirements), evaluation is needed to answer causal questions (objectively knowing if implemented artifacts have desired effects) [0]. This could be achieved, for example, using a number of strategies for generalizing SE theories [0]. Using these frameworks could have guided the authors of these methodologies to better articulate the knowledge contributions of their research, and to state their future work in terms of a more rigorous evaluation of their solutions in order to enhance their future contributions to the RE/SE knowledge base.

Conclusion

This research-in-progress stands as a proof-of-concept that existing Design Science research (DSR) methodologies can be used to analyze research developed in the field of Requirements Engineering/Software Engineering (RE/SE), in order to clarify the nature and scope of their research outputs and provide guidance to further their knowledge contributions. Given the increased use of DSR by graduate students and researchers new to this research approach – in the field of RE/SE and beyond –, providing such guidance is important to ensuring that DSR principles (embedded, among others, in its methodologies) are correctly applied. Maintaining recognized DSR standards in graduate work and published literature that use DSR as a research paradigm could in turn contribute to the recognition and relevance of DSR.

This research-in-progress addressed a limited number of articles given its early stage. To address this limitation, in our future work, we plan to ensure that a wider range of RE/SE papers are included in the study. This will ensure that, among other things, papers that have different DSRM entry points and weaknesses will be analyzed. Since research within requirements engineering is often concerned with stakeholder interactions, taken to be vital in eliciting quality and complete requirements, we will explore the possibility of using additional DSR methodologies or frameworks to analyze these papers. For example, Action Design Research, which recognizes that artifacts emerge in interactions with organizational elements [0], could provide a relevant analytical framework for interaction-focused methods in RE/SE. The results of this future research could serve as the basis for the development of guidelines for researchers wanting to adopt a DSR paradigm. These guidelines could usefully complement existing literature explaining how to apply DSR frameworks and methodologies [0, 0, 0].

Reference

Ackoff, R.L. (1962). Scientific method: optimizing applied research decisions. Wiley & Sons, New York. Pg 6.

Akhigbe, O. S., Amyot, D., Richards, G. (2014a). A Framework for a Business Intelligence-Enabled Adaptive Enterprise Architecture. In: *33rd International Conference On Conceptual Modeling (ER'14), LNCS Vol. 8824. Springer Berlin*, pp: 393–406.

Akhigbe, O., Alhaj, M., Amyot, D., Badreddin, O., Braun, E., Cartwright, N., Richards, G., Mussbacher, G. (2014). Creating quantitative goal models: governmental experience. In: *33rd International Conference On Conceptual Modeling (ER'14), LNCS Vol. 8824. Springer Berlin*, pp 466–473

Badreddin, O., Mussbacher, G., Amyot, D., Behnam, S. A., Rashidi-Tabrizi, R., Braun, E . and Richards, G. (2013). Regulation-Based Dimensional Modeling for Regulatory Intelligence. In: *6th Int. Workshop on Requirements Engineering and Law (RELAW*), pp. 1–10

Barone, D., Yu, E., Won, J., Jiang, L., Mylopoulos, J. (2010). Enterprise Modeling for Business Intelligence. In: *The Practice of Enterprise Modeling, LNCS Vol. 68, Springer Berlin Heidelberg*, pp. 31-45

Barone, D., Jiang, L., Amyot, D., Mylopoulos, J. (2011). Reasoning with Key Performance Indicators. In: *The Practice of Enterprise Modeling*, *LNCS Vol.* 92, *Springer Berlin Heidelberg,* pp. 82-96

Gregor, S., Hevner, A.R. (2013). Positioning and presenting design science research for maximum impact. *MIS Quarterly. 37(2),* 337-356

Hevner, A.R., March, S.T., Park, J., Ram, S. (2004). Design science in information systems research. *MIS Quarterly 28(1)*, 75-105

Hevner, A.R. and Chatterjee, S. (2010). Design science research in information systems. Springer US

Horkoff, J., Barone, D., Jiang, L., Yu, E., Amyot, D., Borgida, A., Mylopoulos, J. (2012) Strategic business modeling: representation and reasoning. *Softw & Syst Model 13*, pp.1015-1041

Jiang, L., Barone, D., Amyot, D., Mylopoulos, J. (2011). Strategic Models for Business Intelligence. In: *30th International Conference On Conceptual Modeling (ER'11), LNCS Vol.6998. Springer Berlin Heidelberg*, pp. 429-439

Marca, D.A. and Macgowan, C.L. 1988. SADT: Structured Analysis and Design Technique. New York: McGraw-Hill.

Mackenzie, N., Knipe, S. (2006). Research dilemmas: paradigms, methods and methodology. *Issues Educ. Res. 16(2)*, pp. 193–205

Peffers, K., Tuunanen, T., Rothenberger, M.A., Chatterjee, S. (2007). A design science research methodology for information systems research. In*: JMIS 24,* pp. 45-77

Rashidi-Tabrizi, R., Mussbacher, G., Amyot, D. (2013). Transforming regulations into performance models in the context of reasoning for outcome-based compliance. In *6th International Workshop on Requirements Engineering and Law (RELAW)*, pp.34–43

Simon, H.: The sciences of the artificial. MIT Press, Cambridge, Mass. (1996)

Sein, M.K., Henfridsson, O., Purao, S., Rossi, M., Lindgren, R. (2011). Action Design Research. *MIS Quarterly 35(2)*, 37–56

Tawhid, R., Alhaj, M., Mussbacher, G., Braun, E., Cartwright, N., Shamsaei, A., Amyot, D., Behnam, S.A., Richards, G. (2012). Towards Outcome-Based Regulatory Compliance in Aviation Security. In: *20th IEEE Int. Requirements Engineering Conf.,* pp. 267–272

Vaishnavi, V., & Kuechler, W. (2004). Design Science Research in Information Systems. Retrieved January 31st 2016 from http://www.desrist.org/design-research-in-information-systems

Vaishnavi, V., & Kuechler, W. (2008). Design science research methods and patterns: innovating information and communication technology. Auerbach Publications, Germany

Welman, C., Kruger, F., & Mitchell, B. (2005). Research methodology. Oxford Uni. Press.

White, B. Mapping Your Thesis: The Comprehensive Manual of Theory and Techniques for Masters and Doctoral Research. ACER Press. Retrieved Janaury 25th 2016 from http://books.google.ca/books?id=3zuvCHDA5cAC

Wieringa, R. (2009). Design science as nested problem solving. In: *Proceedings of the 4th International Conference on Design Science Research in Information Systems and Technology, DESRIST '09. ACM,*.

Wieringa, R. J. (2014).Design Science Methodology for Information Systems and Software Engineering. Springer, Heidelber

Wieringa, R.J., Daneva, M. (2015). Six strategies for generalizing software engineering theories. *Science of computer programming 101*, pp. 136-152.

46. Designing Knowledge Interface Systems: Past, Present, and Future

Shirley Gregor[1], Alexander Maedche[2], Stefan Morana[2], and Silvia Schacht[2]

[1]The Australian National University, Canberra, Australia ACT 0200
[2]Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany

shirley.gregor@anu.edu.org,{alexander.maedche,stefan.morana,
silvia.schacht}@kit.edu

Abstract. *Knowledge interface systems (KIS) enable a dialogue between human and machines by utilizing an underlying knowledge-based system. The design and the effects of KIS have been a focus of researchers' interest for decades. Yet the existing knowledge of KIS is scattered, and researchers as well as practitioners face the danger of re-inventing KIS for a specific purpose or, worse, repeating mistakes of the past. This conceptual paper provides an overview of KIS capabilities and outcomes of their usage from the past to the present and proposes directions for future research. Our analysis shows that, in general, there is evolution of work on KIS over time, rather than revolution. This research will enable researchers to identify their contribution more clearly over and above what has been done before.*

Keywords: knowledge interface system, knowledge-based system, human-computer interaction, user interface

Introduction

Advances in technology mean an increase in the sophistication of interactions between human and machines. Greater intelligence in even simple tools such as email means that the tool can give targeted advice by pointing out missing steps in a process. Advances with 'big data' mean huge volumes of information are available to inform human decision making. Yet this information can be overwhelming without appropriate presentation and interpretation – a significant challenge to decision makers [1]. Thus, there is the need for an effective knowledge interface system (KIS) that enables a knowledge dialogue between human and machines. KIS have been developed and studied since the earliest days of knowledge-based systems (KBS) albeit under a variety of labels. They have been referred to as help or assistance facilities, explanations, recommendations, advice, nudges, data representations, dashboards, visualization, and guidance. The term KIS is compatible with the conceptualization of the "user interface" in early KBS such as decision support systems (DSS) (see [2]). Sprague and Watson [3] suggest that the user interface is the most important component of a KBS, because much of the power, flexibility and ease-of-use characteristics of KBS derive from this component. The ongoing importance of KIS is demonstrated by the example of advanced data visualization – the ability to present complex data in informative and aesthetically pleasing ways both quickly and clearly [4]. Businesses that make effective use of big data and visualization benefit, with research showing that data-driven businesses are six percent more profitable and five percent more productive than their competitors [5]. Pirolli [6], however, points out that we have limited understanding of how people navigate through the graphics in data visualization. Thus, there is a need for continuing research on KIS.

Despite the importance of KIS, the related research remains scattered and we believe the potential for integrating design-related knowledge across different forms of KIS has not been sufficiently realized. New forms of KIS are being developed without the benefit of lessons learned from the past or from the design of other members of the same system families. Furthermore, KIS appear in a primary role as a core element of the user interface and a secondary role in the form of an assistance function. Clarification of these two roles is necessary as otherwise researchers working with the secondary role may not realize that the design principles they employ may have commonalities with KIS in the primary role. This shortcoming should be of interest to members of the design science research (DSR) community engaged with new forms of KIS. Thus, the aims of the paper are to: (i) argue that KIS should be recognized as a special class of systems so that commonalities in design can be realized and leveraged, (ii) present some of the important lessons learned surrounding the design and use of KIS, and (iii) create an awareness for KIS design in the DSR community.

The paper has theoretical significance in that it represents an initial step in integrating design knowledge, past and present, for an important class of systems. The need for a cumulative tradition in theorizing in Information Systems has long been recognized [7]. Here we show how design knowledge and theory can be accumulated around a class of systems, identified by a common overarching purpose – in this case enabling knowledge interaction between a computer system and a human user. The establishment of an integrated body of knowledge means that researchers will be better able to demonstrate how they make a new contribution to knowledge. An integrated knowledge also means a better base for developers of KIS in research and practice.

The scope of the paper is restricted in that we are looking at human-computer interactions – not human-to-human communication as may occur in knowledge sharing communities. In addition, the focus of this paper is on the human's interaction with the knowledge and the design of this interaction, from a behavioral and technological perspective, and not the creation of the knowledge in the underlying KBS. Finally, it must be recognized that due to space limitations this paper identifies only a limited number of key themes relating to KIS. A full synthesis requires a longer treatment.

Knowledge Interface Systems

KIS are a form of human-computer interaction (HCI), a field that has a long history and well-developed and useful bodies of knowledge (e.g. see [8, 9]). KIS are a special case of HCI, however, in that they are concerned with the transmission of knowledge rather than simple data input and output. The knowledge on the machine side is generated by a KBS, such as a DSS, an expert system (XPS), a geographic information system, or a big data analytics application. In general, KBS capture, represent, and apply knowledge in different contexts [10]. KBS can involve a variety of intelligent capabilities, such as data mining, language processing, or sentiment analysis. KIS are distinguishable from the underlying KBS that generate knowledge – the KIS is a layer on top of the KBS. KIS can give varying forms of advice to the user to encourage different outcomes. A recommendation agent could give suggestions such as: "*Your recommendations are books by Austen, Elliot, and Hardy*". A more sophisticated KIS could include an explanation function that gives the reasons for the recommendations: for example, other customers who buy the same books as you also buy books of these authors. This additional explanation has been shown to increase trust in the recommendation agent and enrich user experiences [11].

Note that KIS are not used only with systems whose primary aim is decision support or knowledge transfer. The KIS can also join a secondary knowledge base to a general application system, where the user is engaged with a task and the KIS assists with the task accomplishment. An example could be the processing of emails and the KIS makes a suggestion about how the task could be better performed: e.g. "*Did you mean to include an attachment in your email*?" Thus we distinguish two roles for KIS: primary and secondary (assistance) (see [12]). In the secondary role, KIS assist users in the usage of many forms of application systems, such as ERP, CRM, or groupware. In both cases the characteristics of the users should be considered. Figure 1 illustrates these two roles and they are discussed further below.

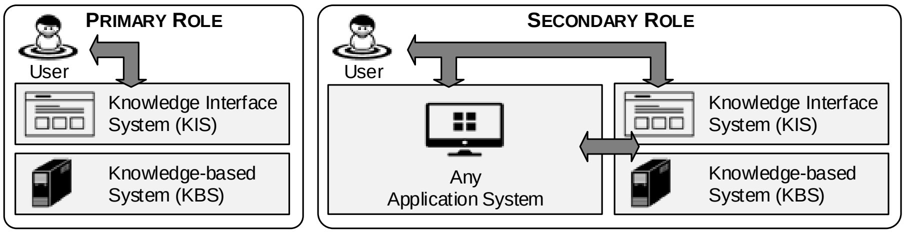


Fig. 1. Different Roles for Knowledge Interface Systems

Past, Present and Future: Revolution or Evolution of KIS?

It is of interest to see how past research on KIS compares with more recent research. Has there been a revolution in KIS or a steadier evolution? Is there some design knowledge or theory that has become well established in a cumulative tradition? What can we infer for the future?

For purposes of analysis, we compare how KIS were treated in the "past" (approx. before the year 2000) with research in the present (approx. since 2000). The choice of this point of time is somewhat arbitrary, but it represents something of a turning point in that new Web technologies and interfaces became increasingly available from this point. Further, we can locate textbooks and review articles that give an overview of knowledge concerning KIS at approximately that point (e.g. [2, 13, 14]).

Our aim is to overview some of the important knowledge that was built up around KIS in these periods, in terms of their design and the outcomes that resulted from their use. We use four dimensions for the comparison of KIS design knowledge: function (including content), presentation, provision mechanism, and context/user model. These dimensions are derived from previous work on explanation facilities [13] and intelligent assistance [14]. The dimensions are independent and each requires separate design decisions. For example, when considering an explanation capability, a core function could be a rule trace, presented in a textual format, user-invoked and adaptive to the user type (novice or expert). Similarly, in designing a visual analytic capability in a Business Intelligence and Analytics (BI&A) systems context, the designer can consider what functions to include (e.g. what parts of a data to display), how to display the data (e.g. 3D), what interactive mechanisms to allow (e.g. focus & context), and whether to track where the user's attention is mostly focused and then use these observations to adapt visualization algorithms (see [15]). Table 1 provides an overview of KIS capabilities and outcomes of their use for the "past" and the "present" along the four dimensions introduced above. Further observations on the systems in use in the two periods follows.

Table 1. Overview of KIS Research Past and Present

Design dimension of the KIS capability	KIS in past (before 2000)	KIS in present (since 2000)
Function	Basic explanations provided to improve **performance, learning, persuasion**, **trust, and acceptance** of advice [13]. Help functions used a repository of task knowledge to assist users in task performance [12].	Extensions to use with **recommendation agents** that build trust [11]; **affective KIS** to create emotions such as enjoyment [16, 17], for example, by **gamification,** or **persuasion** mechanisms [18, 19]; extraction of explanations from **neural networks** for legal compliance [20].
Presentation	Usage of various presentation formats such as **natural language (text-based)** and **multimedia (graphics, images, animations, and voice)** formats [13].	More extensive use of **graphics** (e.g. in process modelling) [21], **virtual reality** (e.g. in form of avatars) [22]; **visual analytics** [15, 23]; and **voice** as input and output (e.g. Siri) [24, 25].
Provision Mechanism	Provision of explanations either **automatically** or **manually** adapted to the **user context** [13].	Provision of explanations that are **intelligently** adapted to users and their usage context [26].
User Model	User model derived based on **user characteristics** (e.g. demographics) or **simple tracking/logging mechanisms** [2].	User model derived based on sensor data, e.g. use of **physiological and "emotional" monitoring** [27].

For analysis of the "past", we considered KIS primarily in three types of KBS that were prominent before 2000: XPS, DSS, and intelligent assistance (help) systems.

Expert systems (XPS) were first developed in the 1970s and can solve problems that ordinarily require human expertise [28]. Turban and Aronson [2] state that an XPS should contain a "user interface", a component for "*friendly, problem-oriented communication between the user and the computer… Sometimes it is supplemented by menus, electronic forms and graphics*". The XPS will usually also contain an “explanation sub-system”, which can explain the reasoning behind a conclusion. Gregor and Benbasat [13] propose that the design of an explanation sub-system should be considered in terms of the (i) content type – type of explanation function, (ii) the explanations presentation format – text-based and multimedia, and (iii) the provision mechanism describing how the explanations are invoked – either by the user or the system.

Decision support systems (DSS) serve the central purpose of supporting and improving human decision making [2]. The DSS architecture should include a “user interface (dialogue) subsystem” that includes the capabilities for a natural language dialogue and interactions between the user and other DSS components, presentation of data in various formats including graphics, and help and diagnostic support [2].

Intelligent assistance systems facilitate both the accomplishment of a task by a user who does not know how to do it and aid users’ learning processes so that their performance is improved in their primary task with the system [14]. Delisle and Moulin [14] consider that the KIS for an intelligent assistance system could include: (i) a user model, which keeps track of what the user is doing and what the user knows and does not know; (ii) a natural language interface; and also potentially (iii) an explanation facility. It can be seen from the above that there is overlap between the capabilities that each of the three types of KBS could possess. DSS and XPS can have help functions and intelligent assistance systems can include explanation facilities.

For the “present”, we considered newer forms of KBS growing in importance since 2000 in addition to extensions to older KBS and use of new technologies: for example, KBS based on large amounts of structured and unstructured data such as BI&A as well as recommender systems.

