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A Model-Based Approach to Guide Digital Transformation

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***Abstract*—The digital transformation of our society is happening. In this paper, we try to provide means to deal with this phenomenon. We introduce and examine a new approach to show how to capture the impact of digital transformation methodically, and by doing so, how to guide the complex unpredictable process of digitalization in our social environment. After showing related work on artifacts, on the representation of things, on modeling, and finally on models as artifacts, we present our new model-based approach, the flow of models we developed, namely models for object characterization, hypothetical story, prediction, and test/experiment/evaluation. Furthermore, we show the context of our research, the role of models in design, and how we broaden our research context from design to digital transformation. Before we conclude our paper, we illustrate our approach on an example from health care, in the scope of an international research project.**

***Index Terms*—digital transformation, modeling, artifacts, health care, digitalization process**

I. Introduction

Understanding societal changes is a difficult task, especially if they are triggered by new technologies in relevant public and private areas of our lives. Technological innovation might have impact on all types of services provided, on methodologies and arrangements of industrial production, as well as on aspects like privacy, security, communication, mobility, etc. In the past, it was almost always about problem solving, especially when new problems occur because of the introduction of innovations – not only technological but also social – into already established systems. Due to the developments in the recent years around digitalization, our society is currently undergoing a remarkable transformation. Some of it has already happened; some is still happening.

The awareness among the population is not as high as it could have been so far. People recognize intelligent systems around them slowly, that can be defined as an interplay of machine learning and artificial intelligence in combination with analysis and use of big data. Mid- or long term prediction of the results of digital transformation and its impact on the society is not easy, apart from being ever possible. In this paper, we try to deal with this challenge by introducing and examining an approach to show how to capture the impact of digital transformation methodically, and by doing so, how to guide the complex unpredictable process of digitalization in our social environment.

Representations of problems and solutions are crucial in complex situations. In this research, we use models to capture the current situations, user needs, and technological requirements related to the context. Models help us to analyze the processes before and after applying or introducing new technologies in different real domains, to think about possible impact of such innovations onto existing systems, to possibly predict follow up mid- or long-term results of any kind, and finally to test or evaluate approaches to avoid negative consequences of the use of such technologies or to improve the ways how new technologies can change our society and us within it when introduced or established.

After showing related work on artifacts, on the representation of things, on modeling – especially in design and engineering – and finally on models as artifacts, we will present our new model-based approach, by showing the context of our research, the role of models in design, and how we broaden our research context from design to digital transformation. Before we conclude our paper, we illustrate our approach on an example from health care, in the scope of an international research project.

II. Related Work

Within the CSCW (Computer Supported Cooperative Work) research, artifacts were always a useful tool to help representing things, like problems, solutions, or processes [5] [6] [7] [8] [9]. Several terms and frameworks were introduced and studied, like organizational memory via artifacts [10] [11] [12] [13] [14]; artifacts creating and helping maintain common information spaces in work environments [15] [16]; workflow systems realized by using the flow of work artifacts [17] [18]; coordination mechanisms enabled by artifacts to coordinate dependencies between activities [19] [20] [21] [22]; artifacts as boundary objects used across disciplines [23] [24] [25] [26]; etc. In CSCW, the representation of work has always been an important issue, to understand the objects to study. Models are found as very powerful tools for that reason and furthermore for the articulation of activities [2] [3]. Several visual artifacts are usually created in design teams, mostly during team discussions, as an integral part of explanations, developments, and arguments [27]. These are then re-used in follow-up meetings, sometimes with attachments, comments, and modifications for better understanding.

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Models are also used to overcome complexities, e.g., in engineering. Several modeling practices are identified and described [28]: “1) modeling to visualize important issues in a cooperative project, 2) modeling to support collaboration and coordination among members, 3) modeling to support system engineering for individual and group work, and 4) models triggering automated actions in workgroups.” [2, p.113].

Not only in engineering processes but also in any type of processes models are very useful to create a common understanding of the subject discussed or to represent the whole or part of the process as an objectified artifact to reflect on. Seen from actor network theory point of view [29], intermediaries – in form of artifacts – impact the setting in which they evolve so they influence the processes as such. Being part of the network, intermediaries are related to activities or actors.

