Technical Report

Protocol for Case Study on:

Continuous Adaptation Management in Collective Intelligence Systems

Angelika Musil[1,2], Juergen Musil[1], Danny Weyns[2,3], Stefan Biffl[1]

[1]Institute of Information Systems Engineering, TU Wien, Vienna, Austria
{angelika, jmusil}@computer.org, stefan.biffl@tuwien.ac.at

[2]Department of Computer Science, KU Leuven, Leuven, Belgium
danny.weyns@kuleuven.be

[3]Department of Computer Science, Linnaeus University, Växjö, Sweden

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Angelika Musil[1,2], Juergen Musil[1], Danny Weyns[2,3], and Stefan Biffl[1]

[1] Institute of Information Systems Engineering, TU Wien, Vienna, Austria
{angelika,jmusil}@computer.org, stefan.biffl@tuwien.ac.at
[2] Department of Computer Science, KU Leuven, Leuven, Belgium,
danny.weyns@kuleuven.be
[3] Department of Computer Science, Linnaeus University, Växjö, Sweden

1 Introduction

In the last decades, *Collective Intelligence Systems (CIS)*, such as wikis, social networks and media sharing platforms, enable enhanced knowledge creation and sharing at organization and society levels alike. Today, they constitute a very relevant new system domain that is widely adopted and influence a large amount of people in their daily lives. Established CIS platforms have a longevity well over a decade and beyond. Consequently, CIS represent a significant system domain to research from different perspectives.

A CIS is a *complex self-adaptive socio-technical multi-agent system* that realizes environment-mediated coordination based on bio-inspired models in order to create a *perpetual cycle* of knowledge and information *aggregation and dissemination* among its *actors* [2,5]. The system is heavily driven by its actors who continuously contribute content to a network of information artifacts [3] (*CI artifacts*), which represents the coordinative substrate and is hosted by an adaptive system layer that handles processing [4,7] of aggregated content (*monitoring, analysis and information filtering*) and information dissemination (using *rules, triggers, and notifications*). This feedback loop between the actor base and the computational system is an essential feature of CIS and must be carefully designed and maintained and may not be underestimated.

From extensive experience in R&D projects with industry partners as well as in-house CIS development, we learned that these platforms typically go through a complex evolution process during which they mature, leading to a significant increase of user base size and accumulated content. With limited development resources in early stages and far-reaching business consequences of design decisions in later stages, software architects are constantly challenged to continuously and carefully plan the evolution of a CIS. Thereby a particular challenge for software architects represent the multiple inherent uncertainties which continuously affect the system. In particular, when designing CIS the available knowledge is not adequate to anticipate all potential changes due to dynamics in the system context, such as changes of conditions, requirements, resources or the emergence of new requirements and factors to consider. One way to deal with and mitigate uncertainties is to design systems that adapt or can be adapted when the missing knowledge becomes available.

A particular challenging aspect with regard to evolution represents *adaptation of CIS*, which is a multi-dimensional problem that spans the full life-cycle of such platforms. However, the aspect of adaptation has not yet been investigated from a CIS architecture perspective. Traditional adaptation approaches that are applicable to common software system concerns in CIS are not directly applicable to CIS-domain-specific concerns, e.g., possible adaptation elements in the information dissemination phase of the feedback loop, when in the CIS life-cycle are adaptation activities be performed, or how to address uncertainties effecting the significant CIS perpetual cycle. Based on experiences from stakeholders in industry as well as our own experiences with studying and developing CIS, we identified a lack of consolidated design knowledge about the adaptation solution space specific to these systems. Current practice in the CIS domain from stakeholders we talked to showed that adaptation in CIS is added in an ad-hoc manner as a reaction to certain major incidents such as rapid decrease of user activities or spam information generated by bots. However, incorporating adaptation mechanisms in such an ad-hoc way may lead to unpredictable consequences on the system and unintended system behavior. Furthermore, there is a lack of methods to support software architects, product developers and platform stakeholders to address CIS-specific adaptation with reasonable effort and systematically design, describe and plan it.