Business intelligence and analytics (BI&A) and the related field of big data analytics cover data-related problems to solve contemporary business problems. Since the early 2000s, BI&A emerged as a class of KIS that aims to analyze huge amounts of data, implementing mechanisms such as web intelligence, web analytics, and user-generated content through Web 2.0-based social and crowd-sourcing system. Thus, BI&A evolved to enable analysis of not only structured, but also unstructured content [23]. A challenge of modern BI&A systems is the visualization of the data and thus, is also an issue that should be addressed by an appropriate design of the KIS.

Recommender systems aim at assisting users in their decision making based on the previously collected and aggregated data from other humans [29]. The underlying knowledge base is used to support users, but also created by investigating the users. Thus, research addressing KIS in the context of recommender systems focuses on the one hand on providing the actual recommendation to the user, and on the other hand, the discovery, aggregation, and collection of data for the knowledge base.

What can we conclude for the future based on the comparison between the past and the present? If the trends for KIS observed in recent times compared with earlier times continue, then we should expect the following: (i) new forms of KIS arising to match new forms of KBS, as observable with big data analytics; (ii) more functions included in KIS capabilities, such as emotion elicitation and gamification; (iii) growth in KIS for intelligence assistance in a secondary role following from what has occurred with recommendation agents in e-commerce and process guidance in enterprise systems; (iv) many opportunities for new and innovative KIS/KBS in a secondary role as an intelligent assistant; (v) new forms of provision mechanisms as interaction technologies develop; (vi) a maturing of user modelling and tracking techniques and more integration to mainstream usage; and (vii) hopefully, attention paid to design principles that have been shown to be sound over almost six decades, such as the efficacy of explanation functions in many different types of KIS.

There are many opportunities for designers. A designer can develop novel ideas by considering work done with KIS in sum and utilizing different options in combination: for functions, presentation, provision mechanism and user modelling.

Summary

This paper presents an overview of research addressing KIS from the past to the present. We perceive KIS as an important class of systems for users interacting with knowledge-based systems in particular, in addition to many application systems more generally. The existing body of knowledge contains much important design knowledge for KIS, but a common consideration of this knowledge is missing. Research on KIS design is scattered and researchers as well as practitioners face the danger of re-inventing KIS for a specific purpose or, worse, repeating the mistakes of previous researchers. An example of lack of consideration of existing KIS knowledge is the work on developing explanations for neural networks [20] which ignores prior work on explanations in different KBS. Pu and Chen [30] research explanation interfaces for recommender systems, but ignore important prior work on explanations (e.g. [13]) and other work on explanations in recommender systems (e.g. [11]).

To address this problem, our paper provides an overview of KIS design capabilities from the past to the present and proposes possible future research directions for KIS. Our analysis shows that in general there is an evolution of work on KIS over time, rather than a revolution. For example, the importance of justification explanations in KIS has continued to be demonstrated [11, 13]. Our work will enable researchers to identify their contribution more clearly over and above what has been done before. Importantly, we clarify the architecture of KIS in relation to KBS in general, and distinguish between the primary and secondary roles for KIS.

This paper presents an early stage of our research on KIS and has some limitations that should be taken into account. The overview of KIS research is selective and we do not claim exhaustiveness. Rather, we aim to raise interest in this interesting and important research field and give a baseline for future research and theorizing. Nevertheless, the analysis covers more than 40 years of research on KIS and indicates the benefits of treating KIS as an important class of systems. This work is a first step towards a comprehensive review of research in KIS that will serve as a base for theorizing around this important class of system. In subsequent work we will provide both more breadth and depth to conceptualization and analysis

References

1. Avenade: Global Survey: The Business Impact of Big Data, http://www.avanade.com/~/media/documents/research and insights/big data executive summary final seov.pdf (accessed January 21, 2016).

2. Turban, E., Aronson, J.: Decision Support and Intelligent Systems. Upper Saddle River, NJ: Prentice-Hall. (2001).
3. Sprague, R.H., Watson, H.J.: Decision Support for Management. Upper Saddle River, NJ: Prentice-Hall. (1996).
4. Lycett, M.: "Datafication": Making Sense of (Big) Data in a Complex World. European Journal of Information Systems. 22, 381–386 (2013).
5. McAfee, E., Brynjolfsson, A.: Big Data: The Management Revolution. Havard Business Review. 90, 60–68 (2012).
6. Pirolli, P.: Powers of 10: Modeling Complex Information-Seeking Systems at Multiple Scales. Computer (Long. Beach. Calif). 42, 33–40 (2009).
7. Keen, P.G.W.: MIS Research: Reference Disciplines and a Cumulative Tradition. In: ICIS 1980 Proceedings. paper 9 (1980).
8. Shneidermann, B., Plaisant, C.: Designing the User Interface: Strategies for Effective Human-Computer Interaction. Boston, MA: Addison-Wesley. (2005).
9. Carey, J., Galletta, D., Kim, J., Te'eni, D., Wildemuth, B., Zhang, P.: The Role of Human-Computer Interaction (HCI) in the Management Information Systems Curricula: A Call to Action. Communications of the AIS. 13, Article 23 (2004).
10. Dhaliwal, J.S., Benbasat, I.: The Use and Effects of Knowledge-based System Explanations: Theoretical Foundations and a Framework for Empirical Evaluation. Information Systems Research. 7, 342–362 (1996).
11. Wang, W., Benbasat, I.: Interactive Decision Aids for Consumer Decision Making in e-Commerce: The Influence of Perceived Strategy Restrictiveness. MIS Quarterly. 33, 293–320 (2009).
12. Preece, J., Rogers, Y., Sharp, H., Benyon, D., Holland, S., Carey, T.: Human-computer Interaction. Harlow, England: Addison-Wesley (1994).
13. Gregor, S., Benbasat, I.: Explanations from intelligent systems: Theoretical foundations and implications for practice. MIS Quarterly. 23, 497–530 (1999).
14. Delisle, S., Moulin, B.: User Interfaces and Help Systems: From Helplessness to Intelligent Assistance. Artificial Intelligence Review. 18, 117–157 (2002).
15. Keim, D., Andrienko, G., Fekete, J.-D., Görg, C., Kohlhammer, J., Melançon, G.: Visual Analytics: Definition, Process, and Challenges. In: Kerren, A., Stasko, J., Fekete, J.-D., and North, C. (eds.) Information Visualization SE - 7. pp. 154–175. Springer Berlin Heidelberg (2008).
16. Lin, A.C.H., Fernandez, W.D., Gregor, S.: Understanding web enjoyment experiences and informal learning: A study in a museum context. Decision Support Systems. 53, 846–858 (2012).
17. Riaz, A.: Designing websites to elicit emotions and enhance comprehension of web-based information., unpublished PhD thesis, Australian National University (2015).
18. Schacht, S., Morana, S., Maedche, A.: The Project World - Gamification in Project Knowledge Management. In: Proceedings of the 2014 European Conference on Information Systems (ECIS 2014). Track 04, Paper 10 (2014).
19. Hamari, J., Koivisto, J., Pakkanen, T.: Do Persuasive Technologies Persuade? - A Review of Empirical Studies. In: Spagnolli, A., Chittaro, L., and Gamberini, L. (eds.) Persuasive Technology SE - 11. pp. 118–136. Springer International

Publishing (2014).
20. Baesens, B., Setiono, R., Mues, C., Vanthienen, J.: Using Neural Network Rule Extraction and Decision Tables for Credit-Risk Evaluation. Management Science. 49, 312–329 (2003).
21. Morana, S., Schacht, S., Scherp, A., Maedche, A.: Designing a Process Guidance System to Support User’s Business Process Compliance. In: ICIS 2014 proceedings. paper 6 (2014).
22. Chang Lee, K., Chung, N.: A web DSS approach to building an intelligent internet shopping mall by integrating virtual reality and avatar. Expert Systems with Applications. 28, 333–346 (2005).
23. Chen, H., Chiang, R.H.L., Storey, V.C.: Business Intelligence and Analytics: From Big Data to Big Impact. MIS Quarterly. 36, 1165–1188 (2012).
24. Assefi, M., Liu, G., Wittie, M.P., Izurieta, C.: An Experimental Evaluation of Apple Siri and Google Speech Recognition. In: Proccedings of the 2015 ISCA SEDE (2015).
25. Huang, X., Baker, J., Reddy, R.: A Historical Perspective of Speech Recognition. Communications of the ACM. 57, 94–103 (2014).
26. Ngai, E.W.T., Leung, T.K.P., Wong, Y.H., Lee, M.C.M., Chai, P.Y.F., Choi, Y.S.: Design and development of a context-aware decision support system for real-time accident handling in logistics. Decision Support Systems. 52, 816–827 (2012).
27. Liao, W., Zhang, W., Zhu, Z., Ji, Q., Gray, W.D.: Toward a decision-theoretic framework for affect recognition and user assistance. International Journal of Human-Computer Studies. 64, 847–873 (2006).
28. Russell, S., Norvig, P.: Artificial Intelligence: A Modern Approach. Upper Saddle River, NJ: Prentice-Hall (2003).
29. Resnick, P., Varian, H.R.: Recommender Systems. Communications of the ACM 40, 56–58 (1997).
30. Pu, P., Chen, L.: Trust-inspiring explanation interfaces for recommender systems. Knowledge-Based System. 20, 542–556 (2007).

Mining Social Media Data from Sparse Text: An Application to Diplomacy

Cecil Chua[1], Xiaolin (David) Li[1], Mala Kaul[2], and Veda C. Storey[3]

[1] Information Systems and Operations Management Department, University of Auckland Business School,
University of Auckland, Auckland 1010
aeh.chua@auckland.ac.nz, david.xiaolin.li@gmail.com
[2] Dept of Information Systems, College of Business, University of Nevada,
mkaul@unr.edu
[3] Department of Computer Information Systems, J. Mack Robinson College of Business
Georgia State University, Box 4015 Atlanta, GA 30302
vstorey@gsu.edu

Abstract. Publicly available data in social media provides a wealth of unstructured data for applications, such as sentiment analysis and location-based services. This research analyzes a specific application of diplomats, who seek to understand the people with whom they must negotiate. Social media data about a negotiating partner can, potentially, be used to build a profile of that partner. However, such data is difficult to mine effectively because it has sparse text with high dimensionality. This research uses a design science approach to develop a method for extracting critical information from sparse text. The method mines sparse text from publically available Facebook data to extract patterns from individual communications. The method is applied to Facebook posts of a political figure to identify meaningful categories of information for insightful inferences. Preliminary evaluation shows support for the method.

Keywords. Design application, diplomat, natural language processing, sentence clustering, sparse text mining, semantic chain

1. Introduction

Intelligence, the collection of information of value, is important to organizations and nations across the world. Diplomats, for example, often desire a deep understanding of the people with whom they must negotiate. This includes knowing who else the other party has talked to, when, where, and on what topic. Much intelligence is gathered from public or near-public sources. Social media has become a ubiquitous source of publically available information, which can be found in one place and applicable in many domains, including politics and foreign affairs, enabling one to derive "actionable information" [13]. Such information is valuable prior to engaging in discussions or negotiations. Manual review and analysis of such data, however, is time consuming, so a (semi-) automated approach to analyzing the data could significantly reduce the time spent on dealing with the large volume of data and might yield patterns, hints, or indicators of useful information. For example, the following post from a Prime Minister deals with crime and, one could infer, the results of an election.

> *"People want to know they are safe on their streets and in their homes - and our plan to make sure they are is working. We've cut red tape and given police one*

simple target: cut crime. And, thanks to the efforts of hardworking police officers, crime is down by over 10% since the election."

Existing text-mining algorithms require a large text corpus[1] for extracting useful information. Data on social media such as Facebook, however, tends to be sparse text, where each data point can comprise 10 words or less, whereas most text-mining algorithms require each data point to have at least 70 words. The research problem then becomes how to derive meaning from inferred semantic relationships between words, focusing on fragmented text in social media. This is an important design problem, common in many domains. Many businesses use social media platforms to receive customer complaints and/or feedback. Businesses would like to aggregate these complaints to identify systematic issues to correct. For example, KLM, the flag carrier airline of the Netherlands, is reported to answer 92% of complaints on their Facebook page with an average first response time in less than 30 minutes [9]. They currently do so manually. (Semi-) automated processing could potentially reduce the response time and labor cost. Similarly, businesses can mine the social media pages of their competitors to infer competitor strategy.

The objective of this research is to develop a method to mine (cluster) large amounts of sparse text found in social media data. The problem arises from: (1) the number of documents in the corpus being very large; and (2) the length of each document being very short. To evaluate the method, we apply it to Facebook data of politicians and/or public figures to derive actionable intelligence. The contribution is to provide a method for clustering vast amounts of social media data, with a sparse sentence structure with no explicit embedded metadata (e.g., hashtags), to develop a partial profile of an individual as might be used for negotiation purposes. A design science research approach is applied to develop the method artifact.

2. Related Research

Existing benchmarks for clustering "sparse text" are considerably different from those pertaining to social media data. Benchmarks of sparse corpii designate content of 6-7 paragraphs and approximately 1000 words.[2] Even research on "short sentence clustering" within narrow domains (e.g., medical corpus), includes approximately 70 words [2]. Research on information retrieval considers documents with less than 60 words as "short" [7]. Some research has been applied to Twitter [14], but such research relies on structured elements of Twitter communication such as #hashtags. The Facebook corpus has on average, 11 distinct words, after excluding "stop words," etc. An associated problem with sparse text is high dimensionality; that is, there are many possible ways in which a naïve algorithm can group the few words across sentences. Thus, to solve the sparse text problem, it is important to address the challenges of short sentences and high dimensionality.

Prior approaches have incorporated information from external sources to enhance naïve algorithms. The most frequently employed algorithms are based on either TF-IDF (i.e., term frequency – inverse document frequency), or bag of word representations [6]. TF-IDF counts the number of times words appear within and across

[1] The set of sentences to be processed is referred to as a corpus.

[2] http://about.reuters.com/researchandstandards/corpus/statistics/index.asp

documents. Words that appear frequently in a few documents are granted higher weight than words appearing frequently across many documents or words that appear infrequently. Bag of word representations create a two-dimensional matrix of the words and attempt to calculate similarity scores between them.

In addition to this frequency-based approach, there are knowledge based approaches where information is captured in the form of a lexicon (e.g., WordNet) or an ontology, or even an information source containing links from which an algorithm can infer information, such as a wiki. Supervised learning approaches also exist. None of the approaches, however, are designed to address the sparse text problem, such as that found in Facebook and tend to produce suboptimal results. Nevertheless, these approaches are a promising initial basis for our research.

3. Research Approach

This research follows a design science approach [8] to propose a method for mining sparse text and identifying patterns. The method is instantiated to provide proof-of-concept by applying the data mining method to three months of Facebook data of a politician. In general, the proof-of-concept stage involves instantiating a concept to provide evidence that the system can perform as conceptualized, to demonstrate feasibility [11]. Technical, observational, empirical, and theoretical insights together generate a potentially unique or innovative solution. The nominal process sequence [12] followed in this research is summarized in Table 1.

Table 1: Design Science Approach to Sparse Text

Step	Sparse Text Sentences
Problem identification and motivation	Valuable information can be obtained from text mining of social media data. How can valuable insights be extracted when text is sparse?
Objectives of a solution	Develop a method (artifact) for sparse text mining
Design and development	Method based upon data mining techniques, natural language parsing, and semantic clustering.
Demonstration	Application to Facebook data over 3 months
Evaluation	Application to corpus
Communication	Document analysis of resulting chains

For the initial development, the input to the method is a corpus of Facebook posts, e.g.:

> *"Our long-term economic plan is helping people across the country who want to work hard and get on in life …"*
> *"The biggest quarterly increase in employment on record. More jobs means more security, peace of mind and opportunity.."*
> *"We need everyone in the country to get behind our long-term economic plan. Our plan builds a stronger, more competitive economy and secures a better future…"*

The focus of this paper is extracting information that specifically addresses "what" a politician is talking about. Eventually, the method should be able to extract information that also addresses "who," "what," "when," "where," and "how."

4. Method for Sparse Text Mining

This research is based upon word and phrase parsing as well as clustering algorithms. The main steps are: *preprocessing*, *similarity calculation*, *generation of semantic chains*, and *sentence clustering*. The fundamental idea behind the semantic clustering is that, with the help of WordNet, the similarities among all of the words that appear in a corpus are compared. The similar words form different clusters, based upon the similarity scores calculated, are called "semantic chains." Then, all of the posts are grouped around the "selected" semantic chains of median length.

Preprocessing. The text is preprocessed by: (1) removing stopwords, (2) word lemmatization, and (3) indexing the words. Similar processes have been implemented in systems such as the SMART Information Retrieval System [4] and the Snowball text-mining system [1].

Stopword Removal. As a classic pre-processing strategy [5], stopword removal is used for two reasons. First, stopwords occur frequently so eliminating them greatly speeds up text mining algorithms. Second, these words disrupt many text mining algorithms because they rely on matching common words across pieces of text. There are two kinds of stopwords: (1) common (e.g., "the", "and," "in"); and 2) domain-specific. In the diplomat domain, for example, continent-words such as "Asia" and "Europe" are not helpful when one wants to know which specific countries in Asia and Europe the prime minister of New Zealand**,** John Key**,** visits. This research adopts the Snowball stopword list, comprised of 102 words [1]. The adoption of the Snowball list resulted from an earlier empirical test that compared Snowball to other stopword lists in our data set.

Word Lemmatization. Lemmatization removes inflectional endings. For example, in simple lemmatizers, the words "organize," "organized," and "organizing" are treated as the same word. We employ the Lemmatizer in NLTK [3]. This lemmatizer derives the root of a word, but then identifies all words in WordNet that have that word as a root. This is necessary, because we employ WordNet later to perform similarity calculations.