In this paper, we choose models as intermediaries to deal with complexities we are currently facing due to the digital transformation. We believe that models can help us to see the relations between different aspects of the application of new (intelligent) technologies in several societal areas. Since we have already developed in our previous work a model-based approach for design processes and showed how to relate them with the following engineering practices, in this paper we continue on our research on models as artifacts helping to understand and to guide the digital transformation of our society. We want to provide means for dealing with it – while it is happening and not then when it is over.

III. A NEW MODEL-BASED APPROACH

After introducing the context of digital transformation we will present our model-based approach, the flow of models we developed, namely models for object characterization, hypothetical story, prediction, and test/experiment/evaluation. This is the main contribution of this paper.

A. Digital Transformation as Context

In the scope of an on-line real-time Delphi study the Center of Informatics and Society at the TU Wien (C!S)[1] has investigated relevant factors and their relations in the understanding and discussing the current (technological and socio-economical) development and its impact. Based on a thorough literature review and several interviews with international experts C!S identified four dimensions that help to understand the intertwined aspects of digital transformation [4]. These are *societal areas*, *issues*, *global challenges*, and *technologies*.

Societal areas cover a wide range of aspects of society, from personal life to health care, education, mobility, or economy. The categories are kept broad intentionally, allowing for some overlap to provide opportunities for discussion within the study itself, as well as leaving certain aspects open to interpretation.

As with any paradigm shift on a larger societal level, the digital transformation gives rise to a number of *issues* that challenge its potential positive effects. The ubiquity of digital devices amplifies issues of privacy and computer security, and transforms the way we see and present ourselves and our digital identities. Changes in the way we produce and consume news require changing how we gauge the veracity of media content, and striving for equality must now include addressing a growing and transforming digital divide that leaves vulnerable members of society behind. Finally, an economy that is increasingly based on automation, be that in manufacturing, logistics or even the service industry, must provide answers to issues of reduced employment opportunities and job security.

Looking beyond local issues, humanity faces a number of *global challenges* that will require cooperation and sustained, combined efforts to solve. The digital transformation carries the potential to provide solutions to these challenges, but also amplify the related issues: while digital technologies can help battle climate change, advance equality and improve human rights, they can also have a potentially adverse impact on geographic regions affected by poverty, war, or economic underdevelopment. Finding the answers to these problems and determining how to utilize digital technologies to address these challenges are the first steps towards a successful global digital transformation.

Finally, a core aspect are the (digital) *technologies* advancing the digital transformation of society. Some technologies, like the Internet itself, have had time to mature, while others are comparably new, making their future impact on society a difficult matter to predict. Not all of these technologies will prove to have a lasting impact or even relevance, but they all carry the potential to broadly affect our daily lives in one way or another. The rise of machine learning and autonomous agents or the advances in robotics give way to socio-technical systems that are only now finding their way to the end user, and yet their impact is already palpable, not least due to the possibility for rapid deployment and dissemination across the globe.

The Delphi study showed the potential of a large number of research subjects related to digitalization and digital transformation in the next five years. The biggest attention should be given – as the experts of the study agreed upon – to the societal areas economy, industries, and health care as well as to problematic issues such as privacy and security. Technologies like machine learning, automation, social media, and Internet of things are still the most likely to exert a strong impact in the years to come, especially when considered in relation to the academic disciplines of social sciences and humanities.

In our illustration we focus on health care and automated data gathering of medical care information, due to the limited space without going into details of technologies applied.

B. The Role of Models in Design

In a previous work [1], we introduced the approach ***mDT**, **multidisciplinary Design Thinking*** by describing the methods as well as their relation to each other in a time line (Fig. 1). The focus of *mDT* is providing means to improve the communication among stakeholders involved in a design project by creating and maintaining common understanding among all. It

[1]cisvienna.com

applies models for the mediation and exchange. Furthermore, *mDT* systemizes models based on their purpose and content to express the areas of communication like use aspects, system properties and functions as well as interaction mechanisms.