To address these challenges, we study the *what*, *when* and *how* of continuous adaptation management in the CIS domain. Our goal is to provide software architects with CIS-specific adaptation decision-making and management capabilities during the evolution of a CIS software architecture. To achieve this goal, we applied an empirically grounded research approach. We have been studying various CIS with a particular focus on CIS-specific adaptability and adaptation management across the system's life-cycle to realize a continuously growing and successful platform. In addition, we reviewed literature if there is existing research work that addresses adaptation-related concerns and specifics with focus on CIS. Next, we conducted a series of in-depth interviews with companies that have successfully built and operate CIS in order to identify their problems and challenges and also to collect best practices with regard to adaptation management in CIS. The collected data provided input for identification of relevant stakeholders, their concerns during architecture design and model requirements to address these CIS-specific concerns. Based on the consolidated data and synthesized knowledge, we developed a novel architecture viewpoint aligned with the ISO/IEC/IEEE 42010 standard [1] which provides an adaptation-specific view on CIS architectures and is implementation agnostic. The *architecture viewpoint for continuous adaptation management in collective intelligence systems (CIS-*

ADAPT)[4] comprises four model kinds and aims at supporting software architects across the CIS life-cycle, whereby a particular focus is on the adaptation areas of modeling, scoping, binding time and evolution of CIS. The viewpoint frames the essential concerns of stakeholders with an interest in handling CIS-specific adaptation across the system's life cycle, starting from its inception and during its operation. It unifies CIS-specific aspects with established adaptation approaches so that this approach represents a useful addition to domain-specific adaptation approaches. It is important to note that the focus of the viewpoint is on CIS-specific adaptation and its impact on the system architecture. As such, architects may use additional architectural approaches, such as additional viewpoints or patterns, to deal with adaptation in traditional software system elements and other stakeholder concerns.

2 Research Method

We consolidated knowledge gained through previously performed investigations and surveys of CIS as well as interviews with CIS technical stakeholders from different companies and organizations that operate a CIS platform. As a result of this research, we propose the architecture viewpoint for continuous adaptation management in CIS as a new developed method for future CIS architects that will assist them in the development of their system designs with an adaptation-specific view on CIS key elements and processes. The purpose of this study is to provide qualitative evidence of the usefulness and applicability of the proposed CIS-ADAPT viewpoint with an in-depth study. We define a set of research questions with respect to the viewpoint's usefulness and applicability and perform a *case study* that aims to answer these questions. To apply this research method in an unbiased, objective and systematic way, we follow the guidelines for case studies in software engineering provided by Runeson et al. [6].

To achieve the goal of this study, we define the following research questions:

RQ1 - To what extent does the viewpoint support correct handling of CIS-specific adaptation problems?

RQ2 - How useful are the model kinds with regard to managing CIS-specific adaptation?

3 Case Study Design

In order to obtain qualitative evidence of the usefulness and applicability of the proposed CIS-ADAPT viewpoint, we will perform a *case study* with a group

[4] Documentation of the CIS-ADAPT viewpoint is available at: `http://qse.ifs.tuwien.ac.at/ci/material/pub/ecsa19/documents/cis_adaptation_viewpoint.pdf`

of experienced engineers who are active in industry. They will apply the architecture viewpoint in three adaptation-related design tasks addressing CIS key elements of a given system scenario. The study will be conducted in March 2017 at TU Wien, Austria. Based on the number of participants, the study will comprise one ore more study sessions, where one session will take five hours on average.

The study process starts with defining an initial protocol describing the design and plan for conducting the case study. Since the protocol is a critical element of each systematic study, it is reviewed by an external researcher who is not involved in this study. In the following, the study protocol is revised with respect to the review results. Once all researchers agree on the protocol, the phase of conducting the study starts by applying the criteria for participant selection, preparing the study setting and material, executing the data collection strategy, data analysis methods, and reporting strategy defined in the protocol.