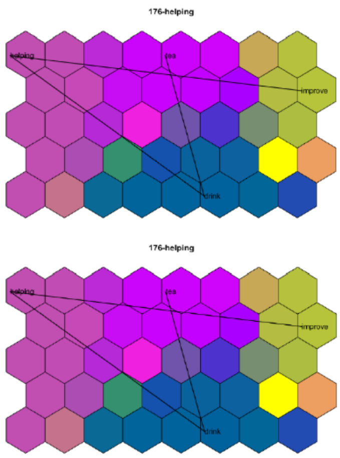
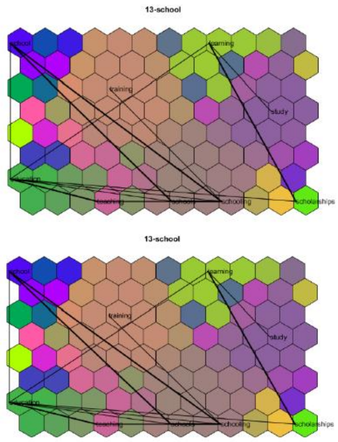
Indexing. Each remaining unique word is given an index number, with their frequencies of appearance throughout the entire corpus recorded. The frequency of each word is an important base statistic used in text mining [6].

Similarity Calculation. The similarity calculation is based on WordNet [10]. In WordNet, a hyponym is a word or phrase that is "similar to" (semantically) another word. A similarity score between every possible pair of words is calculated.

Generation of Semantic Chains. Semantic chains have been used extensively for keywords extraction. A semantic chain is a sequence of words (e.g., education, budget) deemed to be related. We generate semantic chains incrementally. First, we generate all semantic chains comprising two words. We then attempt to add a third word to each of these chains, etc. The size and quantity of chains is determined based upon a similarity threshold. The longer and more chains we have, the more complex the later part of the processing will be. A threshold of 0.4 appears to produce computationally tractable chains. Chains that are "too long" are eliminated, as well as those that are "too short." Preliminary analysis shows that chains of approximately 5-10 words seem to be best, which is what is currently implemented.

Besides selecting median-sized chains, chains are eliminated by calculating a normalized connectivity score of a chain, defined as $\frac{S}{n \times (n-1)}$, where S is the sum of the similarity scores of each pair of words and n is the number of words in the chain. This determines the "average" similarity score across all words in a chain. A more cohesive chain is expected to have a higher normalized connectivity score, as can be observed through visualizing the detailed structure for each semantic chain.

To illustrate, for our sample corpus, chain 176 (helping) in Figure 1a, has a normalized connectivity score of 0.75. The words in the chain do not form a cohesive topic; e.g. the words "tea" and "helping", "drink" and "improve" are not related semantically. On the other hand, in Figure 1b, where the normalized connectivity score is 1.44, the words in this semantic chain 13 (school) are gathered around the topic "education," and are more semantically related. The 150 semantic chains with the highest normalized connectivity score are used for the analysis. Otherwise, the number of semantic chains would be too many to compute effectively.

<table>
<tr><td>
</td><td>
</td></tr>
<tr><td>Figure 1a. Connectivity Graph for chain 176 (normalized connectivity score 0.75)</td><td>Figure 1b. Connectivity graph for chain 13 (normalized connectivity score 1.44)</td></tr>
<tr><td colspan="2">Figure 1: Sample Connectivity graphs for 2 chains</td></tr>
</table>

Figures 1a and 1b are produced by Self-Organizing Maps (SOM) using the term-document matrix generated from the corpus. In a corpus containing d terms and n documents, the term-document matrix is a d x n matrix, in which the (i, j)th entry is the frequency of the ith term in the jth document. For the semantic chain i with words denoted by $\{v_1, \cdots, v_{N_i}\}$, the visualization is produced by taking rows in the term-document matrix with index $v_1, \cdots, v_{N_i}$ to train the SOM. After the training, each grid on the SOM is accompanied with an n-dimensional vector. The colors on each grid are produced by first reducing each n-dimensional vector to 2-dimensional using Curvilinear Component Analysis (CCA) and then converting the 2-dimensional vector into color. One can consider the background color on each grid as the similarity derived from the text contexts of the original corpus. After adding the edges by referring to the similarity produced by WordNet, the additional similarity identified by using WordNet is clearer.

Clustering. Any sentence containing a word in the semantic chain is considered to belong to the same "group."

5. Application of Method

The method is being applied to the Facebook page of John Key (Prime Minister of New Zealand) to build, evaluate, and refine it. The corpus consists of 499 extracted posts over a three month period. The resulting 150 clusters that formed were sorted into three groups: 1) "clusters that look reasonable to a human;" 2) "clusters that do not make sense to a human;" and 3) "clusters that somewhat look reasonable to a human." One of the main issues causing sentences to fall into the "do not make sense" category is when clusters mainly comprise verb or action roots, as opposed to sentences in the "look reasonable" category that do not tend to be verbs. The next iteration will strip all such words before clustering to assess whether doing so improves accuracy. There were also words common across many documents in the clusters that do not make sense, implying the need to incorporate TF-IDF into the method. An example of a resulting chain and its evaluation is given in Figure 2.

Chain 92 has the following words:
enjoy loving employ commit enjoyed enjoying
Chain 92 has the following posts around it:
15: Blenheim really turned it on today. Enjoyed meeting so many people during the Royal visit.
26: Enjoyed helping out at Henderson Primary Breakfast Club this morning. 25,000 children each week in 372 schools are taking part in KickStart. It really shows how communities, businesses, and the government can work together to help children in need.
33: Really enjoyed the NZ Shearing Champs this evening in Te Kuiti. Brilliant shearing skills. Congrats to all the winners tonight.
51: On Saturday I enjoyed mixing with the crowds at the Pasifika Festival.
69: Plenty of selfies at O-week at Vic. Loving their enthusiasm.
97: Am enjoying chatting with you all on Newstalk ZB Wellington this morning.
107: On 11 February, I enjoyed taking part in Chinese New Year celebrations at Parliament.
128: At Red Stag timber in Rotorua with Todd McClay MP – it's a local success story, employing 360 staff.
Comments: sentences centre around the word "enjoy". Score 1.67

Rank: Good.

Figure 2: Chain 92 words and posts

As can be seen, the chain scored reasonably well suggesting evidence of a successful application.

6. Conclusion

The mining of sparse text is a general problem for extracting value from social media data. This research proposed a method for addressing sparse sentence structure (sparse text) problems and applied it to the analysis of diplomatic relationships as found in an online presence. A design science research approach was used to create the method artifact through adoption of prior work on natural language parsing and semantic clustering, extended and refined through an iterative process of testing and use. This method is illustrated through the mining of Facebook data to make inferences intended to lead to a profile of a public figure. To test the feasibility of the research, the method has been applied to 499 posts from the Facebook posts of one diplomat. Initial results suggest that the method appears feasible.

The research extends prior work on sparse text mining by providing a method for mining and clustering sparse text resulting in a visualization of patterns using connectivity graphs and chains. This research contributes to social media intelligence by developing and implementing a method for finding patterns in social media data. This general method could potentially be applied to multiple applications of mining sparse text for the purpose of drawing inferences from patterns of connections between words. For example, it could be used for profile development which has applications in law enforcement, marketing (customer profiles), or other behavior analysis such as in sentiment analysis or in fraud detection. Future research will involve further development of the method and testing and extending it to inferences dealing specifically with questions of "who, what, where, and when" pertaining to diplomats. It will then be tested on other applications.

References

1. Agichtein, E., Gravano, L. (2000) Snowball: Extracting Relations from Large Plain-Text Collections. Proceedings of the Fifth ACM International Conference on Digital Libraries, pp. 85-94. San Antonio, TX: Association for Computing Machinery, 2000.
2. Avendano, D.E.P. (2007) Analysis of narrow-domain short texts clustering. (Diploma of Advanced Studies thesis), Retrieved from http://users.dsic.upv.es/~prosso/resources/PintoDEA.pdf.
3. Bird, S., Klein, E., and Loper, E. 2009. *Natural Language Processing with Python*. O'Reilly Media, Inc.
4. Buckley, C. (1985) Implementation of the SMART Information Retrieval System. Technical Report, Cornell University Ithaca, NY, USA.
5. Callan, J.P., Lu, Z., Croft, W.B. (1995) Searching distributed collections with inference networks. Proceedings of the 18th Annual International ACM SIGIR Conference on Research and Development in Information Retrieval, pp. 21-28.

6. Deerwester, S., Dumais, S.T., Furnas, G.W., Landauer, T.K., and Harshman, R. (1990) "Indexing by Latent Semantic Analysis," *Journal of the American society for information science* (41:6), pp. 391-407.
7. Jing L., Ng M. K., Yang X., and Huang Z., A Text Clustering System based on k-means Type Subspace Clustering and Ontology, International Journal of Computer, Electrical, Automation, Control and Information Engineering Vol. 2, No. 4, 2008.
8. March, S. T., and Smith, G. F. 1995. "Design and Natural Science Research on Information Technology," *Decision Support Systems* (15:4), pp. 251-266.
9. McCrea, L., (2012) 16 Brands Leading the Way with Exemplary Social Media Customer Service. Ignite Social Media blog.
10. Miller, G., and Fellbaum, C. 1998. "Wordnet: An Electronic Lexical Database." MIT Press Cambridge.
11. Nunamaker Jr, J.F., and Briggs, R.O. 2011. "Toward a Broader Vision for Information Systems," *ACM Transactions on Management Information Systems (TMIS)* (2:4), p. 20.
12. Peffers, K., Tuunanen, T., Rothenberger, M. A., and Chatterjee, S. 2007. "A Design Science Research Methodology for Information Systems Research," *Journal of Management Information Systems* (24:3), pp. 45-77.
13. Zeng, D., Chen, H., Lusch, R., Li, S. H. (2010). Social media analytics and intelligence. *Intelligent Systems*, IEEE, 25(6), 13-16.
14. Kosinski, M., Stillwell, D., and Graepel, T. (2013). Private traits and attributes are predictable from digital records of human behavior. *Proceedings of the National Academy of Sciences* 110 (15), 5802-5805.

Architecture of In-App Ad Recommender System

Anik Mukherjee*, RP Sundarraj*, Kaushik Dutta$

*Department of Management Studies, Indian Institute of Technology, Madras
Sardar Patel Road, Chennai, Tamil Nadu 600036 – India.
$Department of Information Systems and Decision Sciences, Muma College of Business, University of South Florida, United States of America
{*anikit.jgec@gmail.com; *rpsundarraj@iitm.ac.in; $duttak@usf.edu }

Abstract: *Increased adoption of smartphones has caused mobile advertising to be the second-most revenue-generating medium among all forms of existing online advertising. Application (henceforth called app) developers try to monetize their apps by selling in-app ad-spaces to the advertisers (or ad-agencies) through various intermediaries such as ad-networks. Surveys, however, indicate that mobile ad campaigns are not as successful as they can be, in part due to inappropriate audience targeting, and in turn, user-apathy toward such ads. This motivates the need for a system, where both advertisers and mobile-app developers gain from the in-app advertising eco-system. In this paper, we propose an architecture of design-science artifacts for an ad-network, to meet the objectives of both these stakeholders.*

Keywords: Negotiation, Recommender System, Integer Programming Model.

1. Introduction

Online advertising has been growing on importance during the last decade. It comes in different forms such as display, digital audio and video, banner, social media, and mobile, and of these, display and mobile are among the most popular. An Internet Advertisement Bureau (IAB) report[3] indicates that more than 30% of the total online advertising revenue comes from mobile advertising, this being second only to the 38% market share of display advertising. In terms of revenue, too, online advertisement has exceeded the $50 billion mark in 2015, which suggests that mobile-ad revenue contributes more than $15 billion[1].

Research on display advertising has been dealt with from multiple perspectives, for example, from: (a) the publisher; (b) advertiser and (c) ad-networks. However, these results are not translatable to the mobile situation, owing to some fundamental differences. First, in the display scenario, typically, the advertisement placement happens through off-line negotiation. For example, if one needs to put an advertisement at CNN.com, s/he needs to negotiate directly with the Turner on the cost of putting such an advertisement. Second, display web sites resort to other ways of generating revenue such as selling user data, registration fee to access premium content, and fee to put up the content (such as a pharma company putting ads in WebMD.com). In contrast, the majority of mobile apps are free, and rely on advertisement-based revenues. Additionally, mobile apps market is populated by mobile apps developed by not so well known publishers that do not have the resources to negotiate ad-pricing with individual

[3] Available at: http://www.iab.com/wp-content/uploads/2015/10/IAB_Internet_Advertising_Revenue_Report_HY_2015.pdf

advertises or their agencies. Therefore, they resort to programmatic ad-buying through ad-networks. However, the lack of any standardized framework that would address the need of publishers, advertisers and ad networks all together had made the mobile ad ecosystem unreliable[4,5]. Most of the ad-networks deliver ads that are optimized for advertisers (giving maximum click or maximum impressions) and does not address the need of the publishers. In this paper, we propose the design of an architectural framework for an ad-network that seeks to balance the needs of both publishers and advertisers. Rather than treating the interest of the publishers and advertisers dis-jointly, in our proposed framework, we address them together, to determine which advertisement to deliver when and at what price.

2. Literature review

Keyword search is one way of audience targeting[6] in website, where keywords are extracted from website contents and publishers bid for key words. According to Hermann et. al. [1], if one website contains certain keywords, advertisement targeted to those keywords will be displayed in the website. Keyword based advertisement is not applicable to in app advertisement. In the past, researchers had tried to solve web-site advertising problem from scheduling problem's perspective. Menon et al. [2] has proved web based advertising problem to be NP-Hard problem. Deane et al. [3] has followed artificial intelligence based technique to solve online ad-scheduling problem. However, in mobile apps ad-placement problem is not only a scheduling problem, as discussed later in the paper it needs to address several other aspects such as audience targeting, price negotiation, target negotiation etc. In mobile programmatic ad delivery platform, ad-networks act as the bridge between advertiser and publisher to make automated in-app advertising happen in real time. However, there is paucity of research in this domain. Recently, [4][5] proposed a mathematical model and rule generation approach to maximize the revenue of publishers. In this paper, we aim to extend that work to the next level by proposing the architecture of entire in-app advertising eco-system that addresses publishers', ad-networks' and advertisers' needs jointly.

3. Design Science Research Problem Statement and Objective

Of the five design steps [6][7] (Problem Statement, Objective, Design Artifacts, Demonstration and Evaluation), in this work-in-progress paper, we have addressed the first three. Further, part of our proposed architecture has been evaluated in [5][4].

3.1. Problem Statement

Advertisers and *publishers* represent the two main stakeholders in the online advertising eco-system. Ad agencies help interested advertisers to register in their ad-networks to display their ads in different online websites or media.

---

4 Available at: http://www.emarketer.com/Article/Marketers-Wasting-Money-on-Mobile-Ad-Clicks/1009351

5 Available at: http://www.mobilemarketer.com/cms/news/research/9015.html

6 Available at: https://www.google.com.sg/adwords/

A stream of ads from advertisers (or their agencies) is coming to ad-networks to be pushed into multiple available ad-slots available to publishers. The number of available slots at any instant depends on the number of users of apps at that instant. Owing to limited number of slots, not all the ads can be picked up simultaneously. Hence, we need to select ads in such a way that it contributes enough to the return-of-advertisement-dollar to advertisers (measured by number of clicks or number of target impressions), as well as to the revenue generation of publishers. Moreover, the problem is complex as well, as given below.

Issue 1: Impression Requirement Negotiation

In order to do effective app-targeting, apps need to be ranked on some measure. However, what is unique about apps, as compared to websites, is that this ranking can be very unstable [8]. The number of users of a particular app varies widely even within a day, and except for a few apps, the others loose their popularity after a few days. This makes smartphone app-targeting difficult. Thus, advertisers cannot negotiate for impression requirements and price over a long scheduling horizon, as is the case with websites. Instead, they need to negotiate for a small time-horizon of, say, a few hours. Short time-frames can lead to inefficient negotiation, in turn resulting in a loss to both parties. Thus, any system that is created must address the issue of short-term, albeit effective, negotiation.

Issue 2: Efficient ad-selection for publishers

From the publisher perspective, revenue must be maximized, by allowing advertisers to push ads in their online available ad-spaces. When an ad is placed in a slot in an app, the publishers of that app gets revenue. Additionally, if the user of the app clicks on the placed ad, there is possibility of additional revenues to publishers. However, all decisions regarding the selection of ads are to be made by ad-networks in the order of tens of milliseconds; IAB report[1] states that the time must be under 50 milliseconds. Given the complexity of the problem, optimal ad-selection can be a challenge.

Issue 3: Proper Audience Targeting for advertisers

Researchers have done extensive research in website advertising where cookies keep track of the behavior of web site users. The absence of cookies in mobile apps is a key issue. Audience targeting is a crucial part for advertisers to maximize their return-on-ad-spend.

3.2. Objective of the problem

The overarching objective of our research is to develop an automated in-app advertisement system for ad-networks, by considering the perspectives of multiple stakeholders. To address the three issues given above, we define three specific objectives:

- ➔ *Objective 1*: Ad-Agency Publisher Negotiation
- ➔ *Objective 2*: Publisher's Ad-Selection
- ➔ *Objective 3*: Online Ad Recommendation

To address the *Issue1* of our problem, we aim to negotiate with the ad-agencies and publishers in *Objective1* whereas *Objective2* addresses the *Issue2* by selecting ads in such a way that it generates maximum revenue of the publishers. Last challenge of our problem is efficient audience targeting. *Objective3* of our problem is to develop an Online Ad-recommendation engine to solve *Issue3*. This directly depends on the output of first two objectives and its own advertiser based internal algorithm. Once the *Objective3* is solved, our system places the best ad in the corresponding mobile app.