There are three types of design models: use models, systems models, and interaction models. *Use models* represent the use aspect of the design: who is the target group; what are the characteristics of the potential users, their habit, computer literacy, and expectations; what is the use scenario, are there restrictions, givens, and other circumstances that should be considered (in the design); are there dependencies between tasks needed for use, etc. *Systems models* represent the system mainly from functional, structural, and interfaces point of view: how are the user interfaces look like; what are the interfaces between system components; what is the technological architecture and the implementation, etc. *Interaction models* represent the interaction mechanisms and the product as a whole: how can users interact with the systems; what is the branding, form, content, functionality, and architecture of the product; how is its use and administration and configuration carried out; how much does it cost; what are the services provided around the product, etc.

Design models are mainly concerned with the design of technologies, by involving their users and their real settings. They address only the designers and engineers of software and information systems. They build an interface and communication channel to cross the boundaries to other disciplines like engineering, management, or marketing.

C. Broadening the Context from Design to Digital Transformation

Based on the models developed for the design process [1] we have extended our approach to include the four layers (societal areas, issues, global challenges, and technologies) that we identified to study in the context of digital transformation. The approach presented in the Fig. 2 is based on scientific principles. It consequently consists of the main elements of the scientific method: characterizations, hypotheses, predictions, and experiments.

All models on the left side of the Fig. 2 (design, object characterization, hypothetical story, prediction, and test/experiment/evaluation models) are connected to each other, by having an order in their realization and impact to each other. The so called "final product" (in the scope of design and engineering) or rather in this context "(socio-technical) transformation" is the result of the interrelated processing – by creating, using, analyzing, adapting, and adjusting – of the design, object characterization, hypothetical story, prediction, and test/experiment/evaluation models. It can also be tested and evaluated directly with the appropriate evaluation models.

a) Object Characterization Models: Characterizations define the subjects of investigation which might be unsolved problems – in case of digital transformation, phenomenons, scenarios as well as settings, in which the application of a technology can have impact on the individuals or on their surrounding systems. In our approach we call them "objects" (objects-in-study). These objects can be observed or measured to clarify definitions, constraints, and dependencies. The first step in this approach is to study and identify the objects, determine their characterizations, and describe the more complex settings (situations, actions, social relations, work-related issues, economical or societal issues, etc.).

After capturing object-related data by means of design models including use, systems, and interaction models (see Fig. 1), we first create an ontology of the entities with their properties and interfaces (to other entities) to define the context of the application scenario. Notice that we do not have the aim of modeling the whole world with such object characterization models (what designers tend to do). We only want to model the objects to set up the scope of our study and investigations and to create a base understanding for further steps in the process. Second, rules help to capture repeatable conventions established to arrange activities or interactions between people or systems. Third, dependencies between activities and relations between entities are also important to consider in the characterization models.

To realize these models, UML[2] can be used, with its class diagrams for entities and relations between the entities, activity diagrams for actions and dependencies among them. Last but not least, ECA[3] rules can be implemented as part of the UML activity diagrams with small extensions. Events can be internal or external, or time-related. Conditions are combinations of expressions and (event, environment, and device) variables. Actions are for service invoking or creating other internal or external events. Activity diagrams connect all models to each other so that a final model is delivered at the end of this step.

b) Hypothetical Story Models: In scientific context, a hypothesis can be a statement proposing a correlation between phenomena or explaining certain phenomena. Hypotheses are particularly relevant in case of studying digital transformation due to the uncertainty of future developments and their impact. In case a hypothesis is a limited statement with a cause and effect in a specific situation, it can be tested by experimentation and observation or by statistical analysis of the probabilities from the data obtained.

Based on the results of the object characterization hypotheses and connected explanations can be created in form of narratives or story-based presentations, which can be called story models including stories consisting of hypothetical situations. The underlying methodology is here storytelling. In case of single statements hypotheses can be modeled by means of UML class and activity diagrams.

c) Prediction Models: Predictions are results of deductive and inductive reasoning of hypotheses. The prediction can be about an unknown outcome of a laboratory experiment or of an observation of a phenomenon in a real setting. It can be statistical or descriptive. If predictions based on the hypotheses are not accessible by data or experience than the hypothesis

