# ICCGI 2021

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**ICCGI 2021 Editors**

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# ICCGI 2021

# Forward

The Sixteenth International Multi-Conference on Computing in the Global Information Technology (ICCGI 2021) continued a series of international events covering a large spectrum of topics related to global knowledge concerning computation, technologies, mechanisms, cognitive patterns, thinking, communications, user-centric approaches, nanotechnologies, and advanced networking and systems. The conference topics focus on challenging aspects in the next generation of information technology and communications related to the computing paradigms (mobile computing, database computing, GRID computing, multi-agent computing, autonomic computing, evolutionary computation) and communication and networking and telecommunications technologies (mobility, networking, bio-technologies, autonomous systems, image processing, Internet and web technologies), towards secure, self-defendable, autonomous, privacy-safe, and context-aware scalable systems.

We take here the opportunity to warmly thank all the members of the ICCGI 2021 technical program committee, as well as all the reviewers. The creation of such a high quality conference program would not have been possible without their involvement. We also kindly thank all the authors who dedicated much of their time and effort to contribute to ICCGI 2021. We truly believe that, thanks to all these efforts, the final conference program consisted of top quality contributions. We also thank the members of the ICCGI 2021 organizing committee for their help in handling the logistics of this event.

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# Co-Creating Interactive Virtual Reality Training Environments

## Reflections on a Model for a Participatory Design Process

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***Abstract*—This paper discusses the activities of an ongoing research project related to open science. Based on the involvement of team leaders, an interactive Virtual Reality training for social skills has been developed. Yet, the participatory and co-creative elements of the process encountered a series of limitations. Analyzing the difficulties of the case, we outline an ideal-typical model for the participatory development of socio-technical information systems.**

***Keywords-virtual reality training; co-creation; participatory research; open science.***

## I. Introduction

Any IT-based design is not limited to technological issues but has also specific societal and ethical implications. Such implications can and should be addressed in co-creative processes, especially when novel technologies are developed, or new fields of potential applications emerge. Co-creative processes in this sense are value-based [1], i. e., they should include dialogue and discussion at eyelevel between developers and users on the ethical and societal aspects that are relevant for the respective design project. Since co-creation is not limited to the exchange of ideas among different stakeholders but should include methods and ways of common decision making, processes of value-based co-creation include also participatory elements.

In this paper, we present an ongoing implementation case of a co-creative design of a socio-technical information system. The research and development project Virtual Skills Lab, funded by the Austrian Research Promotion Agency, aims at developing an interactive Virtual Reality (VR) environment for the training of social skills for mid-level managers. The project was designed as a transdisciplinary process with co-creative and participatory elements. The rest of the paper is organized as follows: In Section II, we describe the structure of the research process, highlighting its co-creative and participatory aspects. In Section III, we present some considerations on the limitations of our case regarding co-creation. In Section IV, we outline a categorization of the building blocks of the process regarding co-creation, as well as participation and critically appraise the extent and intensity of co-creation in the Virtual Skills Lab. Based on this appraisal, in Section V, we will outline a process design for an ideal-typical co-creative and participatory development of an interactive VR environment. The paper concludes with Section VI, which contains an outlook of the project and future work of the authors.

## II. Virtual Skills Lab – A Transdiscplinary Project with Co-Creative and Participatory Elements

The idea of the Virtual Skills Lab was created in September 2018 in a five-day seminar structured in form of a sandpit named 'Ideas Lab' [2]. It was organized by the Austrian Research Promotion Agency. The overarching topic of the lab was the future of human-machine interaction, especially in working environments [3]. Within the seminar, a group of researchers, developers and practitioners, representatives of five organizations, was constituted around the idea of developing an interactive VR environment for social skills training. The group, later enlarged by other members of the consortium's organizations, consisted of a software developer specialized in learning technologies, a human-computer interaction researcher specialized in user experience, a psychiatrist, a sociologist specialized in the sociology of technology and a philosopher with a specialization in corporate culture and social skills training.