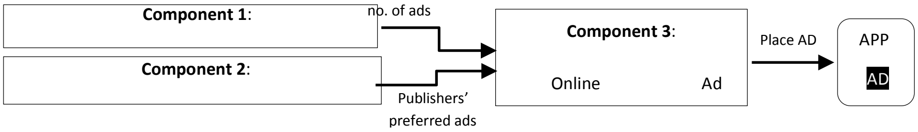


Figure 4: High Level Architecture of In-App Recommender System

The high level architecture of our system is given in Figure 1. The detailed architecture of our system is presented in Section 4. According to Figure 1, *Component 1* and *Component 2* provide inputs to C*omponent 3* which decides the single best ad to be pushed into each individual online available ad-slot within 50 milliseconds. First two components run offline based on machine learning based algorithm. The last component of our system forwards ads based on greedy recommendation algorithm in real time. This happens online. *Objective 1* of the system is partly implemented in our previous works [5] [4].

4. Design Science Artifacts

Artifacts are the core components of a DSR-based system. According to [6], *artifacts*, broadly include, constructs, models, algorithms and system instantiation; the artifacts we have proposed herein are algorithms pertaining to each of the three components in Figure 1.

4.1. Component 1: Ad-agency Publisher Negotiation

In in-app advertising, a direct-buying mechanism[7] is used to decide the number of ads that needs to be displayed by a publisher. On behalf of advertisers, ad-agencies buy available online ad-spaces. This is often done through a negotiation process [9]. Given the advances in negotiation support systems, our architecture entails a negotiation engine described below.

4.1.1. Artifact 1: Advertiser-Publisher Negotiation

The advertiser-publisher negotiation artifact is a multi-agent negotiation system where ad-agency represents buyer and publisher represents seller (see Figure 2). Since negotiation can be a long-drawn process and can also be involved, we propose that an automated negotiation-system be used for this purpose. As shown in the figure, in the online negotiation agent, multiple ad-agencies negotiate with publishers via negotiating agents known as ad-agent and pub-agent, respectively. The well-known alternate-

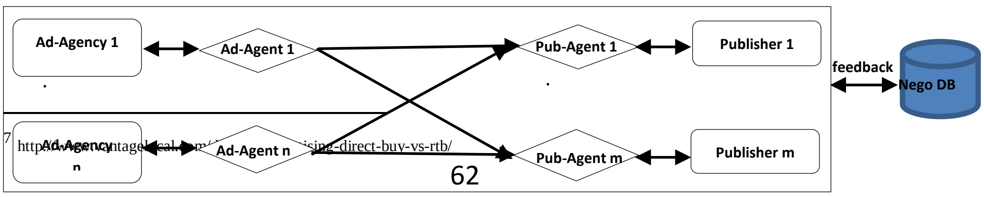


Figure 5: Online Negotiation Agents interaction

[7] http://...ntagelocal.com/...ising-direct-buy-vs-rtb/

offers protocol [10] is used. Agents are guided by different parameters to make the trade happen. Parameters associated with the buyer include click-through-rate, conversion rate, and expected number of audience reachable. Example-parameter for the seller include monetary value for the publisher, minimum/maximum number of ads advertiser is willing to display, and payment for impressions. Details on how to structure electronic-negotiation can be found, for example, in [11], [12].

4.2. Component 2: Publisher's Ad-Selection Component

Once the required number of ads is decided by the negotiation engine, we need to develop offline methods to support the online component in Section 4.3. We adopt a two-step procedure for this purpose [5, 6]: a revenue-based optimization model whose results are used by a rule-generation system.

4.2.1. Artifact 2: Revenue-based Optimization Model

The revenue-based model is used to generate selection/rejection decisions for past dataset. The immediate past is used to make the results relevant for practical application. An Integer Linear Programming (ILP) model with revenue maximization objective is used. The model's revenue function includes Click-through cost, impression cost and conversion cost. Constraints include: (a) limitations on the availability of the total number of ad-spaces; (b) pacing constraints to spread the budgetary spending across different periods of the planning horizon; (c) impression requirements; and (d) a constraint to ensure that a particular ad-space can have no more than one ad at any given time. Details of the model can be found in [4], [5]; the model is NP-complete.

4.2.2. Artifact 3: Rule Generation

The term rule refers to an authoritative statement of what to do or not to do in a specific situation issued by an appropriate person or body. In our context, the rationale for the rule-generation is two-fold. First, rules represent a practical approach to provide a real-time decision in the allowed short time-window, especially given the complexity of the optimization model. Second, our rule generation is based on the optimization model's results (with the immediate past data), thereby seeking to ensure the accuracy and usefulness of the rules to the extent possible. We generate two kinds of rules: positive rules (based on selected ads) and negative rules based on rejected ones. The rule generation artifact consists of three main parts [5, 6]: (a) Data Classification Engine; (b) Rule Engine; and (c) Rule Optimization Engine.

4.2.2.1. Data Classification Engine:

Preliminary observation with the optimization model's results indicated that the selection/rejection decision depends on the value ranges of the data. In our case, each tuple of the dataset represents individual ad with six different attributes such as Click-through Rate (CTR), Click Price (CTRPRICE), Conversion Rate (CONV), Conversion Price (CONVPRICE), Price for each impression (IMPPRICE), Winning bid price of ad (BID). We use K-Means clustering to divide each attribute of the dataset into predefined clusters.

4.2.2.2. Rule Engine

The clustered data set is fed into the rule engine. The apriori algorithm, drawn from the area of machine learning, is used by the rule engine. The apriori algorithm is used, for example, in market-basket analysis to find out the most-sold products of a store/company, based on the probability of occurrence of that product in store's transactional database. This helps decision makers to pinpoint the reason behind an ad campaign for that product. We apply this idea to find out the patterns among the aforementioned six different attributes and generate rules of the form X, Y ➔ Z, where the antecedents X, Y imply that Z has occurred. Two control parameters are used to moderate the number and quality of the rules: *support* representing the percentage of times in which the antecedents have occurred and *confidence,* which stands for the probability of occurrence of the rule. Thus, based on support and confidence values, the set of rules can change.

4.2.2.3. Rule Optimization

From the previous discussion, we can see that lower (higher) support and confidence values implies higher (lower) number of rules. The robustness of our proposed architecture is dependent on the quality of rules generated. Large number of rules could tend to improve accuracy (i.e., quality of the selected ads), but also increase decision-making time. This implies that the support and confidence values must be optimized. Genetic algorithm based rule optimization technique can be used [13] to come up with the best set of rules from among the pool of rules.

4.3. Component 3: Online Ad Recommendation

Online Ad Recommendation engine is the last component of in-App advertising architecture. It consists of two sub-components: Recommender System which works from the advertiser's perspective and greedy algorithms which picks up the one final best ad based on outputs of all other components and few criteria.

4.3.1. Artifact 4: Recommender System

According to Forbes[8], advertisers are spending money on mobile advertising without getting any significant profit. Thus, the recommendation system is used to help advertisers; specifically, from the real-time stream of ads, it recommends ads to ad-spaces. It takes into account context-specific information, and hence, can help draw audience attention; in turn, this provides the possibility of increasing revenue. Ads are ranked by the ad-scoring algorithm inside recommendation engine, based on similarity of ad with respect to the targeted in-app ad-space. The "Top-N" ads are then sent to the rule-based greedy algorithm for the next level of filtering.

[8] Available at: http://www.forbes.com/sites/baininsights/2012/07/03/when-is-advertising-a-waste-of-money/#67b8000f70c2

4.3.2. Artifact 5: Rule Based Greedy Algorithm

The rule-based system takes three inputs: (a)negotiated number of impressions from negotiation engine; (b) the ads after applying the rules from the (offline) rule-generation artifact on real-time stream of ads; and (c) the ads from the recommendation system. The greedy algorithm applies the rules and checks negotiation results to make an intermediate select/reject decision on each incoming ad. This decision is compared with that of the recommendation systems and priority will be given to that which appears in both sets, thereby attempting to account for the priorities of both the advertiser and the publisher. The detailed architecture summarizing all the discussion is given in Figure3.

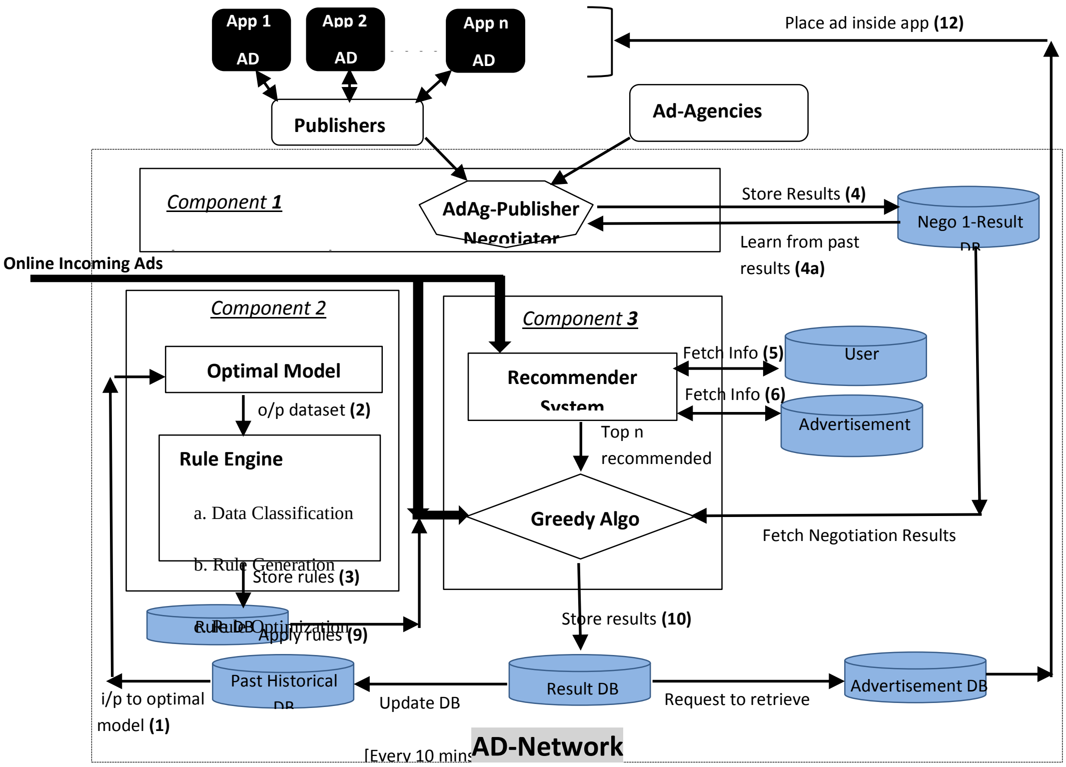


Figure 3: Architecture of In-App Ad Recommender System

5. Conclusions

In this research we present the design of an architectural framework for mobile ad network that addresses the need for publishers (revenue maximization) and the need for advertisers (maximization of the return on advertisement dollar) simultaneously. Unlike past research that has dealt with either publisher or ad network or advertisers, in this research we take a holistic approach by proposing a rule based negotiation engine. We have described the key component of this complex system. The future research on this will focus on developing the details of the individual components. In future we also intend to implement and evaluate the proposed framework in a simulated environment and compare with the existing silo based approach.

6. References

1. Hermann, C., Francine, C., Ayman, F., GREENE, D.: Server-based keyword advertisement management, http://www.google.com/patents/US20050144064, (2005).
2. Menon, S., Amiri, A.: Scheduling Banner Advertisements on the Web. INFORMS J. Comput. (2004).
3. Deane, J.: Hybrid genetic algorithm and augmented neural network application for solving the online advertisement scheduling problem with contextual targeting. Expert Syst. Appl. 39, 5168–5177 (2012).
4. Mukherjee, A., Sundarraj, R.P., Dutta, K.: Online Programmatic Ad-Placement for Supply Side Platform of Mobile Advertisement : An Apriori Rule- generation Approach. Workshop on Information Techologies and Systems. (2015)
5. Mukherjee, A., Sundarraj, R.P., Dutta, K.: AN ONLINE ALGORITHM FOR PROGRAMMATIC ADVERTISEMENT PLACEMENT IN SUPPLY SIDE PLATFORM. Pacific Asia Conference on Information Systems.(2015)
6. Hevner, A.R., Chatterjee, S.: Design Research in Information Systems. Des. Res. Inf. Syst. 28, 75–105 (2004).
7. Peffers, K.E.N., Tuunanen, T., Rothenberger, M.A.M.A., Chatterjee, S.: A design science research methodology for information systems research. J. Manag. Inf. Syst. 24, 45–77 (2007).
8. Petsas, T., Papadogiannakis, A., Polychronakis, M., Markatos, E.P., Karagiannis, T.: Rise of the planet of the apps. In: Proceedings of the 2013 conference on Internet measurement conference - IMC '13. pp. 277–290. ACM Press, New York, New York, USA (2013).
9. Tawfik Jelassi, M., Foroughi, A.: Negotiation support systems: an overview of design issues and existing software. Decis. Support Syst. 5, 167–181 (1989).
10. Rubinstein, B.Y.A.: Perfect Equilibrium in a Bargaining Model Author (s): Ariel Rubinstein Published by : The Econometric Society PERFECT EQUILIBRIUM IN A BARGAINING MODEL. Econometrica. 50, 97–109 (2014).
11. Kersten, G.E., Lai, H.: Negotiation support and e-negotiation systems: An overview. Gr. Decis. Negot. 16, 553–586 (2007).
12. Sundarraj, R.P., Mok, W.W.H.: Models for human negotiation elements: Validation and implications for electronic procurement. IEEE Trans. Eng. Manag. 58, 412–430 (2011).
13. Christian, A.J., Martín, G.P.: Optimization of association rules with genetic algorithms. Proc. - Int. Conf. Chil. Comput. Sci. Soc. SCCC. 193–197 (2011).

AdBo: A Mobile Application to Boost Adherence of Physical Exercises for Elderly Suffering from Cognitive Decline

Mohammed Alsaqer* and Samir Chatterjee*

* Innovation Design & Empowerment Applications Lab (IDEA Labs), School of Information Systems and Technology, Claremont Graduate University, 130 E 9t St, Claremont, CA 91711
Mohammed.alsaqer@cgu.edu, samir.chatterjee@cgu.edu

Abstract. *According to the UN, the number of elderly people over the age of 60 will reach 2 billion by 2050. Aging is accompanied with functional and cognitive decline that impact elderly independence and quality of life. This often results in issues such as forgetting, fall, and depression. Physical exercises can help. However, only 16% of elderly above the age 65 years do enough exercise to meet HHS (Department of Health and Human Services) physical activity guidelines for Americans. Several barriers impact the elderly's adherence to physical exercises. In this paper, we discuss the barriers and proven strategies that can be used to overcome them. Then, we discuss the development of the AdBo smartphone application, which aims to increase the elderly adherence to physical exercises. The application will guide the elderly though appropriate exercises, measure cognition ability before and after the exercises regimen, and track cognitive improvement over time.*

Keywords: Elderly, cognitive impairments, physical exercises, persuasive, design science, app, mobile health.

Introduction and Problem Definition

Major cognitive decline begins after the age of 60 [1]. Cognitive decline is sometimes noted as a syndrome of functional decline that appears in 12% of the elderly people every year [2]. There is evidence that cognitive impairment is a functional decline risk factor [3]. Another study found that there is an association between the severity of cognitive decline and ADL (Activities of Daily Living) and IADL (Instrumental Activities of Daily Living) [4]. We can conclude that both cognitive decline and physical decline are two major issues that are associated with aging.

Exercises can improve both cognitive and functional status in the elderly. According to the NIA (National Institute on Aging), exercising is one of the important things that the elderly need to adhere to, given the fact that only 16% of elderly above 65 years old do enough exercise to meet HHS (Department of Health and Human Services) physical activity guidelines for Americans. NIA also mentioned the need to new approaches to bring physical activity and exercise to the remaining 84% [5]. In addition, there is a need for other interventions that complement the role of health care and motivate the elderly to exercise [6] . Those new approaches are needed more if we know that 50% of the sedentary elderly have no intention to start exercises, and 50% of those who started exercises stop during the first 6 months [6]. More efforts are required toward the elder population since there is clear evidence that physical activities can improve physiological and performance capacities [7]. However, large numbers of the elderly already suffer from cognitive and physical decline, which becomes a barrier to adherence to physical exercises, in addition to other barriers. Therefore, a technology designer who is trying to solve this issue must aim at preventing further decline without forgetting the large number of the elderly who already suffer from cognitive and physical decline as a targeted group.

Efforts have been done in the context of aging and exercises such as CAMMinA that uses virtual coins to motivate the elderly to do exercise [8]; some solutions focus on narrower types of exercises such as fall prevention [9]. In this paper, we focus more on the cause of the issue by addressing the question what prevents the elderly from doing exercises? How can we motivate them, and how can we suggest the right variety of exercises that is suitable for them?

In order to empower the elderly to do exercises using digital technology so we can improve their physical and cognitive health, we need different things. First, we need to understand cognitive and physical barriers that prevent the elderly from doing exercises. Second, apply proven mechanisms/strategies that can be used to overcome those barriers in the design process. Third, we need to capture both physical and mental progress over time since there is a relationship between exercises and physical and cognitive status, and both are important when it comes to the elderly and exercises. To address this issue, we propose the Adherence Booster (AdBo) system. AdBo is a smartphone application designed to overcome the barriers that prevent the elderly from adhering to physical exercise, with a focus on cognitive and physical ability in the design and the objectives of the app.

Research Approach

In general, this study will use the design science research (DSR) approach. Since the main focus of this paper is to assist and change the elderly's behaviors, DSR is the best choice among different approaches. It is stated that " We also recommend using design science such as the DSRM process model (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007) as a methodical tool for developing effective behavior change and assistive technologies" [10]. DSR is defined as a research methodology in which a researcher or designer answers questions relevant to human problems by creating innovative artifacts [11]. DSR has three cycles: the relevance cycle in which the design and its environment are bound together, the rigor cycle in which the design is grounded on and contributed to the knowledge base, and the design cycle which is the actual building and evaluation of the artifact [12]. In this research-in-progress paper, we will focus on defining the problem and detailing the design elements. In the near future, we will evaluate the application based on real-user feedback, and determining the feasibility of the intervention in terms of improvement of adherence to physical exercises.