[2]Unified Modeling Language
[3]Event Condition Action

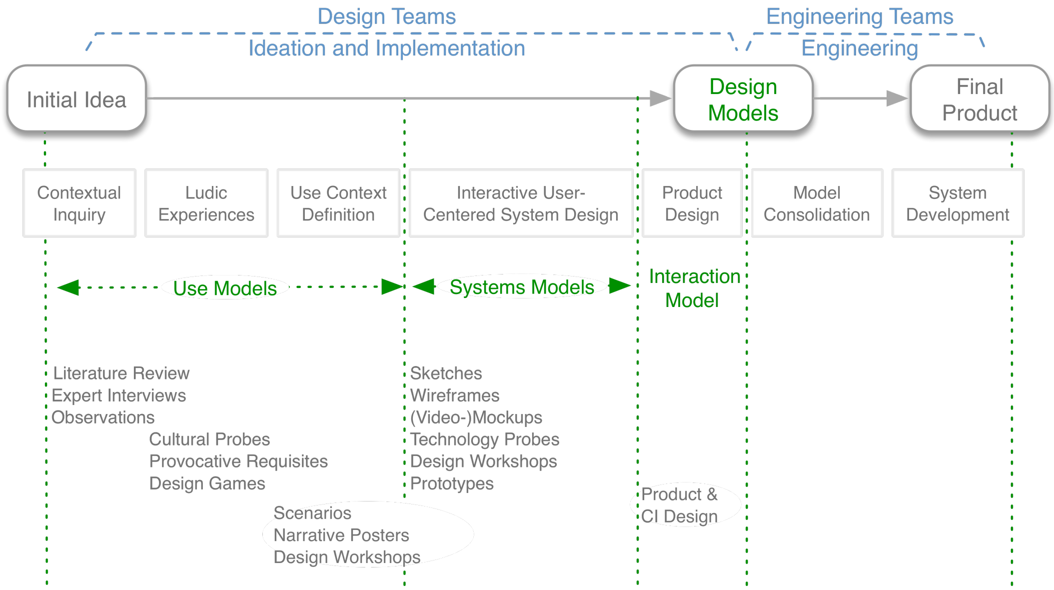

Fig. 1. Overview of the *mDT, multidisciplinary Design Thinking* [1, p.139].

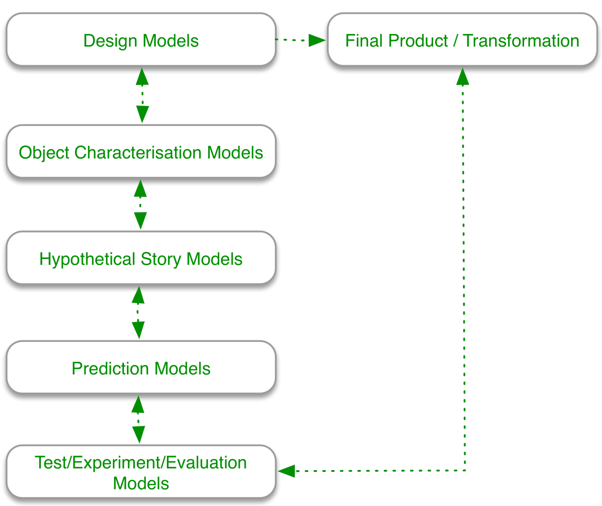

Fig. 2. The flow of models to guide digital transformation.

is not testable. This is a real challenge in scientific work and requires in some cases new techniques or methodologies.

Prediction models are difficult to create but very useful if they can deliver accessible data or empirical generalization of the experiments. So, they help create theories based on the hypotheses. This happens in combination of deductive and inductive reasoning. Predictions can be presented as conditional statements with options (if-then-else), single statements, or stories modeled as UML activity diagrams.

d) Test/Experimentation/Evaluation Models: Predictions usually suggest a solution and an improvement likewise while stressing out the problems that might occur during the application of the technology. They define what to test by considering the hypotheses and object characterizations.

Depending on the context and predictions made, different formats can be considered for testing. In some cases, questions derived from predictions can be for instance evaluated by user tests of the technology provided in a real context (with scenario-based test cases). In other cases, an experiment can be set up to see whether the predicted issues can be reproduced and studied in a lab environment. Other evaluations, especially of very complex matters, might need simulations, in which multiple parameters can be adjusted to achieve a useful result.

In all these formats, data can be gathered by quantitative inquiries as well as qualitative data can be created by interacting with the involved people, in forms of surveys, interviews, or observations. This is again an issue of the content and complexity of the setting to be tested. Finally, all test, experimentation, or evaluation findings need to be verified and analyzed to derive suggestions for a possible improvement of the technology investigated. Here, useful indicators need to be defined. Besides evidence based feedback for design models, this process might deliver additional rules that can be used as input for any kind of modeling in the next iteration.