The case study is conducted by four researchers. All four researchers will define the initial protocol. Three researchers will then perform the participant identification and selection process as well as prepare the study setting and material. Two researchers will execute the data collection procedures. Finally, the four researchers will analyze and synthesize the collected data as well as write the final study report. All steps will be crosschecked by the other involved researchers. Fig. 1 shows the overall systematic case study process that is planned to be applied. Detailed information about each step is provided in the following sections.

3.1 Participant Selection

To identify a number of active engineers interested to participate in this case study, we prepare an invitation comprising a study description, procedure overview and requirements. We distribute this invitation across different communication channels and by sending it also to our industry contacts.

To obtain qualitative data from different perspectives, the participants will be selected by applying the following selection criteria:

- currently active software engineer in industry;
- domain of the company / organization the participant is working for;
- current role as project manager, software architect, or software developer;
- mix of male and female engineers;
- has experience with the design of distributed systems;
- cover broad range of industry experience to get also insights into how less experienced engineers use the viewpoint;
- has experience with UML models;
- has not been involved in the development and design of the CIS-ADAPT viewpoint that is focus of this study;
- has no previous experience in the architecture design of CIS and the use of the CIS-ADAPT viewpoint;

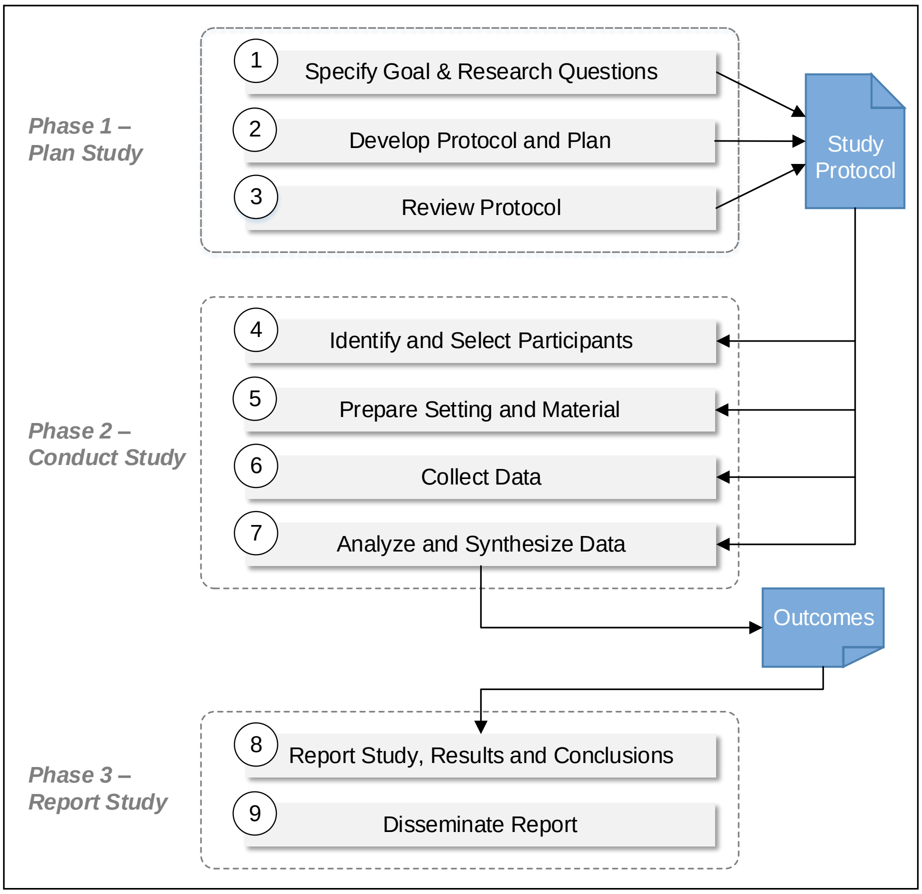

Fig. 1. Planned systematic case study study process

– has excellent English skills.

The involved researchers will apply the selection criteria to identify candidates for participation.