Fig. 1 highlights the components of AdBo system with numbers indicating the flow of events. Numbers 1 and 2 show how aging and cognitive decline among the elderly create barriers to adherence (see section 3). Number 3 indicates how those barriers are considered in the design of AdBo (see section 4). Number 4, 5, and 6 show how the interaction with AdBo can help the elderly overcome the barriers and adhere to exercises. Finally, AdBo will track improvement in adherence to exercises, and assess the cognition overtime to give insights for physicians and caregivers.

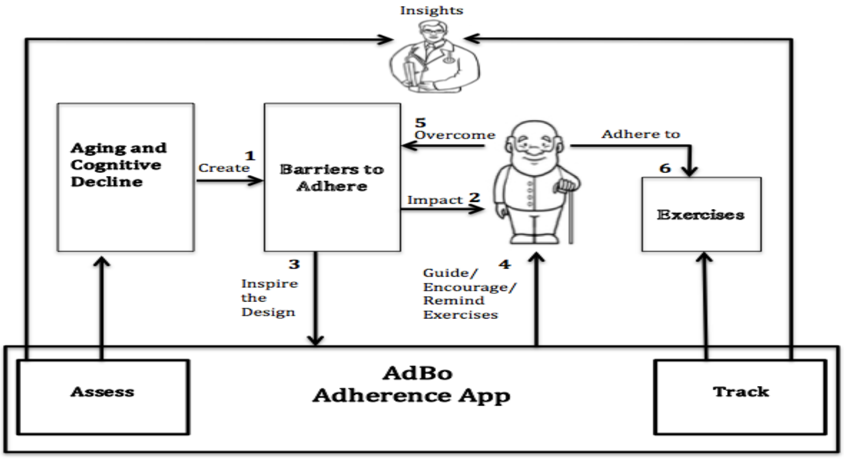


Figure 6. Conceptual Design of AdBo Stages.

Barriers and Mechanisms

To design an effective solution, we have to understand the nature of barriers that prevent the elderly from doing exercises, and then define the mechanisms that should help the elderly overcome those barriers. Those mechanisms should be implemented as design specifications in the produced artifact. Regarding the barriers, social cognitive theory can help in explaining two barriers that prevent the elderly from adhering to physical exercises. The two main concepts in social cognitive theory are self-efficacy and outcome expectation [13]. Self-efficacy is the person's belief that he is capable of performing an action, and outcome expectation is the belief that this action can produce desired results. Both self-efficacy and outcome expectation are two factors that influence adherence among older adults with cognitive impairments [14]. Four mechanisms can enhance self-efficacy: 1) performance accomplishment or enactive mastery experience (successful experience), 2) verbal persuasion (encouragement and feedback), 3) vicarious experience (observing someone else performing a similar task), and 4) physiological states (such as anxiety) [13]. High arousal weakens performance, and performance accomplishments and vicarious experience can eliminate anxiety [13]. Those four mechanisms should address the self-efficacy barrier.

Outcome expectations is another important barrier related to elderly adherence [14]. Education is one strategy that increases adherence in which information about the regimen is a necessary first step [14]. The elderly must comprehend the benefit of the regimen before they make the adjustment in lifestyle. In addition, "show and tell" is mentioned as an effective strategy [14]. In "show and tell," the elderly are provided with each exercise, and then told what this exercise is for and how is it performed.

Cognitive impairment should be improved by exercises, but it is also an exercise barrier by itself. The impact of aging on adherence is mediated by cognitive impairments [15]. It is possible to skip doing exercises or forget how the exercises are performed because of memory decline. Despite the prevalence of medically-explained cognitive impairment among the elderly such as dementia or Alzheimer Disease, Medically Unexplained Memory Loss (MUML) and Cognitive Impairment No Dementia (CIND) have prevalence ranging from 10.7%-26.6% according to different studies in different countries [16], [17], [18]. One of the strategies to increase adherence in people with memory or general cognitive impairment is via automated reminding service [19].

Table 2. Barriers to adherence and overcoming strategies.

Barriers	Overcoming mechanisms/ strategies
Self-efficacy	• Performance Accomplishment • Verbal persuasion and encouragement • Vicarious experience • Improving psychological State
Outcomes expectations	• Education • Show and tell
Cognitive Decline	• Reminding system
Physical Decline	• Appropriate Exercises

The physical decline described above justifies the need for elder-friendly exercises. In fact, we should differentiate the type of the elderly's exercise from other younger age-group exercises [6] . "Appropriate exercises" is an important factor that influence exercises adherence among the elderly. The National Institute on Aging defines four types of exercise that are necessary and appropriate for older adults (endurance, strength, flexibility, and balance) [20]. Therefore, choosing the appropriate exercises is an important mechanism or strategy to improve the elderly's adherence to physical exercises. Table 1 summarizes the elderly's exercises adherence barriers and the corresponding strategies to overcome each barrier described in this section.

Design and Build of Artifact

From the DSR perspective, Adherence Booster (AdBo) is an instantiation. AdBo is a system that consists of: 1) an iPhone application designed for the elderly to increase adherence to exercises, 2) a server that stores the data collected by the app, supports user login, and handles push notification, and 3) a messaging system. The app will guide the elderly through appropriate daily exercises, monitor their daily progress, remind and encourage them to exercise, and measure their short-term memory at the beginning and the end of a predefined exercise regimen. Each exercise will have a simple description (using images and videos) about the benefits and performance instructions.

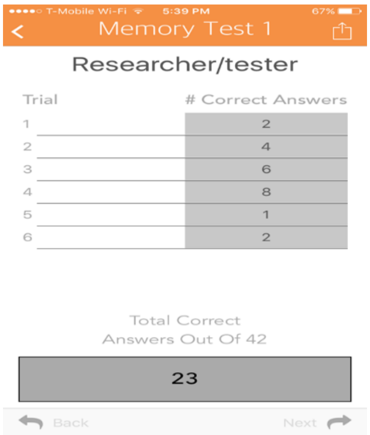


Fig. 7. Initial memory Score.

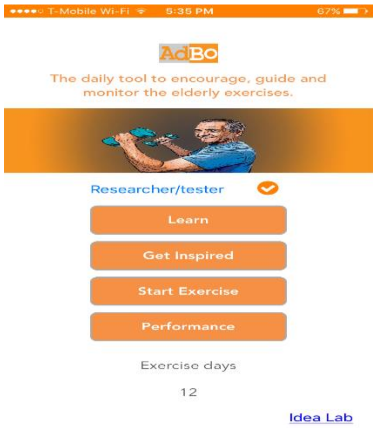


Fig. 8. AdBo's home screen.

The AdBo is in the testing stage of development now. In this section, we will illustrate how the application works. After downloading the application, the user will have to register with a name and password, and he is optionally asked to add an email or a phone number that can be used later by the user to share his progress with peers (another elderly user) or caregivers. During the registration, a video will popup that explains the next screen which is a short memory test consisting of six trials (based on University of Washington Short-Term Memory Test). This memory test is part of the registration. In the memory test, the user will be shown two letters in the first trial for 3 seconds, then those letters will disappear and the user will be asked to type the letters he remembers. The test will get harder in the next trials by increasing the number of letters to remember in the thee-second period. At the end, a score will be assigned to the user based on his performance in the memory test to benchmark his cognitive ability (Fig. 2).

After that, the user will be transferred to the home screen, which consists of four features (Fig. 3). The first feature is "learn," in which a video will explain the four types of exercises in this application and their benefits. This easy and attractive educational video about the application and the exercises should address the outcome expectation barrier of exercise adherence in an easy way using a video. The second feature is "get inspired," where several videos show how peers are doing similar or more difficult exercises with some motivational massages. Some contain verbal messages from physicians as well as success stories. This part of the application is inspired by "verbal persuasion" and "vicarious experience" strategies that improve self-efficacy. Users of the app can also share their performance via SMS or email to motivate each other.

The third feature is "start exercises," which is the heart of the application. In this part of the app, the user will go through 7 daily exercises covering the four types of recommended exercises, which are endurance, strength, balance, and flexibility (Fig. 4). Before each exercise, a video that contains a description about the exercise and a demonstration performed by a certified trainer will be shown (fig. 5). Those exercises

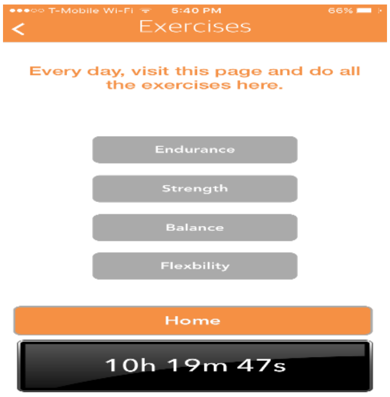


Fig. 9. Four types of exercises each user should go through every 24 hours.

Fig. 10. A video that explains and demonstrates one exercise.

Fig. 11. Collecting data after each exercise.

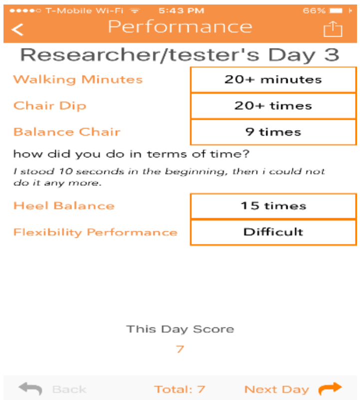


Fig. 12. The third-day performance report.

are adopted from the National Institute on Aging, and they consider the elderly's physical ability. After each exercise, the app will collect two types of data that answer whether each exercise has been performed or not on that day? How many times did the user do the exercise and for how many minutes? It also asks how difficult is that exercise (see Fig. 6)? The reason we collect this data is to use it in the evaluation part of this project and to build daily progress and achievement reports.

The fourth feature on the home screen is "performance," in which we show the previously collected data and the daily progress report (Fig. 7). This report should address the self-efficacy barrier via performance accomplishment mechanism. The user can see his achievements every day and can share it. The app will continuously send push-notification messages to the user with encouraging text to motivate and remind them to do the exercise. This reminding system should address the memory decline barrier. Finally, the app will ask the users to play the memory game at a certain interval of time to assess their short memory. Both physical progress and memory assessment can be shared via email or SMS using the app share feature.

Future work

At this point, we are in the final stages of the application development. The next step will be the evaluation of this application on elderly subjects, in which we will address two important things. First, we will gather the requirements of the next iteration based on the elderly feedback. Second, we will answer the questions whether an easy to use application that overcomes the previously mentioned barrier can improve adherence, and does it have impact on cognitive tests performance? A pre-post learning using paired t-test and post-hoc analysis will be used to accomplish the evaluation. Subjects are being recruited at this time. We anticipate that our strategies could help to improve adherence in different domain such as medication adherence.

References

[1] B. L. Plassman, K. A. Welsh, M. Helms, J. Brandt, W. F. Page, and J. C. S. Breitner, "Intelligence and education as predictors of cognitive state in late life A 50-year follow-up," *Neurology*, vol. 45, no. 8, pp. 1446–1450, Aug. 1995.

[2] R. Hébert, "Functional decline in old age," *CMAJ Can. Med. Assoc. J.*, vol. 157, no. 8, pp. 1037–1045, Oct. 1997.

[3] A. E. Stuck, J. M. Walthert, T. Nikolaus, C. J. Büla, C. Hohmann, and J. C. Beck, "Risk factors for functional status decline in community-living elderly people: a systematic literature review," *Soc. Sci. Med.*, vol. 48, no. 4, pp. 445–469, Feb. 1999.

[4] H. H. Dodge, T. Kadowaki, T. Hayakawa, M. Yamakawa, A. Sekikawa, and H. Ueshima, "Cognitive Impairment as a Strong Predictor of Incident Disability in Specific ADL–IADL Tasks Among Community-Dwelling Elders: The Azuchi Study," *The Gerontologist*, vol. 45, no. 2, pp. 222–230, Apr. 2005.

[5] N. I. on Aging, "Translating research into action: Go4Life Month promotes exercise," *National Institute on Aging*, 31-Aug-2015. [Online]. Available: https://www.nia.nih.gov/research/blog/2015/08/translating-research-action-go4life-month-promotes-exercise. [Accessed: 23-Oct-2015].

[6] R. K. Dishman, "Motivating Older Adults to Exercise," *South. Med. J.*, vol. 87, pp. S79–S82, May 1994.

[7] "Physical Activity and Public Health -- Recom. from CDC & ACSM." [Online]. Available: http://wonder.cdc.gov/wonder/prevguid/p0000391/p0000391.asp?iframe=true&width=95%&height=95%. [Accessed: 04-Oct-2015].

[8] M. D. Rodríguez, J. R. Roa, A. L. Morán, and S. Nava-Muñoz, "CAMMInA: a mobile ambient information system to motivate elders to exercise," *Pers. Ubiquitous Comput.*, vol. 17, no. 6, pp. 1127–1134, May 2012.

[9] B. N. Ferreira, V. Guimaraes, and H. Sereno Ferreira, "Smartphone based fall prevention exercises," in *2013 IEEE 15th International Conference on e-Health Networking, Applications Services (Healthcom)*, 2013, pp. 643–647.

[10] T. Bee Lau, *Assistive Technologies for Physical and Cognitive Disabilities*. IGI Global, 2014.

[11] A. Hevner and S. Chatterjee, "Design Science Research in Information Systems," in *Design Research in Information Systems*, Springer US, 2010, pp. 9–22.

[12] A. Hevner, “A Three Cycle View of Design Science Research,” *Scand. J. Inf. Syst.*, vol. 19, no. 2, Jan. 2007.

[13] A. Bandura, “Self-efficacy: Toward a unifying theory of behavioral change,” *Psychol. Rev.*, vol. 84, no. 2, pp. 191–215, 1977.

[14] S. A. S. PhD, J. K. O. MA PhD, MEd, and K. A. R. PhD, *The Handbook of Health Behavior Change, Third Edition*. Springer Publishing Company, 2008.

[15] L. C. Hutchison, S. K. Jones, D. S. West, and J. Y. Wei, “Assessment of medication management by community-living elderly persons with two standardized assessment tools: A cross-sectional study,” *Am. J. Geriatr. Pharmacother.*, vol. 4, no. 2, pp. 144–153, Jun. 2006.

[16] J. E. Graham, K. Rockwood, B. L. Beattie, R. Eastwood, S. Gauthier, H. Tuokko, and I. McDowell, “Prevalence and severity of cognitive impairment with and without dementia in an elderly population,” *The Lancet*, vol. 349, no. 9068, pp. 1793–1796, Jun. 1997.

[17] Di Carlo A, Baldereschi M, Amaducci L, Maggi S, Grigoletto F, Scarlato G, and Inzitari D, “Cognitive impairment without dementia in older people: prevalence, vascular risk factors, impact on disability. The Italian Longitudinal Study on Aging.,” *J. Am. Geriatr. Soc.*, vol. 48, no. 7, pp. 775–782, Jul. 2000.

[18] F. W. Unverzagt, S. Gao, O. Baiyewu, A. O. Ogunniyi, O. Gureje, A. Perkins, C. L. Emsley, J. Dickens, R. Evans, B. Musick, K. S. Hall, S. L. Hui, and H. C. Hendrie, “Prevalence of cognitive impairment Data from the Indianapolis Study of Health and Aging,” *Neurology*, vol. 57, no. 9, pp. 1655–1662, Nov. 2001.

[19] R. L. Ownby, “Medication adherence and cognition Medical, personal and economic factors influence level of adherence in older adults,” *Geriatrics*, vol. 61, no. 2, pp. 30–35, Feb. 2006.

[20] “NIHSeniorHealth: Exercise: Exercises to Try - Flexibility Exercises.” [Online]. Available: http://nihseniorhealth.gov/exerciseandphysicalactivityexercisestotry/flexibilityexercises/01.html. [Accessed: 26-Oct-2015].

Ontological Support for the Use of Design Science Research Results

Emanuel Reiterer, and John R Venable

Curtin University, School of Information Systems, Perth, WA, Australia
e.reiterer@curtin.edu.au, j.venable@curtin.edu.au

Abstract. *In applied fields of research, Design Science Research (DSR) produces practical and theoretical knowledge in the form of descriptions of new artefacts with utility for particular purpose(s). People, including researchers and practitioners, need to identify, access, comprehend, and synthesize DSR results. This paper addresses these issues by describing and demonstrating a design of a formal DSR ontology approach to represent the essential semantics of the DSR results presented in a DSR document. The proposed ontology (DSRDCO) extends the UMBEL reference ontology of over 35,000 concepts. DSRDCO can be used in the context of a digital library or of the semantic web and can support search and automatic summarisation of DSR publications. Ideally, a summary of DSR results would fulfil five Cs: comprehensive, concise, coherent, correct, and clear. Feasibility of this approach has been evaluated by demonstration, which will be followed by an expert evaluation.*

Keywords: Design Science Research, digital library, ontology, ontology population, exploratory search

6 Introduction

Researchers and practitioners need to identify, access, comprehend, integrate, and synthesise DSR results reported in documents (papers, books, websites). However, doing so presents problems in locating documents, interpreting those documents into DSR knowledge, and merging and understanding knowledge contained in publications.

Existing digital library systems' search facilities and web search engines mainly return answers to queries in the form of lists of publications. These lists sometimes contain snippets, excerpts, or definitions from trusted sources of the searched documents. However, a more useful search result would attempt to summarise the essential information of the returned documents from a perspective that is relevant to and usable for the user. A highly useful search result summary would ideally meet five desirable characteristics (the five Cs): comprehensive, concise, coherent, correct, and clear.

For example, practitioners might want to find all solutions for a specific problem or researchers might want to search for all applications of a particular artefact.

One potential approach to achieve the five Cs in summarising DSR research is to codify the DSR knowledge contained in papers according to a formal ontology of DSR. This approach has three main components: (1) a formal ontology to represent the essential semantics of DSR results presented in a DSR document called the DSR

Document Core Ontology (DSRDCO), (2) ontological representations of DSR publications and (3) cloze text patterns for presenting DSR result summaries.