IV. Illustration of the Approach

In this section we will present an illustration of the approach by using an example of an international European AAL project called TOPIC (The Online Platform for Informal Caregivers). TOPIC aimed to advance the understanding of elderly informal carers needs and design ICT solutions to support their daily lives [30] [31] [32] [33]. It addressed the lack of an integrated social support platform and the lack of accessible ICT applications for elderly people involved within informal care. The project congregated nine partners located in Austria, Germany, and France. It was undertaken with information scientists, sociologists, and media scientists together with partners from professional care institutions and engineering companies from 2013-2016. The overall aim of the project was to understand the care practices of elderly informal caregivers and how they relate to opportunities for support by designing a web-based care platform that could integrate various services, including information provision, social networking, and coordination tools. We chose this case for the illustration because it presents very good how digitalization changed the life of informal caregivers in respect to their communication with professional care organizations. Through this, we want to make our point that our model-based approach helps capture, analyze, and modify processes around us due to the changes caused by digital tranformation.

a) Object Characterization: Our illustration case is as follows: We have a caregiver who is taking care of her husband and has a question about his care situation. She thinks that the health situation of her husband is worsened and the health care support (in form of monthy payments) she gets for her husband should be increased. To communicate this new situation she writes a message to the professional care services that would contact the health care authorities to get their confirmation about this requested change in the status of the health care support level of her husband. She also sends an attachment of relevant care-related documents, in which the whole care history can be followed because it is (digitally) well-documented so far, and legal documents showing the status of the care support level that should be adjusted after examination. The professional care triggers the follow up activities of this request. After getting the response of the authorities it answers this question via an email. So, the mail message contains legally relevant personal data about the care situation, informing all stakeholders like care receiver, caregiver, and official administration body taking care of care support levels, including care procedures and regulations set up for the specific care situation. And the rule is that if there is a change in the health condition of the care receiver (E) and the level of care support is lower than needed (C) then the caregiver can apply for an increase of the care level support for the care receiver and probably gets it improved (A).

Here some explanations of our setting: The care support levels defines how much monetary support the care receiver can get based on his/her current health condition and care needs. In some Austrian families the care support money is the only income of the whole family. This is a very delicate issue for some of the caregivers, especially for the ones who are occupied 24/7 for caring their relatives and cannot have a job for their own.

Before digitalization the documents were paper-based kept normally in a folder. Now everything is digital and accessible to anyone who is involved in health care procedures, no matter from medical, legal, or organizational point of view. This is something new that the caregiver in our case is very skeptical about.

The setting described here can also be represented by using models (Fig. 3), as introduced in the last section. We can represent the situation of the caregiver in a health care situation (Fig. 4). The caregiver takes care of her care receiver. Professionals of different kind help the caregiver in health care activities. All activities are documented and arranged around the patient record that includes several types of data about the health care situation, partly created manually partly automatically.

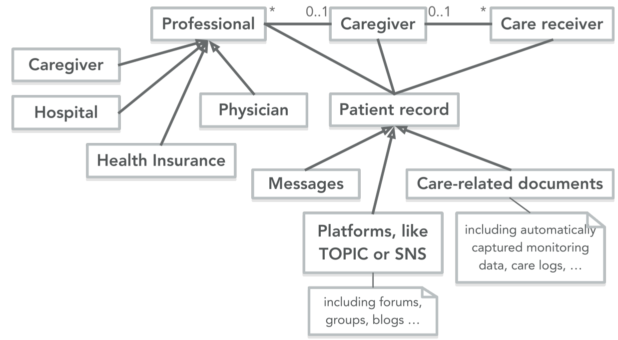

Fig. 3. A simplified object characterization model around caregivers in a health care setting, selected for our illustration.

Based on the class diagram we can represent our illustration case with an activity diagram (Fig. 4), which makes it easier to focus on the main issues that are problematic.

b) Hypothetical Story: In fact, we identified more than two hypotheses in this case. But for simplicity and making our point we chose only two of them for the illustration here. In both cases the caregiver is not aware of the digital monitoring because it is not transparent to her. She does not know, which data is logged and communicated to the professionals.