3.2 Procedure of a Study Session

In this case study the participants, in the role of a software architect, are instructed to apply the new developed architecture viewpoint in three adaptation-related design tasks addressing CIS key elements which should be accomplished in the context of a given CIS scenario. We provide all participants the same material that they should use to perform each task.

Before starting with the design tasks, participants are introduced to CIS and their characteristics in general, software architecture concepts in the context of

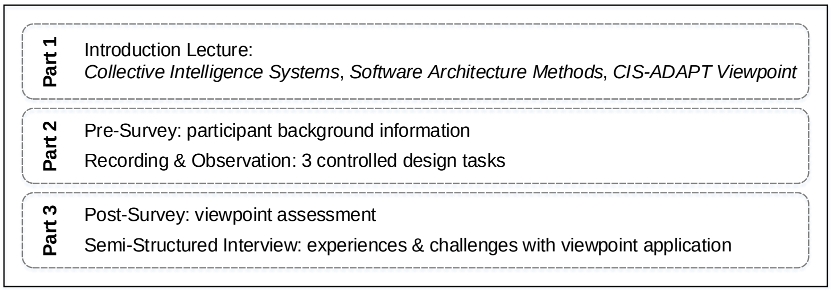

Fig. 2. Overview of the planned study session

ISO/IEC/IEEE 42010 [1], and the architecture viewpoint for continuous adaptation management in CIS. In addition, participants are introduced to the CIS scenario and the tasks and questions from individuals related to the instructions will be answered to avoid any misunderstanding of the assignment.

After the first part, participants are asked to complete a short survey to gather their background information, including their education, work and experience with (CIS) software architecture design as well as adaptation handling in architecture design.

While the participants perform the design tasks, we will video record and observe their actions and progression to gather data how they use the viewpoint to create an adaptation-specific architectural view in the given scenario. At the end of each study session, we will collect the modified architecture models and the participants are asked to complete a short survey to assess the applicability, usefulness and understandability of the architecture viewpoint and its model kinds that they applied for performing the design tasks using five-level Likert scale. Finally, we will conduct short individual semi-structured interviews of about 10 minutes to collect data about the participant's experiences and challenges during the application of the viewpoint.

Fig. 2 shows an overview of the planned study session.

3.3 Study Material

For the study procedure we prepare the following set of material to provide each participant:

- **CIS Scenario:** A general description of a fictive CIS scenario and its application domain and stakeholders.
- **Design Tasks:** A description of three design tasks that each participant has to perform by applying the developed CIS-ADAPT viewpoint.
- **Architecture Model Templates:** A set of pre-defined architecture models related to the particular view on adaptation management for each design task which the participants have to extend or modify with regard to the particular task.

– **CIS-ADAPT Viewpoint Documentation:** A documentation of the CIS-ADAPT viewpoint and its model kinds and analyses for the use of the model templates in order to perform the design tasks.

The design tasks are defined for a (fictive) emerging online encyclopedia WikiBritannica. The task of the participants is to guide the evolution of the platform and support the engineering team with strategic architectural decision making and planning. For the described system scenario, an architecture description with multiple architecture views and related models has been created. One of these views focuses on adaptation management and its impact on the architecture of the system. For each of the given design tasks a set of pre-defined architecture models are defined that the participants have to extend or modify with regard to the tasks.

Task 1 - Extend each of two pre-defined adaptation elements with a new option. In a recent incident, a spam bot managed to create thousands of spam pages. As a result the security analyst recommended to switch from the existing CAPTCHA to CAPTCHA+, as well as to extend the monitoring mechanisms with an abnormal behavior page spam monitor mechanism. So far, existing monitoring mechanisms only prevent the creation of spam accounts. The task is to extend the *interaction rule* adaptation element and the *monitoring mechanism* adaptation element.

Task 2 - Modify an existing element adaptation option from manual to automated change of the option at run time. The administration of a country is currently plagued by new scandals every day, which also increased the edits of the involved pages in WikiBritannica. In addition to the usual updates, there is an increased report on incorrect contributions. This circumstance increases the workload of the available editors, because currently they temporarily need to turn on and off the page protection for the respective pages by hand. The management decided that under the current circumstances it is better to shift to an automated page protection that is done by the system itself instead of the operator. The task is to modify the existing page protection option to support automation during run time.