DSRDCO extends the UMBEL ontology (Structured Dynamics LLC 2012), which currently contains over 35,000 concepts. The DSR content of each DSR paper is stored according to the DSRDCO, together with links to the relevant parts of the original documents. DSRDCO can be used in digital libraries or on the web to support search and automatic summarisation of DSR publications. Instances of DSRDCO for individual publications can either be stored collectively with publications in a database or could be distributed as annotations to publications across the web. The implemented reasoning strategies to create summaries use certain features of ontologies, such as UMBEL. Some features used to identify, for example, artifacts or similar artifacts, are hierarchical information and logical descriptions of classes, also called complex classes. Cloze text templates provide patterns for summaries that can be filled in with instances of concepts drawn from the DSRDCO representation of individual DSR publications.

The next section provides a literature review of DSR and formal ontologies, followed by an analysis of the requirements of the proposed approach. After that, the proposed ontology and the cloze text templates are described followed by a demonstration. Finally, the paper concludes with a discussion of the proposed approach.

7 Literature Review

This section reviews key literature on DSR and formal ontologies to provide a better understanding of the problem domain. This key literature together with a more extensive set of DSR literature has been used to identify main concepts of DSR and their relations, which was used in the top-down design process of the DSRDCO.

Venable and Baskerville (2012, 142) define DSR as “research that invents a new purposeful artefact to address a generalised type of problem and evaluates its utility for solving problems of that type.” It must be a means to achieve some end or purpose.

The term Design Science Research follows from Simon’s The Sciences of the Artificial (Simon 1996) and is commonly used in the field of Information Systems. The DSR research paradigm applies in any applied field, which universally develops new technological means to solve problems and make improvements (Venable 2010).

March and Smith (1995) identified four kinds of “design artefacts“ produced by DSR: constructs that describe problems or solutions, models that express relationships between constructs, methods also called process artefacts, and instantiations that realize a model or method.

Many proponents of DSR see design theories as a product of DSR (Baskerville and Pries-Heje 2010, Gregor and Jones 2007, Walls, Widmeyer, and El Sawy 1992). A design theory asserts a relationship between the artefact’s purpose and solution. There has been less agreement about the need for other components proposed for design theories, including kernel theories (Walls, Widmeyer, and El Sawy 1992) or justificatory knowledge (Gregor and Jones 2007), testable hypotheses (Walls, Widmeyer, and El Sawy 1992) or testable propositions (Gregor and Jones 2007), artefact mutability (Gregor and Jones 2007), and principles of implementation (Gregor and Jones 2007).

Models for how to conduct DSR reach from simple two stage models (“build“ and “evaluate“ (Hevner et al. 2004, March and Smith 1995)) to more complex process models with multiple stages (Peffers et al. 2007, Vaishnavi and Kuechler 2004). However, all of these process models include a stage or activity for evaluation.

The term formal ontology used in this paper refers to an information object used as a computational artefact and is defined as an “explicit, formal specification of a shared conceptualization” (Borst 1997). This paper deals with the category of core ontologies (Breuker, Muntjewerff, and Bredeweg 1999). Core ontologies define what is relevant in a domain (Breuker, Muntjewerff, and Bredeweg 1999) (in our case DSR).

Various languages, e.g. OWL (web ontology language), are used to express ontologies. Basic elements of OWL are classes, properties, instances of classes, relationships, and axioms (W3C 2012). An ontology usually consists of Terminology boxes and Assertional boxes (Baader 2003). T-boxes define the classes, properties, relationships, and axioms, while A-Boxes provide instantiations of those definitions, similar to how objects instantiate a class. Ontologies can be stored in text files, relational databases, and triple or quad stores. A triple consists of a subject, a predicate and an object. A quad extends this triple by a graph element that can used to represent the context.

8 Requirements Analysis for DSR Search Support

A high quality DSR article representation or summary would have five qualities (the five Cs). Such a summary would be (1) *comprehensive* if it includes all the relevant concepts and knowledge conveyed in an article. Such a summary would be (2) *concise* if it does not contain irrelevant concepts and knowledge. It would be (3) *coherent* if all the concepts and knowledge are well organised and related to each other. It would be (4) *clear* if all concepts and relations can be clearly understood and (5) *correct* if it does not draw any incorrect conclusions, including inconsistencies. A summary needs to be produced automatically, which requires computer-readable and computer-processable content. The purpose of the DSRDCO is to provide a data structure that makes it possible to store essential information about DSR documents and support reasoning over instantiations of this ontology to extract information to get a summary and/or a combined search result that meets the five Cs. The five Cs are based on the semiotic metrics suite for ontology evaluation by Burton-Jones et al. (2005) to reflect syntactic, semantic, and pragmatic aspects. All these aspects relate to the informativeness and quality of summaries mentioned in (Lloret and Palomar 2012).

9 Design Science Research Document Core Ontology (DSRDCO)

The DSRDCO represents the domain of DSR in addition to argumentation in publications that follow the DSR paradigm. Figure 1 depicts core DSR concepts (which will serve as reference concepts) that make up the DSR-specific portion of DSRDCO. Links to UMBEL supertypes as well as other aspects of DSRDCO, such as document structure, document meta-data, etc. are not shown in figure 1, but are part of DSRDCO. The OWL DL ontology language has been chosen to describe DSR publications.

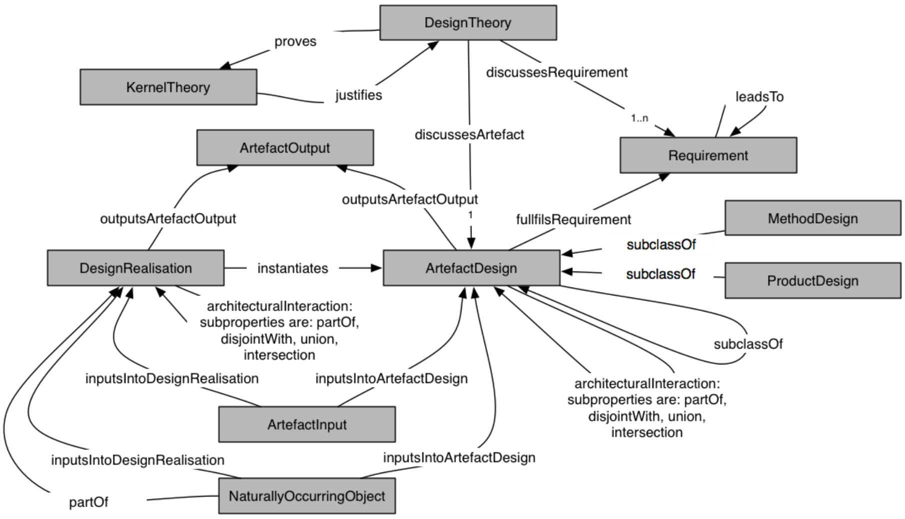


Fig. 13. Ontology Model of DSR aspects of DSR Document Core Ontology (DSRDCO)

The DSRDCO needs to fit a shared understanding of DSR. The following concepts are used by many proponents of DSR as outlined in section 2. A bottom-up approach was also used to identify concepts out of DSR articles. Firstly, in DSR, *ArtefactDesigns* are produced. These artefacts are either models (*ProductDesign*) or methods (*MethodDesign*). The concept *Requirement* together with the concept *ArtefactDesign* expresses the context of a specific piece of DSR. We chose the name *ArtefactDesign* (in comparison to *DesignArtefact*) to emphasise the design aspect of DSR. A *DesignTheory* consists of one *ArtefactDesign* that fulfils a set of *Requirements*. A *DesignRealisation* is usually used to evaluate a *DesignTheory* in providing evidence that the *ArtefactDesign* is capable of reaching the requirements. A *DesignRealisation* must also instantiate any components or other assertions that have been made concerning its corresponding *ArtefactDesign*. Interaction between *ArtefactDesigns* and *DesignRealisations* are either of functional (use of *ArtefactInput* and *ArtefactOutput*) or architectural nature. Object properties, such as *fulfilsRequirement*, are used to define associations between instances of classes and are important to express semantics to relate concepts.

A key aspect of a good DSR article is its argumentation (not included in figure 1). Two main things have to be argued about: *ArtefactDesign* and its *Requirements*. The thesis or *MainClaim* of a DSR paper is that the focal *ArtefactDesign* fulfils some *Requirement(s)*. The *MainClaim* is supported by expressing its *TheoreticalSignificanceClaim*, its *PracticalSignificanceClaim*, and by providing evidence that the *ArtefactDesign* fulfils the *Requirement(s)* through an *EvaluationArgument* or possibly a *BasisArgument*, in which an *ArtefactDesign* is based on an earlier *ArtefactDesign*.

Cloze Text Templates for Summaries

Below is an excerpt of a cloze text template for summarising a single article. Other templates (not included for space reasons) would be appropriate for summarising more than one article that matches a search query and require additional logical reasoning to fill the cloze text. In the template in figure 2 below, items within guillemets (e.g. "«top-level *ArtefactDesign*»") identify the blanks to be filled in and describes how they would be filled by reasoning from the reference concepts in the DSRDCO for the DSR publication being summarised.

«top-level *ArtefactDesign*»

Thesis statement

«*PublicationAuthor, PublicationYear*» describes an artefact named «top-level *ArtefactDesign*». The proposed artefact fulfils the requirements to «list of all *Requirements*».

Significance

The requirements to «list of *Requirements* with same significance» are significant to a «number of *StakeholderRole*» number of «*StakeholderRole*». In prior publications, «list of *CitedPriorArtPublications*», «*CitedPriorArtPublication's ArtefactDesign*» has been proposed using «list of *ArtefactDesigns* that are *partOf CitedPriorArtPublication's ArtefactDesign*». The novelty of the «main *ArtefactDesign*» lies in «list of *ArtefactDesigns* that (are *partOf* the main *ArtefactDesign*) and (are not *partOf* the *CitedPriorArtPublication's ArtefactDesign*)». In comparison to publications «list of *CitedPriorArtPublications*», a «*ImprovementType*» in «improved *Requirement*» of «*ImprovementAmount*» can be achieved.

Artefact description

The «top-level *ArtefactDesign*» consists of «list of second-level *ArtefactDesigns* that are *componentsOf the* top-level *ArtefactDesignn*».

[For each component with sub-components - recursively]

«component *ArtefactDesign*» consists of «list of *ArtefactDesigns* that are *componentsOf the* focal *ArtefactDesign*». …

[End For]

Evaluation

The artefact was evaluated by «EvaluationTechnique» with «Number» participants. Each participant conducted the following tasks: «list of tasks». The following aspects were evaluated: «list of evaluated *Requirements*».

[For each evaluated requirement and sub-requirements - recursively]

```
    «evaluated Requirement / sub-requirement» was evaluated by
     «EvaluationCriterion».
[End for]
```

Fig. 14. Partial Cloze Text Template for a Single DSR Publication

10 Example Demonstration

The ability of the DSR Ontology approach described in this paper has been demonstrated by (1) realizing DSRDCO representation in OWL, (2) applying DSRDCO to codify the essential DSR knowledge of sample DSR publications (i.e. creating a DSR Document Ontology instantiation), and (3) demonstrating that a cloze text summary template can be populated from the DSRDOs generated in demonstration step 2.

As a simplistic, but illustrative example of demonstration steps (1) and (2) above, figure 3 shows an OWL representation of the design realization portion of a DSRDCO.

```
<owl:Class rdf:ID="ArtefactDesign" />
<owl:Class rdf:ID="DesignRealisation" />
<owl:ObjectProperty rdf:ID="designRealisationInputsTo">
    <rdfs:domain rdf:resource="#DesignRealisation" />
    <rdfs:range  rdf:resource="#DesignRealisation" />
</owl:ObjectProperty>
<owl:ObjectProperty rdf:ID="artefactDesignInputsTo">
    <rdfs:domain rdf:resource="#ArtefactDesign" />
    <rdfs:range  rdf:resource="#ArtefactDesign" />
</owl:ObjectProperty>
<ArtefactDesign rdf:ID="TextFeatureExtractionSequence">
    <artefactDesignInputsTo rdf:resource="#ClassificationStep" />
</ArtefactDesign>
<ArtefactDesign rdf:ID="ClassificationStep" />
<DesignRealisation rdf:ID="PrototypeOfTextFeatureExtractionSequence" />
    <designRealisationInputsTo rdf:resource="#PrototypeOfClassificationStep" />
</DesignRealisation>
<DesignRealisation rdf:ID="PrototypeOfClassificationStep" />
```

Fig. 15. OWL representation of a Design Realisation

Continuing the illustrative example and considering demonstration steps (2) and (3), figure 4 shows example potential output of the filled-in cloze text summary of a simplistic fictional paper using the cloze text (partial) provided earlier in figure 2. Note that the guillemets in figure 4 would not ordinarily be included in the summary.

Multi-speed bicycle architecture *a fictional example*
Thesis statement

«AuthorA, 19aa» describes an artefact named «multi-speed bicycle architecture». The proposed artefact fulfils the requirements to «commute cost effectively», and «commute with little human effort».

Significance

The requirements to «commute cost-effectively», and «commute with little effort» are significant to a «high» number of «people».

Artefact description

The «multi-speed bicycle architecture» consists of «derailleur gears». «Derailleur gears» consist of «a chain», «multiple sprockets», and «a gear shifting mechanism» that «moves the chain from one sprocket to another».

Evaluation

The artefact was evaluated by «a naturalistic human use experiment» with «30 participants». Each participant «travelled» «20 kilometres» «per day» for «3 days» «in an urban setting». The following aspects were evaluated: «commuting effort», and «commuting cost».

«Commuting effort» was evaluated by «measuring» «heart rate».

Fig. 16. Fictional example of populated single publication cloze text

Whereas researchers are naturally interested in the evaluation and significance aspect, practitioners usually use the evaluation aspect implicitly because it is part of the reasoning strategy. Significance statements are important for practitioners to see what novel concepts have been introduced or to see the benefit in using a specific approach.

11 Discussion

This paper presented parts of the design of a formal ontology to represent the domain of DSR results in DSR publications and examples of a part of its evaluation (through demonstration). This ontology is intended to be applied in ontology-enhanced digital libraries for DSR publications or across the semantic web. This approach will support the presentation of and reasoning over comprehensive, concise, coherent, correct, and clear summaries of publications that follow a DSR approach to support researchers and practitioners in their work. The problem addressed is general in nature and present in virtually all applied fields.

The evaluation has shown that the manual population of such an ontology is possible and that the proposed ontology includes all components necessary to describe a scientific article about DSR problems. Correctness and clarity of summaries will be evaluated in the follow-up expert evaluation to provide further evidence of the utility of summaries. These evaluations are currently in the process of being conducted for single document and multiple document summaries of real articles.

Evaluations conducted so far only artificially demonstrate the approach for formative (and illustrative) purposes. Further evaluations are under development to naturalistically evaluate outputs of the approach with both DSR and domain experts based on sample extant DSR publications in one or more applied domains.

References

Baader, Franz. 2003. *The description logic handbook: theory, implementation, and applications*: Cambridge university press.

Baskerville, Richard, and Jan Pries-Heje. 2010. "Explanatory Design Theory." *Business & Information Systems Engineering* 2010 (5):271-282.

Borst, Willem Nico. 1997. *Construction of engineering ontologies for knowledge sharing and reuse*: Universiteit Twente.

Breuker, J., A. Muntjewerff, and B. Bredeweg. 1999. "Ontological Modelling for Designing Educational Systems." *Proceedigns of the Workshop on Ontologies for Intelligent Educational Systems at AIED99*.

Burton-Jones, A., V. Storey, V. Sugumaran, and P. Ahluwalia. 2005. "A semiotic metrics suite for assessing the quality of ontologies." *Data & Knowledge Engineering* 55:84-102.

Gregor, Shirley, and David Jones. 2007. "The Anatomy of a Design Theory." *Journal of the Association for Information Systems* 8 (5):312-335.

Hevner, A., S. T. March, J. Park, and S. Ram. 2004. "Design Science in Information Systems Research." *MIS Quarterly* 28 (1):75-105.

Lloret, Elena, and Manuel Palomar. 2012. "Text summarisation in progress: a literature review." *Artificial Intelligence Review* 37 (1):1-41.

March, Salvatore T., and Gerald F. Smith. 1995. "Design and natural science research on information technology." *Decision Support Systems* 15 (4):251-266.

Peffers, Ken, Tuure Tuunanen, Marcus A. Rothenberger, and Samir Chatterjee. 2007. "A Design Science Research Methodology for Information Systems Research." *Journal of Management Information Systems* 24 (3):45-77.

Simon, Herbert A. 1996. *The Sciences of the Artificial*. 3rd ed. Cambridge, Mass.: MIT Press.

Structured Dynamics LLC, and Ontotext AD. 2012. "UMBEL Specification." Last Modified 5. http://techwiki.umbel.org/index.php/UMBEL_Specification.

Vaishnavi, Vijay, and William Kuechler. 2004. "Design Science Research in Information Systems." Association for Information Systems, Last Modified 23 October 2013 Accessed 8 February. http://desrist.org/design-research-in-information-systems/.

Venable, John R. 2010. "Information Systems Design Science Research as a Reference Discipline for Other Business Disciplines." International Academy of Business and Public Administration Disciplines Conference (IABPAD 2010), New Orleans.

Venable, John R., and Richard Baskerville. 2012. "Eating Our Own Cooking: Toward a More Rigorous Design Science of Research Methods." *Electronic Journal of Business Research Methods* 10 (2):141-153.

W3C. 2012. "OWL 2 Web Ontology Language document overview." Accessed 2012-03-27. http://www.w3.org/TR/owl2-overview/.

Walls, Joseph G. , George R. Widmeyer, and Omar A. El Sawy. 1992. "Building an information system design theory for vigilant EIS." *Information Systems Research* 3 (1):36-59.