- Hypothesis 1: The health care situation of the care receiver is really worsened. Although the estimation of the caregiver is correct (but obviously not as much as it is needed to jump to a higher care support level), the monitored data does not support the estimation of the caregiver by showing completely different evidence about the situation of the care receiver. That is why, the authorities do not permit the increase of the care support level requested because they rather rely on the data delivered digitally than on the estimation of the caregiver.
- Hypothesis 2: The health care situation of the care receiver is really worsened. The estimation of the caregiver is correct. The documented data supports this estimation about the care receiver's condition. The permission is granted.

The Fig. 5 illustrates these two hypotheses in an activity diagram including the decision making process in these two cases.

c) Prediction: If the digital documentation of the care activities is not transparent to the caregiver, she would not trust the data delivered to the professionals, as follow up, she would not trust the professional care institution and health care services for their decision – of course only in case of a rejection of the request. If the digital information gathered is transparent and understandable to her, in best case even explained and discussed with the professional caregiver per-

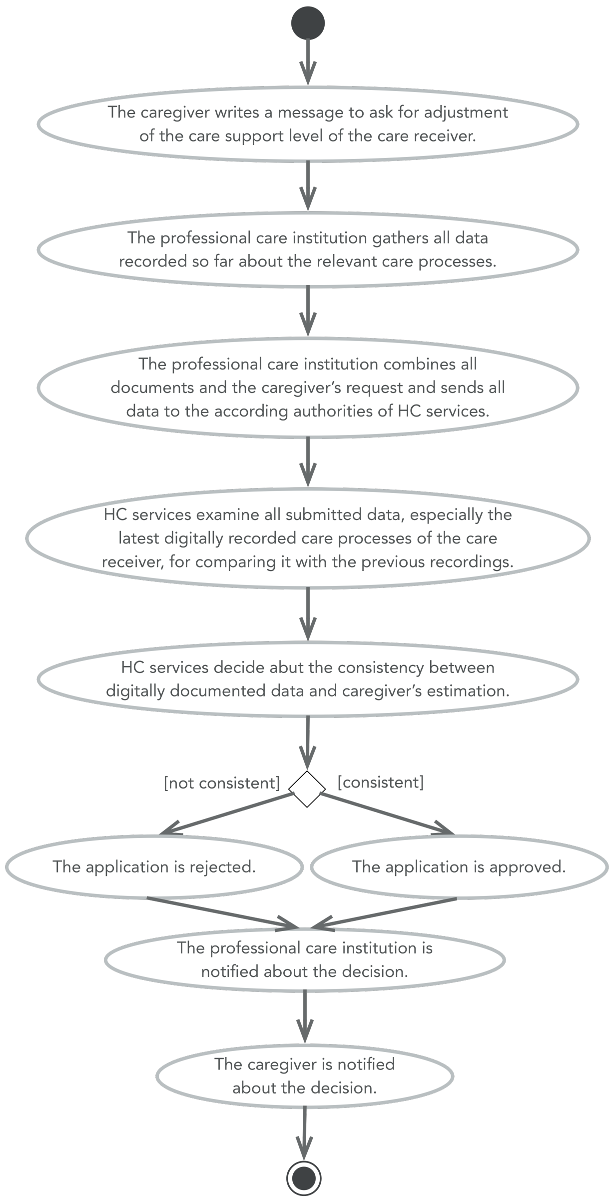

Fig. 4. Object characterization model showing the scenario of our illustration case.

sonally, there would be no problem for the informal caregiver to accept the decision taken by the authorities.

d) Test/Experimentation/Evaluation: In our case the issues to test would be: How transparent is the system used to capture the care practices around the care receiver to the involved informal caregiver? What are the issues that need to be considered in the interaction, visualization, and maintenance of the monitoring system? How can it be insured that the caregiver has a common understanding of the data gathered automatically about her activities in caring her husband?

