Playware Research – Methodological Considerations

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Abstract

Several sub-disciplines of engineering are driven by the researchers' aim of providing positive change to the society through their engineering. These researchers are challenged by the traditional research method of experimental research with a waterfall model which demands clearly defined project definition and functional requirements, and impose a sequential processes leading to the final system evaluation, which may lead to solutions which work in the lab, but have little impact in the messy real world. Based on two decades research in developing engineering systems with a societal impact (e.g. in robotics, embodied AI, and playware), in this paper we suggest a cyclic research method based on a mix between participatory and experimental processes. In particular, inspiration from the action research method applied to interdisciplinary technology development becomes a participatory approach characterized by rapid prototyping cycles which allow iterative technology specification and development together with people in their real world environment.

Keywords: Playware, Research Method, Synthesis, Rapid Prototyping, Modular Technology.

1. Introduction

Development of different research methods have often been neglected in the engineering discipline, since the discipline has followed the traditional natural science research methods of performing experimental research of a positivist nature. This involves rigor in controlling parameters keeping specific parameters constant and others variable in empirical testing. Hence, the research method arises from a reductionist belief that systems can be described fully by its components and their interaction with a fixed and constant environment. This "ideal" view of the world often leads the engineer to a conventional development approach termed as the waterfall model[1] with clearly identifiable and separated sequential processes of 1) Project definition, 2) Functional requirements, 3) Functional design, 4) Implementation design, 5) System assembly, and 6) System evaluation.

However, engineering is also about creating and bringing technological solutions to people and the society. Several sub-disciplines of engineering are driven by the researchers' aim of providing positive change to the society through their engineering. These researchers are challenged by the traditional research method. Insight from social science, humanities, and arts tells us that people and the society may not be as rigorously controllable as lab conditions, industrial factory halls, etc. where the conventional engineering research method and the waterfall model has been applied with success. In the wild, messy real-world, there may be a need for another research method for researchers who aim at developing technological solutions that have a deep impact on people in their daily life and on the society.

Here we suggest a cyclic action research method based on a mix between participatory and experimental processes. In particular, inspiration from the action research method applied to interdisciplinary technology development becomes a participatory approach characterized by rapid prototyping cycles which allows

iterative technology specification and development together with people in their real world environment.

2. Mixed Research Method

With the mixed research method, we suggest that there are cases, where approaches from the positivistic and interpretivistic epistemologies can and should be merged. Health care technology is one such case. Health care technology aims at providing new technological solutions for the public health care sector, e.g. for hospitals, for rehabilitation and care centres, and for care in the private home. Developing such solutions demand a broad knowledge about health and disease, engineering competencies, and interdisciplinary competencies to develop health care solutions. The mixed action research method is therefore particularly well suited for performing such research in health care technology.

Traditional action research methods for addressing the needs and practice in care centers and private homes are clearly different from traditional research methods in medicine of performing experimental research e.g. effect studies through a randomized controlled trial. However, both issues are crucial to include in research which aims at having an impact on society. Without an iterative participatory development, it is unlikely that users will see the technology fit into their lives and practice, whereas it is unlikely that health authorities will accept the technology without experimental research according to the acknowledged protocols within the field of medicine. There is little chance that our society will accept technological health care solutions without the rigorously controlled experiments that provide evidence of effect and potential collateral effects. Hence, a mixed research method is a necessity to ensure impact in the society. Indeed, it would be clearly against the aims of action research of creating society improvements not to include such rigorously controlled experiments in sub-processes of the research method, since these experiments are the cornerstone for the society to accept the health care technology. Hence, in such a mixed action research, some sub-processes in the iterations can be performed in a participatory manner, whereas other sub-processes must be performed through controlled experiments.

Other examples include contextualized IT training and community-based rehabilitation, which by their nature are close to action research and participatory

methods. Nevertheless, in the case of contextualized IT training there may still be a need to perform experimental research on technology and educational outcomes in order to obtain impact in society, and in the case of community-based rehabilitation, there is the need to perform rigorous effect studies similar to those for other health care technologies.