Check the temperature. Rapid assessment of common ground in startup teams

Riccardo Bonazzi, Francesco Maria Cimmino

University of Applied Sciences Western Switzerland
Techno-Pôle, Sierre, Switzerland
riccardo.bonazzi@hevs.ch;francesco.cimmino@hevs.ch
Abstract. *This research in progress aims at identifying a set of design guidelines to perform rapid diagnostic of common ground among participants of a startup team and their coach. Previous studies have shown that teams with high common ground are more efficient. Nonetheless, no existing tool can rapidly monitor its progression and visualize it in a simple way to allow the coach to perform team diagnostic. In this paper we present a prototype, which monitors the evolution of joint objectives and joint resources among team members and that represents the updated path of a startup team in less than five minutes. Empirical data collected at a startup weekend shows that it is possible (a) to rapidly monitor the evolution of common ground within the team, (b) to intervene whenever the joint commitment of participants gets too low and (c) positively affect the performance of a startup team.*

Keywords: collaboration engineering, entrepreneurship education, common ground, startup coaching

12 Introduction

"You've got to be a thermostat rather than a thermometer. A thermostat shapes the climate of opinion; a thermometer just reflects it." (Cornel West)

This article proposes a set of design guidelines to build a device that supports entrepreneurs and experts in the field of entrepreneurial education. A new stream of research highlights the possibility to quickly assess the dynamic of a project team and to increase the quality of its supervision [1]. Nonetheless, there are not clear specifications to design a device for startup coaches to perform rapid diagnostic and to suggest a course of action. Henceforth, we define *entrepreneurship education* as "the transfer and facilitation of knowledge and skills on how, by whom and with what effect the opportunities to create future products and services are discovered, evaluated and exploited" [2]. Moreover, we focus on the task of a coach, who helps a startup begin its entrepreneurial adventure, and we refer to the notion of *mentoring* as "the establishment of a supportive relationship to a novice entrepreneur (mentee), thanks to the support of an experienced entrepreneur (mentor), allowing it to develop as a person" [3]. Indeed, the entrepreneur interacts with a large set of other agents, some of which belong to the initial team that created the enterprise. Henceforth, we refer to the notion of *collaboration engineering*, which can be defined as "an approach to designing collaborative work systems for high-value tasks, and transferring them to practitioners to execute for themselves without ongoing support from collaboration experts" [4]. In that sense, the mentor of a startup might be asked to act as a collaborator engineer, and to describe the outcome of such activity, we define *common ground* as "a collection of mutual knowledge, mutual beliefs, and mutual assumptions" [5], which is known to influence the performance of project teams [6].

In this study, we seek for a diagnostic tool that (a) allows monitoring the development of common ground in a startup as a sign of team performance -that is a *thermometer*- and (b) enables proactive control in different shapes -that is, a *thermostat.* Hence, our research question is: *how can we design an artifact to rapidly assess the evolution of common ground within a startup team?*

The rest of the article is organized as it follows. In the next section we will briefly introduce the constructs that allow us to answer our research question. In section three, we present our theoretical model and in section four we illustrate how we designed and developed our device. Section five illustrates the results of an empirical test and section six discusses the limitations of our study and future works.

13 Literature review

Our research spans across three topics: (a) entrepreneurship education, (b) collaboration engineering, and (c) team common ground. *Entrepreneurship education* increases the skills needed to create a successful startup, and the issue at hand now is not whether we can learn entrepreneurship, but how it can be taught to students [7]. Nonetheless, expert entrepreneurs follow a set of principles, which appear to be almost the opposite of what young entrepreneurs do. Indeed, one could conclude that causation starts from objectives and moves towards means, whereas effectuation starts from available resources and defines its objectives. Nowadays, there is no device that allows to rapidly identify if a team is following a causal or a effectual path.

Collaboration engineering (CE) metrics and so-called ThinkLets [4], which are collaboration pattern to increase team performance, have been induced from practical experience and need to be further tested in an experimental context. Previous studies have been trying to empirically assess the effectiveness of collaboration engineering over team performance [8], but additional research on the empirical effects of ThinkLets is still required [9].
High *common ground* is known to increase team performance [10]. Previous research have proposed a design theory to supports real-time assessment of common ground, by using four variables[1]: (a) Joint objectives: what the participants intend to do together; (b) Joint Resources: what the participants need, to play their part; (c) Joint commitment: What participants expect each other to do; (d) Joint risks: What could prevent participants from playing their part.

14 Theoretical model

We aim at designing a tool for proactive monitoring of the evolution of common ground among team members. That should allow the coach to perform diagnostics and to take informed decisions about the best way to help the team grow. We also believe that entrepreneurs could use the tool to perform a self-assessment. Nonetheless, the software is not designed to take decisions, while replacing a trained coach.
Our theoretical model has three *constructs*, which are derived from the theory of common ground and that are measured by a survey: (1) joint understanding, (2) joint resources, and (3) joint commitment. Each constructs is operationalized by less than four questions and it is measured by 5-point Likert scales. In the end we obtain less than ten questions in the survey, to allow data collection among team members in less than 5 minutes. Our *kernel theory* is the extension of the notion of common ground, which was proposed by Mastrogiacomo et al. [1]. The notion of joint objectives resonates with the concept of project-based conditions. The notion of joint resources recalls the concept of company resources. The notion of joint commitment can be associated to the notion of mutual trust described by Das and Teng [11]. Since we wanted to test the effects of our artefact on startup coaches, we set a constraint concerning the time needed for data collection (5 minutes) and we predicted that a startup team with an empowered coach will learn faster and will progress more than a normal startup team. Accordingly, assuming that there is no difference between the

supported teams and the control teams, we can derive two hypotheses: *the use of our device by a coach will affect (H1) the performance and (H2) the progression of the startup team, which is getting coached.*

15 Methodology

To develop our prototype, we have followed the guidelines of Peffers et al. [12]. The problem associated with startup coaching was already identified, but no device was allowing rapid diagnostic. Hence we defined two objectives for our solution: (a) data collection in less than 5 minutes, and (b) simple visualization to let the coach decide how to support each startup team. We iteratively developed, tested and evaluated our prototype three times. We initially developed a dynamic graph to understand how a coach was mentoring a team. Then, we included a new dynamic chart with detailed information about each team member, which the coach was not able to collect. Finally, we developed a dynamic graph to assess the intervention of each coach. In the rest of the paper we describe how we collect and analyze data.
Data collection. The Google Form has nine questions. The first question allows identifying the participant, whereas the remaining eight questions assess concern the team common ground.

Table 3. Operationalization of constructs

Construct	Items
Joint Objectives: We all understood what we intended to do together about...	JO1... design and functionality of our product/service
	JO2... the development of a distinctive image with from our competitors
	JO3... a narrow, clearly defined market segment
Joint resources: Every team member had sufficient resources in terms of...	JR1 …Time
	JR2 ... Competences
	JR3 ... Useful contacts in our network (coaches, sponsors, partners)
Joint Commitment: We were clear about the commitment of each member and ...	JC1… Everyone was motivated by our goals
	JC2 …Everyone felt he/she can contribute to our goals

Data analysis. Figure describes the columns of the five tabs in our Google Sheet. There are two tabs to set up the parameters (list of teams and assignment of participants to teams). One tab dynamically collects participants' answers from the Google Form and coverts the timestamp into a time cluster by using the formula MONTH *10000+DAY*100+ HOUR. One tab contains a pivot table, which dynamically returns the perception of joint objectives, joint resources and joint commitment of each participant at a given time. One tab contains a pivot table, which dynamically returns the average of teams perceptions.

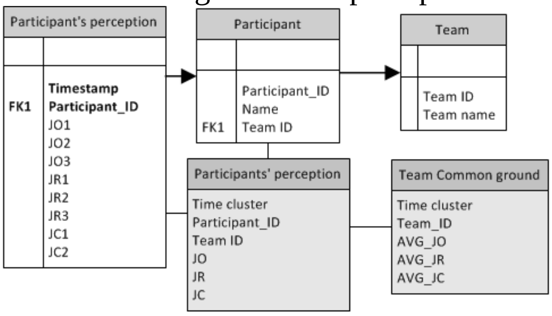


Fig. 17. Relationships among the five tabs of our Google Sheet

Data visualization. We use Google motion chart to show the evolution of the common ground. We can obtain three dynamic graphs: (a) the perception of each team member, (b) the perception of the team and (c) the perception of the team and the team coach. In each dynamic graph, the X axis of the first graph represents the average of team members' Joint Objectives at time t, the Y axis represents the average of team members' Joint Resources at time t, whereas the bubble size represents the variance of JO. Figure 2 shows how a team starts with a low amount of Joint Objectives and Joint resources (point 1, in the bottom left corner), increases its amount of JO (points 2 and 3), and it finally increases its amount of JR (points 4 and 5). Each point is associated to a set of data collected at a specific time.

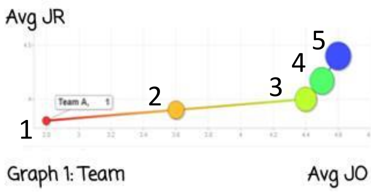


Fig. 18. The two axes (JO and JR) and representation of the evolution of team common ground

16 Evaluation

We tested our artefact at a startup weekend (startupweekeend.org), which offers the opportunity for teams to create a startup in 54 hours and allows performing experimental studies in an ideal situation: (a) all teams are in the same location and they are given the same amount of time; (b) sessions with the assigned coach are done via face-to-face conversations; (c) all teams have access to the same set of entrepreneurship techniques; (d) participants come from professional and academic environment, and they don’t know each other before the event; (e) all teams are evaluated at the end by one commission, which uses a predefined set of criteria to assess them.

Fig. 19. Data collection protocol with pre- and post-tests

Data collection. We collected survey data from randomized participants and coaches, after each coach intervention. In the end, we followed six teams, whose members were asked to complete our questionnaire up to four times. As shown in

, we also conducted a pre-test and a post-test: (a) Friday night we collected the opinions of the crowd, and (b) Sunday afternoon we assisted to the discussion among jury members. Table 2 shows the ID of each team, the ID of the coach, the use of our device, the results of the crowd votes and the jury votes.

Table 4. Initial scores and results from the jury of the selected teams

ID	Coach ID	Support ?	Pre-test	Post-test
1	Y	No	16	0
2	G	No	11	62
3	T	No	10	63
4	Y	Yes	10	85
5	G	Yes	10	95
6	T	Yes	16	103

Data analysis. To test whether the two data samples are independent we conducted a Mann-Whitney-Wilcoxon Test by using R software. The results shows that there is no difference between the control group and the observed group at the beginning ($p=0.81$), the difference in terms of final performance between the two groups is statistically significant ($p=0.10$) and the difference in terms of progression between the two teams is statistically significant (p=0.07). Therefore, the null hypothesis is rejected and **H1 and H2 are accepted**.

Exemple of support for coach's intervention. Figure 4 shows how we supported the intervention of a coach. After two iterations (t=200) we noticed that the perceptions of the coach and the team were diverging. By looking at the graph illustrating the participants' perceptions, we noticed that the team leader was losing faith in the joint resources (the other colored bubbles represent the perceptions of the other team members). Hence, we advised the coach to intervene by putting the team in contacts with potential customers. After the intervention, the leader was confident again and the team ended up conceiving the product, which was the most voted by the public.

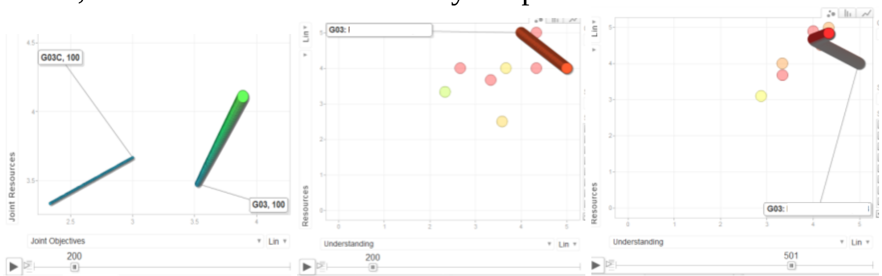


Fig. 20. Assessment of coach and team perception (a), analysis of participant perception before the intervention of the coach (b) and after the intervention of the coach (c)

17 Discussions and Conclusions

In this study, we seek for a diagnostic tool that (a) allows monitoring the development of common ground in a startup as a sign of team performance –referred here as a *thermometer*- and (b) enables proactive control in different shapes –referred here as a *thermostat.* We extend previous works on collaboration engineering to support entrepreneurial education. Preliminary results open new research opportunities regarding the rapid diagnostic of startup teams and the ability to build patterns, which can be used afterwards to teach students how to become expert entrepreneurs. Nonetheless, this article qualifies as a preliminary analysis to prepare a new research study, which will be done on a larger scale. Indeed, a rigorous measurement model should be necessary to make sure that the question items accurately measure the constructs. Another important limitation concerns the fourth dimension of the theory of Mastrogiacomo et al.[1], which is missing in our model. Analysis of preliminary data has shown that this dimension behaves in a different way, but we are currently assessing whether we can consider the joint risks as a form of search for consensus among team members with different risk attitudes.

Acknowledgements. We would like to thank Yves Pigneur, Stéphanie Missonier and Thibault Estier for their advices and feedback, as well as Alexis Moeckli and Nadine Reichenthal for their support at the startup weekends.

18 References

1. Mastrogiacomo, S., Missonier, S., Bonazzi, R.: Talk Before It's Too Late: Reconsidering the Role of Conversation in Information Systems Project Management. J. Manag. Inf. Syst. 31, 47–78 (2014).
2. Shane, S., Venkataraman, S.: The promise of entrepreneurship as a field of research. Acad. Manage. Rev. 25, 217–226 (2000).
3. St-Jean, E., Audet, J.: The effect of mentor intervention style in novice entrepreneur mentoring relationships. Mentor. Tutoring Partnersh. Learn. 21, 96–119 (2013).
4. Briggs, R.O., De Vreede, G.-J., Nunamaker Jr, J.F.: Collaboration engineering with ThinkLets to pursue sustained success with group support systems. J. Manag. Inf. Syst. 19, 31–64 (2003).
5. Clark, H.H.: Using language. Cambridge university press Cambridge (1996).
6. Aral, S., Brynjolfsson, E., Van Alstyne, M.W.: Antecedents and Consequences of Mutual Knowledge in Teams. Available SSRN 1299260. (2008).
7. Kuratko, D.F.: The emergence of entrepreneurship education: Development, trends, and challenges. Entrep. Theory Pract. 29, 577–598 (2005).
8. Hoegl, M., Gemuenden, H.G.: Teamwork quality and the success of innovative projects: A theoretical concept and empirical evidence. Organ. Sci. 12, 435–449 (2001).
9. Seeber, I., Maier, R., Weber, B., De Vreede, G.-J., De Vreede, T., Alothaim, A.: Brainstorming is Just the Beginning: Effects of Convergence Techniques on Satisfaction, Perceived Usefulness of Moderation, and Shared Understanding in Teams. In: System Sciences (HICSS), 2015 48th Hawaii International Conference on. pp. 581–590. IEEE (2015).
10. Aral, S., Brynjolfsson, E., Van Alstyne, M.W.: Antecedents and Consequences of Mutual Knowledge in Teams. Available SSRN 1299260. (2008).
11. Das, T.K., Teng, B.-S.: Trust, control, and risk in strategic alliances: An integrated framework. Organ. Stud. 22, 251–283 (2001).
12. Peffers, K., Tuunanen, T., Rothenberger, M.A., Chatterjee, S.: A design science research methodology for information systems research. J. Manag. Inf. Syst. 24, 45–77 (2007).

Illustrating Emerging Design Principles Enhancing Digital Service Platforms

Hannes Göbel*, and Stefan Cronholm

University of Borås, IT-section, Borås, Sweden
{hannes.gobel,stefan.cronholm}@hb.se

The study is based on the idea that in order to achieve and facilitate innovation of value-enabling services, digital service platforms are necessary. We derived this assertion from both theory and practice. From a research perspective, [1, p. 161] claim that actors in a service ecosystem "*find that service exchange is not very efficient without service platforms, which help to liquefy resources fostering value creation*." From a practitioner's perspective, digital tools that are oriented to collaboration (e.g. a digital service platform) are important. For example, [2] found that, between the years 2003 and 2014, such tools have been located among the most significant IT investments, peaking in the year 2012 in 4th place. Another argument related to practitioners is "*...managers, though motivated to perform and being aware of the links among service, competitive advantage, and firm performance, often fail to execute on service knowledge*" [3, p. 5]. That is, both theory and practice confirm that the significance of digital service platforms is increasing.

However, studies on the phenomenon of service platforms are scarce and insufficient [4]. Existing service platforms that tentatively could support practitioners to innovate value-enabling services, neither fully inscribe axioms of the service dominant logic [1], nor the principles of open innovation [5]. Besides these weaknesses they are seldom digital. Hence, we argue that there is a lack of consolidated normative theory of how to design digital service innovation platforms. This is problematic, because it hampers actors in service ecosystems to combine and advance their capability to co-create value. The problem we address is that there is a lack of generic knowledge for digital service platforms facilitating digital service innovation.

A recommended and popular approach to inform practitioners and researchers about IT-artifacts (such as digital service platforms) is to present generic design principles (DP) as a solution to a shared problem [6]. We argue that purposive normative DPs for digital service platforms could leverage more and better value-enabling IT services, strengthen relationships and support practitioners to understand and manage service innovation. The research question reads: *How should digital service platforms facilitating service innovation in service ecosystems be designed?*

In order to find an answer to this research question, researchers and practitioners have jointly designed and evaluated a digital service innovation platform using the Action Design Research methodology [6]. The digital service platform consists of a web-based IT artifact. In total, 19 organizations from the public, private, and third sectors have been involved in the design and/or evaluation. All the organizations had need of more efficient business models related to the field (or context) of IT Service Management (ITSM). ITSM is customer oriented and relies on several well-defined processes in order to manage digital services. The initial platform design rested upon two kernel theories: service dominant logic (c.f. [1]) and Open Innovation (c.f. [5]) combined with requirements from organizations. We based the formulation of the DPs on theoretical insights and the organizations' experiences of using the digital service platform in different service ecosystems.