Task 3 - Define and introduce a new adaptation element to the system and to assign two options to its adaptation space. In order to increase the degree of automation on the WikiBritannica platform the management and the operator decided that the platform should also be able to support bots in the future. A bot is an automated or semi-automated tool that carries out repetitive and mundane tasks to maintain the pages of the WikiBritannica. At the beginning there should be two options of bots: (1) Anti-vandalism bot which checks pages for unusual edits and marks them as important to be reviewed by users. (2) Spelling bot which checks the text of English pages and replaces US to British spelling. The task is to create a new adaptation element about *bot mechanisms* and create and assign the two bot mechanism options to it.

3.4 Data Collection Methods and Sources

In this study, we plan to obtain qualitative data about the applicability, usefulness and understandability of the CIS-ADAPT viewpoint from design models that the participants will produce while accomplishing the given design tasks, video taped observations on how they used the viewpoint, surveys and semi-structured interviews. We will use triangulation (of data source, observer, and methodologies) to increase the precision and strengthen the validity of our empirical research [6]. We expect to collect data from the following sources:

Assignment Observations and Results. The study execution is planned at TU Wien (Vienna, Austria) and is planned to be organized as a 5-hours working session. The application of the viewpoint in three design tasks will be video recorded for later analysis. Additionally, the present researchers will take notes (observations) to collect impressions of how the models are used by the participants and issues that may arise during the tasks. Besides the modification of the architecture models, we will ask the participants to provide rationals for their decisions and actions that they did to accomplish the task.

The data extracted from the modified architecture models and the observations offers the possibility to investigate the applicability and understandability of the viewpoint artifacts. The observations enable to determine how each participant manages to accomplish the given tasks and their performance. An analysis of these data helps to understand the challenges in the use of the models and the level of their comprehension in order to identify areas for improvement.

Participant Surveys. We create two participant surveys: one should be answered before performing the tasks, and one after the assignment to report their experiences and opinion. In the first survey we ask for demographic information like highest level of computer science-related education, current kind of work and role, major domain of the company / organization they are working for, and years of industrial experience in software engineering/architecture. Further we ask how much experience they have with the design of social media platforms and if they had any previous training in adaptation management in software architecture.

The data of the first survey provides on the one side background information on the participant. On the other side, we seek for participants that had little to none training in adaptation handling and CIS architecture design, in order to avoid carry-over and learning effects from previous experiences, which might have negative effects on external validity.

The second participant survey will be conducted right after the assignment activities. We ask for the usability, usefulness and understandability of the CIS-ADAPT viewpoint and its model kinds. Regarding usability, we ask the participants to judge the level of difficulty to apply the viewpoint and provide specifics on elements or situations that were easy or difficult. With respect to usefulness we ask to rate the usefulness and efficiency of the overall viewpoint and the individual models and also provide further specifics. Then we ask for the most useful element and how it helped during the design tasks. In the last stage, we ask the participants to rate the understandability of the viewpoint and also provide specifics on artifacts that were easy or difficult to understand.

The data of the second survey will provide a better understanding of the models' benefits, but also faced challenges and difficulties. Also this data is one guidance to identify points for improvement.

Participant Interviews. Immediately after the second participant survey, each participant is interviewed by one involved researcher for 5 minutes and asked questions similar to the post-survey. If the participant provides consent, the interview is recorded and anonymized, so that it can be used later for transcription and coding. This round of interviews aims to provide additional information and also identify aspects that further corroborate or reject results from the second participant survey. In addition, the interview provide the participant with the opportunity to share anecdotal insights of how she personally experienced the design tasks and the viewpoint.

The interviews aim to clarify how the participants experienced the design tasks and to provide additional evidence for the usability, usefulness and understandability of the viewpoint and its models.