3. Applying the Method

As an example of applying this mixed research method, let us look at the research field of playware.[2,3] Typically, playware research has a core technology research activity focusing on research into modular playware technology and its supporting fundamental research areas of modern AI, adaptivity, modular robotics, and tangible interfaces. Engineering researchers perform fundamental research in these areas to develop the basis for understanding and creating user-interactive technological systems.
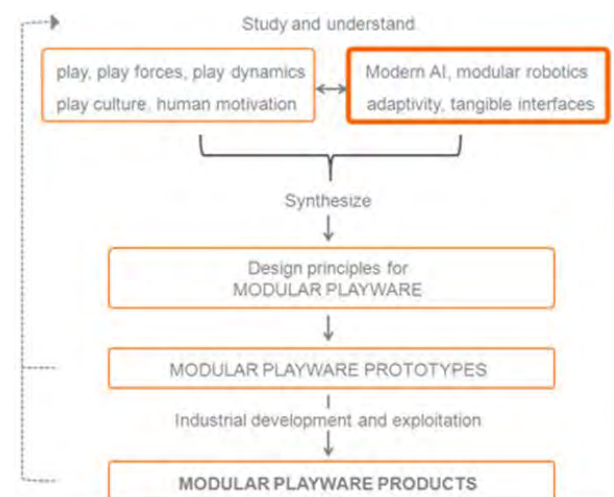

Fig. 1. The combination of several research disciplines in synthesis in an iterative working process

To operationalise this knowledge and develop prototypes with users, the research method takes its point of departure from the technological discipline *and* the humanistic discipline (see Fig. 1) investigating, understanding and exploiting these scientific fields (modern artificial intelligence, modular robotics, and tangible interaction) in combination with an understanding of play and play dynamics, and in more general terms play culture and human motivation. The knowledge is *combined in synthesis* to develop design

principles, prototypes, and demonstrators of playware technology, and a choice of these demonstrators are selected for (e.g. industrial) refinement to become modular playware technology products. The resulting modular playware technology is systematically studied and investigated in the messy real-world environments in order to guide the next cycle of synthesis, demonstrator and prototype development. Hence, the research method is based upon the interdisciplinary research on how playware in the form of intelligent hardware and software creates play and playful experiences amongst the users in their environment.

Within the individual cycle, the systematic study and investigation of prototypes and products in the messy real-world environments can follow an experimental research method and/or an interpretive research method. Indeed, often it may be necessary to perform a number of studies with a plurality of methods, for instance in order to be able to investigate both the technological and the practical feasibility in the environment. There are issues regarding technological stability and robustness which lends itself best to experimental research of a positivist nature, whereas issues regarding human interaction may lend themselves best to participatory research of an interpretivist nature. The combined knowledge from the two research directions' investigations will be the guide for the next cycle of synthesis, demonstrator and prototype development. Combining and weighing the knowledge from the two research directions is challenging and by no means a trivial task. Therefore, the research method demands that participants build shared knowledge and language about the environment, and research focuses on how results from the two directions are to be combined. The research method facilitates this combination by focusing on synthesis in the iterative process.

4. Iterative Approach

The example of applying the mixed research method to playware research points to an iterative approach in which knowledge is built from iterations of synthesis and application in the environment. Indeed, in 1946 Lewin[4] originally pointed to a spiral of steps in action research, and the research method has been known as cyclic action research. In general, the cyclic action research involves identification of a practical problem, making a solution, and reflections about the solution, which then leads to the next iteration of identification,

solution, and reflection, and so on. Indeed, in 1978, Susman and Evered[5] developed the action research cycle to include the five stages of diagnosing, action planning, action taking, evaluating, and specifying learning, which are then iterated, see Fig. 2.
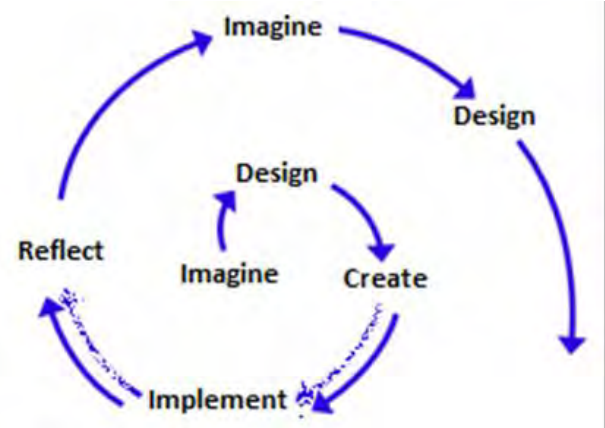

Figure 2. The iterative working process used to create and combine interdisciplinary knowledge in synthesis. There may be parallel processes studying implementation with different scientific methods (double arrows), and the knowledge is combined in synthesis of the subsequent cycle.