By evaluating the digital service platform in several service ecosystems within the context of ITSM, we have been able to present intermediary answers to how digital service platforms facilitating service innovation should be designed. The results presented are mainly three nascent DPs: a design for a dynamic process bridging actors in service ecosystems; a **design to ensure an iterative co-innovation process**; and a design for co-problematization. We have evaluated the digital service platform and collected empirical evidence for the validity, utility, and efficacy in practice (participating organizations). By doing so, we have found the platform to be useful and operational, and that it supports actors to co-create service innovations. Moreover, we have discovered that theoretical statements in open innovation and service dominant logic are coherent and thus can be co-inscribed in a digital service platform applied in the ITSM field. By identifying new DPs while transforming statements in the two kernel theories to DPs, we argue that we answer the call by [3] to generate normative knowledge.

Keywords: Design Principles · Service Innovation · Action Design Research · Digital Service Platform · Service Dominant Logic · Open Innovation

References

1. Lusch R, Nambisan S.: Service Innovation: A Service-Dominant Logic Perspective. MIS Quarterly, March;39(1):155-176. (2015)
2. Kappelman, L., Johnson, V., McLean, E., & Gerhart, N.: The 2014 SIM IT Key Issues and Trends Study. MIS Quarterly Executive, 13(4), 237–263 (2014)
3. Lusch, R.F., Vargo, S.L., O'Brien, M.: Competing through service: Insights from service-dominant logic. Journal of Retailing, 83(1), 2-18 (2007)
4. Yoo, J. H.: Service platform strategy: social networking and mobile service platform perspectives, Doctoral dissertation, Massachusetts Institute of Technology (2011)
5. Chesbrough, H.: Open Services Innovation: Rethinking Your Business to Grow and Compete in a New Era. San Francisco: Jossey-Bass. (2011)
6. Sein, M., Henfridsson, O., Purao, S., Rossi, M., Lindgren, R.: Action Design research, MIS Quarterly, Vol. 35, No. 1, pp. 37-56 (2011)

Toward Theory and Method of Hybrid Data Collection

Mahed Maddah[1], Roman Lukyanenko[1], Monica Chiarini Tremblay[1]

[1] College of Business, Florida International University, Miami, FL USA
{ mmadd011, rlukyane, tremblay}@fiu.edu

Traditionally, information systems were designed to collect data in a structured format [1]. Structured format provides consistent data for data consumers. The explosive growth of social media (e.g., Facebook, Twitter), however, consistently demonstrates the advantages of a different approach to data collection and storage. On social media, people have more freedom to generate content as they leverage the unstructured collection process (e.g., via open textboxes). Applying traditional structured approaches to these settings limits user expressions and prevents users from conveying all the information they want [1], [2]. Unstructured data from social media are challenging to organize, integrate, and aggregate for analysis because they are variable, heterogeneous and sparse. This motivates us to develop novel approaches to collection and storage that combine the advantages of both formats.

We propose a hybrid solution, in which data begins as unstructured and gradually gains structure based on the popular social media practice (e.g., on Twitter and Facebook) of hashtagging. Hashtags are typically inserted by social media users to tag parts of unstructured content [3]. Hashtags do not restrict user input as traditional pre-defined structured fields do, but allow for content to be better categorized, searched and integrated with other content that has the same or similar hashtags.

Despite the benefits, hashtags appear to be quite sporadic and random [3]. Thus, most tweets are posted without any hashtags, and similar tweets may and may not use hashtags [4]. Using hashtags is not mandatory and requires conscious effort and understanding of how and why to apply them. To make hashtags more effective, we propose a novel solution based on machine learning (ML) to make the hashtags more predictable and automatically generate and suggest hashtags. We consider research in cognitive psychology to gain a deeper theoretical understanding of the underlying psychological mechanisms behind human decision to utilize hashtags. We further contribute by suggesting an important connection between structure of human memory and data collection and storage on social media.

When people create information on social media, they frequently reflect on their personal experiences or share notable experiences of others (e.g., friends, public figures). Psychology divides human declarative memory into semantic and episodic [5]. Semantic memory comes from the general world knowledge (shared among humans). Studies show that structured data formats is suitable for capturing semantic memory [6]. On the other hand, episodic memory is the memory of autobiographical events and comes from person's own experiences, which are necessarily unique.

As much of social media content is based on episodic memory, storing it in unstructured format (i.e., free-form text that allows for unabated representation of unique events) appears consistent with human cognition. In fact, imposing structure on this information may inhibit or even distort it [7]. Hashtag thus create a simple way for people to relate their own episodes to similar those of others. Yet, if a hashtag is not utilized, it is more challenging to integrate similar content, due the information's unique and personal nature.

Following the cognitive psychology foundations we thus develop a novel method to enhance the usage and quality of hashtags - "Autotag". Autotag has multiple stages. First, we automatically identify episodic content (which could be distinct from other uses of social media, such as link sharing, or product promotion). Second, we use ML to predict whether a particular social media post or tweet should have a hashtag (this is done by training ML on a variety of historic social media content). This is challenging as content similarity does not appear to be enough to predict hashtag usage [4]. Thus, informed by cognitive psychology, we include context and user profile variables. Finally, we extend existing auto hashtag algorithms [4], [8] by introducing elements of episodic memory theory to predict specific hashtags. We evaluate the ML method by comparing its predictions to real historic social media data and conducting a laboratory experiment with potential social media users.

The Autotag approach carries important implications for social media and information management theory and practice. We believe that, using the theory of human memory, we can design more effective mechanisms that relate and connect unique experiences of people communicated via social media. Implementing this approach could reduce sparseness and heterogeneity of unstructured data without limiting its freedom and could be used in a wide range of applications.

References

[1] R. Lukyanenko, J. Parsons, and Y. Wiersma, "The IQ of the Crowd: Understanding and Improving Information Quality in Structured User-generated Content," *Inf. Syst. Res.*, vol. 25, no. 4, pp. 669–689, 2014.

[2] X. Zhang, Y. Yu, H. Li, and Z. Lin, "Sentimental Interplay between Structured and Unstructured User-Generated Contents-An Empirical Study on Online Hotel Reviews," *Online Inf. Rev.*, vol. 40, no. 1, 2016.

[3] M. A. H. Khan, M. Iwai, and K. Sezaki, "Towards urban phenomenon sensing by automatic tagging of tweets," Networked Sensing Systems (INSS), 2012, pp. 1–7.

[4] J. She and L. Chen, "Tomoha: Topic model-based hashtag recommendation on twitter," presented at the International World Wide Web Conferences Steering Committee, 2014.

[5] E. Tulving, "Episodic and semantic memory 1," *Organ. Mem.*, vol. 381, no. 4, 1972.

[6] E. Goldstein, *Cognitive psychology: Connecting mind, research and everyday experience*. Cengage Learning, 2010.

[7] D. Brown, A. W. Scheflin, and C. D. Hammond, *Memory, trauma treatment, and the law*. WW Norton & Company, 1998.

[8] F. Godin, V. Slavkovikj, W. De Neve, B. Schrauwen, and R. Van de Walle, "Using topic models for twitter hashtag recommendation," International World Wide Web Conferences Steering Committee, 2013, vol. 593–596.

Introducing Information Gradient Theory

Roman Lukyanenko[1], Arturo Castellanos[1]

[1] College of Business, Florida International University, Miami, FL USA
{rlukyane, aancaste}@fiu.edu

Much of modern science and technology relies on the notion of taxonomy (e.g., conceptual hierarchy, set theory). In a typical taxonomy, information is organized based on set/super/subset relationship from most specific to most generic (see Fig. 1a). Set theoretic or hierarchical organization of information is common in mathematics, logic, computing and information sciences (e.g., ontologies, conceptual modeling, and information retrieval). Taxonomic organization of knowledge counts as a theoretical contribution in natural and social sciences, including design science research [1, 2].

While there are advantages to set theoretic/taxonomic organization of information, we identify four important limitations, including (a) ***ontic rigidity*** (e.g., adjacent nodes in a taxonomy must belong to the same ontological kind – concepts and concepts but not concepts and attributes; individuals, when included must be at terminal nodes), (b) ***authoritative origin*** (e.g., taxonomies are typically created by experts and often do not reflect intuitive knowledge) (c) ***linearity*** (e.g., taxonomies are inflexible for depicting non-monotonic, analog structures), (d) bias toward ***property inheritance*** (which is one of many potentially useful ways to organize knowledge).

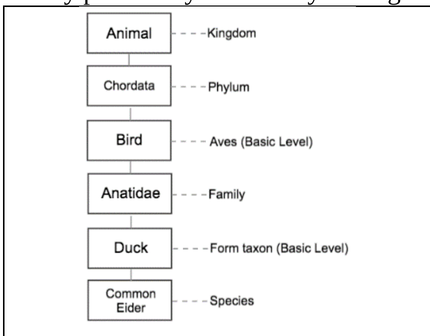


Fig 1a: Established Biol Hierarchy

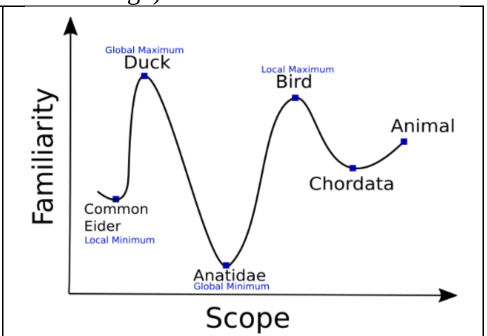


Fig 1b: Information gradient for Fig 1a

Recent developments in psychology suggest a variety of alternative structures for organizing information, including semantic networks, analog and non-discrete representational forms, and prototypical concepts [3, 4]. Research on semantic networks, for example, demonstrates that people form complex relationships between non-adjacent hierarchical nodes defying strict taxonomic arrangements [3]. Research on basic level categories, including in neuroscience, suggests that people privilege (in thinking, communication, action) middle levels (e.g., *bird* and *duck* in Fig 1a) implying that innate organization for humans may break strict traditional taxonomies [4, 5].

Informed by recent developments in psychology, to overcome limitations of set theory (above), we propose **information gradient theory (IGT).** According to IGT, domains can be represented as non-monotonic gradients consisting of continuous or discrete informational units, which may have *any ontic* status (including universals or classes, attributes or features and particulars or individuals) following a chosen organizing criteria (i.e., purpose or goal) that form two or more dimensions. For example, focusing on *familiarity* and *scope*, one can turn the taxonomy in Fig. 1a into an Information Gradient (IG) shown in Fig. 1b by taking each information unit and plotting it based on the organizing criteria (i.e., familiarity, scope) and then fitting a curve to the resulting points. The IG may be different based on another organizing criterion such as perceptual salience, frequency of encounter, ability to visualize, or any other goal. In each case we expect the IG to defy traditional taxonomic organization. Information gradients can be obtained by eliciting concepts from stakeholders or referencing existing information sources. Gradients may differ between individuals, between collectives, and within individuals, depending on the organizing criteria. IGT provides additional information not found in the hierarchical organization of knowledge. In Fig 1b IGT reflects the tradeoff between cognitive capacity (familiarity) and inferential utility (scope) of objects. The average individual may refer to a *Common Eider* as *bird* or *duck* - a tendency not evident in Fig 1 a.

As taxonomies underlie much of modern science and technology, we believe IGT has the potential for a broad contribution. Information gradients become a novel form of knowledge organization. They can be used to compare common knowledge with expert hierarchies, identify inconsistencies between intuitive and expert knowledge, suggest potential conflicts, and uncover conceptual gaps and opportunities. Information gradients can become valuable input for information technology design (e.g., by suggesting which concepts among many are more and less salient for people during data collection, search, and retrieval). Gradients may naturally differ in their shapes (e.g., some may have multiple minima and maxima, sharp vertical distances between nodes) reflecting and representing different in how people relate to the world. We hope that future studies will provide a formal definition of IG, describe its properties, suggest outcomes and explore specific applications of IGT in science and practice.

References

1. Gregor, S.: The nature of theory in information systems. MIS Q. 30, 611–642 (2006).
2. Nickerson, R.C., Varshney, U., Muntermann, J.: A method for taxonomy development and its application in information systems. Eur. J. Inf. Syst. 22, 336–359 (2013).
3. Rogers, T.T., McClelland, J.L.: Semantic cognition: A parallel distributed processing approach. MIT press (2004).
4. Gallese, V., Lakoff, G.: The brain's concepts: The role of the sensory-motor system in conceptual knowledge. Cogn. Neuropsychol. 22, 455–479 (2005).
5. Lukyanenko, R., Parsons, J., Wiersma, Y.: The IQ of the Crowd: Understanding and Improving Information Quality in Structured User-generated Content. Inf. Syst. Res. 25, 669 – 689 (2014).

On semantics-contingent syntax for conceptual modeling

Roman Lukyanenko[1], Binny M. Samuel[2], Arturo Castellanos[1], Mahed Maddah[1]

[1] College of Business, Florida International University, Miami, FL USA
{rlukyane, aancaste, mmadd011}@fiu.edu
[2] Ivey Business School, University of Western Ontario, London, ON Canada
bsamuel@ivey.uwo.ca

Conceptual modeling specifies the kinds of objects to be represented in an information system (IS). It involves documenting knowledge about a domain, defining its scope, and outlining constraints: making it a key element of IS. Conceptual models typically represent classes (categories, kinds) of objects rather than concrete specific individuals. Classes are central constructs in most conceptual modeling grammars (e.g., entity relationship diagrams, ERD, unified modeling language, UML). While representation of classes may differ between grammars, a common design principle (DP)[1] is what we term ***different semantics same syntax*** **(D3S).** Under this DP all classes are depicted using the same syntactic symbol (e.g., box in ERD, see, Fig 1) despite these classes potentially representing very different kinds of entities in the world (e.g., natural kinds, social entities, artificial entities, see below).

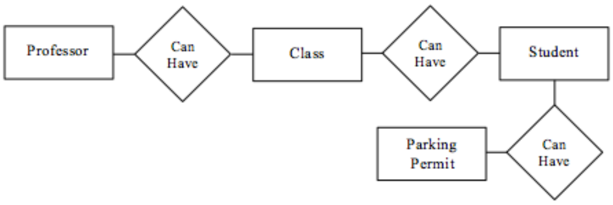


Fig. 1: Entity-relationship diagram adapted from [2]

Despite the wide diversity of approaches and grammars developed since 1970s, the D3S is the prevailing DP in conceptual modeling theory and practice. Recent developments in conceptual modeling's reference disciplines of psychology and philosophy and, however, doubt the theoretical justification of the D3S. Medin et al. [3], for example, distinguish classes based on structural differences, processing differences, and contexts of use. For example, in Fig 1., Professor, Student could have different structure and behavior than Parking Permit (e.g., organizations may not be able to influence some *attribute values* for humans in the roles of professors and students, but can create and manipulate attribute values for parking permits; real-world objects belonging to the professors and students classes may be naturally extremely diverse and not share many *attributes*, while one could force all parking permits to have exactly the same attribute). Some of this information may be valuable to capture graphically, as it affects how one understand the models and develops IS objects (e.g., database schema). Following recent findings in psychology, we introduce a novel DP

– **semantics-contingent syntax (SCS)** whereby syntactic representations of classes in conceptual models ***may*** differ based on their meaning.

To establish specific DPs by which semantics becomes dependent on syntax, we identify theory-grounded patterns along which classes can be grouped, and represented differently in conceptual models. These include distinctions based on isolated and interrelated concepts, physical and mental events, artifacts and natural concepts, concrete and abstract concepts, ad hoc and stable concepts, basic versus subordinate and superordinate level concepts, cross classifications versus taxonomies, bottom-up and top-down classes, naïve, folk and expert taxonomies [3–5]. We then show how each distinction motivates syntax sensitive to particularities of each pattern.

We believe, SCS carries profound implications for theory and practice of IS that we hope to explore in future work. First, it suggests the use of prevailing modeling approaches and grammars may require modifications to be more consistent with the SCS DP (even if it simply means making a comment next to a class). Also, the identification and modeling of classes is a central task of conceptual modeling and research has acknowledged the need for more theory-grounded design [6]. At the same time, more research is needed on the specific benefits and possible negative consequences (e.g., due to increased complexity) of this principle in conceptual modeling grammars. Second, it is important to become aware of the consequences of the SCS DP on database designs. For example, storing ad hoc concepts (e.g., things to take on vacation; that may not share many common attributes) may require flexible, noSQL databases rather than relational ones. Third, SCS can better inform studies on conceptual modeling as it suggests that differences in previous study results *may* be attributed to different kinds of classes [e.g., see 7].

References

1. Gregor, S., Jones, D.: The Anatomy of Design Theory. J. Assoc. Inf. Syst. 8, 312–335 (2007).
2. Rainer, R.K., Cegielski, C.G., Splettstoesser-Hogeterp, I., Sanchez-Rodriguez, C.: Introduction to information systems: Supporting and transforming business. John Wiley & Sons (2013).
3. Medin, D.L., Lynch, E.B., Solomon, K.O.: Are there kinds of concepts? Annu. Rev. Psychol. 51, 121–147 (2000).
4. Weiskopf, D.A.: The plurality of concepts. Synthese. 169, 145–173 (2009).
5. Piccinini, G., Scott, S.: Splitting Concepts. In: Philosophy of Science. pp. 390–409 (2006).
6. Parsons, J., Wand, Y.: Using cognitive principles to guide classification in information systems modeling. MIS Q. 32, 839–868 (2008).
7. Lukyanenko, R., Parsons, J., Wiersma, Y.: The IQ of the Crowd: Understanding and Improving Information Quality in Structured User-generated Content. Inf. Syst. Res. 25, 669 – 689 (2014).