3.5 Data Analysis & Reporting

After data collection, the researchers analyze the data collected from the set of different data sources in order to understand the applicability and usefulness of the CIS-ADAPT viewpoint and its artifacts. The data analysis has the goal to interpret the collected data and answer the research questions.

For this purpose, we will study the video recordings as well as the design models with the rationals that the participants produced while accomplishing the given tasks to identify how they applied the viewpoint and used its model kinds and model elements. The survey results will allow us to better understand and reason about the usefulness and understandability of the viewpoint from an architect's perspective. Finally, the interviews will provide us insights into the experiences and challenges the participants had to face as well as feedback for improvement.

The description of the CIS-ADAPT viewpoint and its evaluation results will be included as part of a research contribution at the European Conference on Software Architecture (ECSA).

4 Threats to Validity

As with any empirical research, there are threats to the validity of this study that need to be considered when interpreting the results. The following potential validity threats have been identified and discussed how to mitigate them in order to strengthen the outcomes of the study.

Internal Validity

- *Multiple sources of data.* Gathering data by applying only one research method increases the risk of bias in the results. Therefore, we used a mixed-methods approach and sought to collect data from multiple different sources: system survey, expert interviews and observations of system pilot developments. This triangulation of the results should obtain a more complete picture of the current situation, strengthen the validity of the study outcomes and increase the value for industrial context.
- *Adaptation of collected data items / questions.* Based on our expertise and previous discussions with practitioners, we defined the set of data items for the data collection of the CIS survey and the design of the interview questions. By using well-defined data extraction forms and an interview guide, we attempted to conduct the study in a consistent and objective way to reduce the risk to affect the validity of the data provided by the study subjects. Especially during the interviews we needed to be very careful when giving specific examples to make some interview questions more comprehensive and clear so that we do not influence the given answers. For both data collection methods we performed a pilot study to refine the data collection forms for the survey as well as the interview guide when identifying questions/data items that are confusing or do not provide enough informative quality. In addition, to ensure industrial relevance of the collected data, we have conducted reviews of the data collection instruments by domain experts. The expert feedback was also used to counter-check the consistency and integrity of the questionnaire.
- *Valid interpretation.* To address the threats of misinterpretation of the collected survey data or the participants' answers and incorrect conclusions, the findings have been derived by two researchers and two additional experienced researchers, who were not part of the data collection process, were later involved in the data analysis and interpretation to cross-check and validate conclusions. Different views of the researchers were discussed and additionally the recorded interviews provided the possibility to easily re-collect and re-analyze data. Furthermore, during the interviews we regularly summarized the given information and asked the participants to verify the correctness of the interpretation.

External Validity

- *Generality of the results.* The presented models are the result of an in-depth analysis of the gathered data and might be limited to the samples we investigated. In order to increase the generalization of the provided results to a broader context and thus strengthen the outcomes of this study, we plan to conduct a CIS survey with a larger system sample and further expert interviews. Potential interview candidates were carefully selected with the goal to gather information from a diverse range of different organizations with CIS in various application contexts and as many different views and

technical-focused roles as possible. The list of collected interview candidates was extended by recommendations of the interviewees. Likewise, the set of surveyed CIS was carefully selected by defining several inclusion and exclusion criteria to ensure sufficient quality of the selected system candidates and availability of information sources. For the evaluation of the viewpoint, we perform a case study with a small number of participants. To enhance generalization of the results, this qualitative inquiry should be extended with additional cases in other domains. We thus are confident that the observations and conclusions reported in this work are providing a significant contribution for the software architecture domain and particularly for the CIS domain.
- *Evaluation with small number of engineers.* To evaluate the viewpoint, we conduct a case study with a group of engineers. Since the effort to execute this study is very high, we decided to fix the number of participants between 5 to 10 for the first evaluation round of the viewpoint. Thus we are very interested to select active participants that have several years of industrial experience in software engineering and architecture. To enhance the validity of the results, a second round of evaluation is planned where this case study is replicated in another industrial context with more participants.

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