For the development of solutions in the mixed research method, performing such iterations is viewed as beneficial to both understanding the environment (users, use cases, practice, etc.) and to specify, develop, and refine the technological solution, since the iterative approach provides repeated observations to detect clear patterns. Further, it is noteworthy and important that users and environments change with the introduction of the technological solutions, as studied through the iterations.

In order to perform these iterations to build knowledge and to perform successful synthesis, rapid prototyping provides a method for ensuring grounding of the technology development in human interaction reality and grounding of the human interaction analyses in the technological reality.

Rapid prototyping is characterized by making iterations of prototypes in a fast manner, where the quick development of prototypes allows constant interaction and testing in the environment (e.g. with the users). This serves both as development of the system specifications themselves and as grounding in reality. Since the rapid prototyping approach recognizes that all requirements cannot be specified a priori, in contrast to

the waterfall approach, the requirements are learned and satisfied incrementally. Hence, small improvements are constantly implemented and aligned with users/environment.

According to the ASTM Standard,[6] in contrast to the waterfall approach of preparing "requirements and design documents that describe the needed system, rapid prototyping methods concentrate on preparing a working prototype. Users and developers learn the functional requirements and an appropriate system design by interacting with a series of prototypes, each of which is rapidly produced from a starting framework or from an earlier version. A prototype can evolve into an operational system, it can serve as an exact behavioral specification of an operational system, or it can be used to explore the feasibility of a new idea or design which can be incorporated in a larger system."

Such rapid prototyping is attractive to perform synthesis, not only because it creates the technological prototypes and advances, but also because it provides all participants (researchers, professionals, users) a common tool to meet around, share, and interact with, thus creating a common language and understanding, which is essential for the interdisciplinary research. The concrete hands-on experience with the prototypes in the environment grounds abstract concepts in concrete actions, which facilitates the creation of a common language and understanding amongst the participants. The common understanding is further refined fast in the rapid prototyping cycles.

This kind of cyclic action research method proposes flexibility in the research design to meet the real needs in the environment. Cunningham stated this in 1976 as: "The action research process makes it highly unlikely that the investigator will know exactly, or in advance, the design of the inquiry. Since every execution has to be evaluated and judged as to how effectively it meets the plan, revisions to fit new needs will be necessary. As hypotheses are validated or invalidated by the interim results, the problem may be redefined and the hypotheses and research methods modified." [7] p. 218.

5. Discussion

Interestingly, the spiral of steps in action research as proposed originally by Lewin[4] seems widely to have influenced other spiral models, which have become known extensively in other engineering and scientific disciplines such as software development,[8,9] design, and constructivist education.[10] For instance, in the creative thinking spiral, people imagine what they want to do, create based on their ideas, play with their creations, share their ideas and creations with others, and reflect on their experiences—all of which leads them to imagine new ideas and new creations.

The iterative process needs to start somewhere. Susman and Evered[5] suggest that the cycle starts with the diagnosing phase. Similarly, the imagine phase provides the start in the creative thinking spiral.[10] This can often be a difficult and abstract phase for researchers and participants. It is our belief that the process can be kick-started in such a diagnosing or imagining phase by the introduction of technology suitable for diagnosing, imaging and creating prototypes. Such technology can ideally have a modular expression to allow any user to easily construct, combine and create prototypes from those modules. Based on a deep engineering and computer science knowledge on modular technology and embodied artificial intelligence, it is possible to develop technological modules that any user can easily understand and construct with within a minute, e.g. Refs. 2, 11, and 12. This provides an important hands-on involvement in the first phase, which makes it easier for participants to ground the diagnosing and imagination in both the world reality and the technological reality.

Acknowledgements

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