V. Discussion and Conclusions

Digital models, in our case created at several stages of the entire process, are artifacts in different formats: as text like in an email message; as images taken as photos of the (medical or care) records folder of the care receiver or scans of any type of medical document; as data about the care situation extracted from other documents or entered by professionals, usually in a central database accessible by several authorized health care institutions and professionals to organize and document the care services planned and executed; as digital (and mostly interactive) visualizations of gathered data about the care situation to enable a focussed representation of all gathered data, e.g., to facilitate the decision making by authorities or physicians; and even as notes taken in conversations, consultations, and interaction with the care receiver or informal caregiver, to name a few. Caregivers are aware of some of these digital models, but they have also no idea about the existence and use of some others. That is why it is crucial to establish a transparent flow of activities – as modelled with the help of our approach (for this case see Fig. 4), and communicate this flow with the caregivers and receivers to increase their affordance.

With the illustration presented above, we aimed to show how our approach can help to capture, model, analyze the new processes caused by new technologies and reflect on, to avoid negative impact on the individuals involved. It goes without saying that data has to be captured before modeling the process. In our project TOPIC, we applied qualitative methods, including ethnographic participatory observations, in-depth interviews with the users, contextual inquiry with cultural probes [34], focus groups, document and artifact analysis, etc. The rich character of gathered artifacts made possible to understand the care setting and the circumstances under which the informal care takes place. In TOPIC, these mentioned methods have been applied in the course of the generation of design models (Fig. 1).

Introducing this model-based approach, we think, is a first step towards a better equipped and aware task force in shaping our future, here to deal with digital transformation. We know that it is very difficult to capture any aspect of the impact in the real world. But we also know that it is almost unbelievable that we do not have so far any means of trying to find out a certain representation of factors and parameters involved in an establishment of digitization in/of our society in all different areas. So, this approach represents a first attempt to try to connect technology development and deployment with the requirements and contexts of ones who are related to their impact. Taking this side of this delicate game seriously helps to move the focus of developments – like here in the course of digital transformation – from technological progress to socio-technical innovation that also considers individual and societal visions beside the economic and technology-driven goals.

The models used in this approach are relatively easy to generate (though with all data capturing and representation complexities). They build means for understanding important issues of different stakeholders that might have been ignored or forgotten to include in this process. We will continue with further detailing and description of this approach in our future work. We will also find ways of verifying the outcome of the

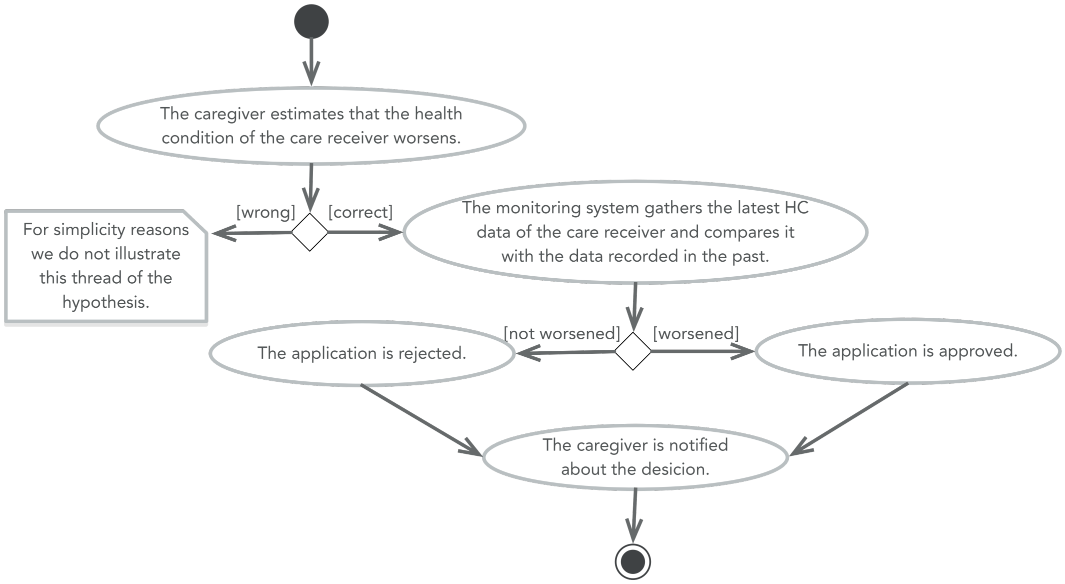

Fig. 5. A simplified hypothesis story model in our case.

models in a more systematic way.

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