Together, this group worked out the proposal for the Virtual Skills Lab project, in which a VR prototype for the training of social skills should be developed. The idea was to use the interactive VR technology in combination with technologies like speech recognition and natural language processing, in order to create a learning experience for team leaders in which they find themselves in the simulation of a difficult communicative situation with a fictional collaborator.

From the beginning, the structure of the project was conceived in terms of a co-creative process. This was especially the case for the Ideas Lab, in which the project idea was born, and for the two-months of writing the full-length proposal required by the funding agency. Furthermore, co-creative elements were planned for the whole implementation period of the project, which continued to be based on a transdisciplinary approach.

On the one hand, the members of the consortium contribute to the project by separately carrying out specialized tasks and work packages. On the other hand, many of these tasks are interrelated, so that there is a lot of

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decentralized coordination and teamwork realized across the boundaries of disciplines and specialization.

During the requirement analysis at the beginning of the project, a series of interviews were conducted with experts from diverse backgrounds: from VR-related research and development to business, training and trade unions. The interviewees were asked to express their views on the various stages of the project. Some of their statements were integrated into the development of the prototype and especially into the reflections on the ethical and diversity-related aspects of the work.

A special focus in terms of co-creation was given to the participation of potential users. This participatory activity consisted of a series of workshops with team leaders of an international organization, in which a storyline was developed. The development of the storyline was based on reflections of the team leaders on the everyday interaction with their team members and other colleagues in the organization. At the end of the workshop series, they decided that, among all the topics raised, “decline in an appreciative way” was the most relevant for creating an interactive scene. A scriptwriter worked out an office scene related to this topic, which was discussed together with the team leaders and further refined. At the end of this process, the scene was accepted as the basis of the prototypical interactive VR scene, in which the fictitious collaborator appears in form of a virtual non-playable character.

In a common discussion process, the members of the consortium had to make a decision on the characteristics of the virtual non-playable character. The perspectives of the sociologists, the screenplay writer, the psychologist, the user experience researchers, and the VR-developers had to be aligned. Finally, the group decided to design the virtual non-playable character as a woman aged about 30 years with a migration background. Furthermore, the decision was taken to design alternative characters according to the features of age, gender, body type, and realism for the evaluation phase of the prototype.

For the involvement of other potential users, various studies in terms of usability and user experience were planned. The research group was invited to take part in two “science meets public” events organized by the city of Vienna in 2020. Both events that would have served not only as a presentation, but also for the testing of the scene by the public, had to be cancelled due to Covid-19.

Not only gender and diversity, but also the reflection of ethical aspects was integrated into the research design. On this behalf, the sociologists have been organizing a series of workshops with experts from diverse backgrounds. In these workshops, issues such as the appearance and back story of the characters of the virtual non-playable character but also the co-creative design of the research process, are discussed and subject to critical appraisal.

## III. LIMITATIONS OF THE CO-CREATIVE APPROACH IN THE VIRTUAL SKILLS LAB

Reflecting on the co-creative and participatory character of the Virtual Skills Lab, we can state that some achievements have been accomplished, particularly concerning the implementation of the transdisciplinary approach. In addition, the openness towards external views and critical stances concerning the project have been appreciated by the experts that have taken part in the interviews and workshops dedicated to ethical issues. Still, the research group has encountered several limitations to a fully co-creative and participative research process.

### *A. Internal and external cooperation*

Although the project has been realized in a very open, transdisciplinary spirit and the coordination between the different actors works well, several stages of the implementation are solely carried out by the respective specialists. There could be more interaction, reflective loops and points of intersection between the different groups.

Coordination is realized in a decentral, network-like, open and non-hierarchical form. Still, we have not explicitly set up decision-making and working methods that could have organized the development in a way to further increase the opportunities for reflecting, deciding, and implementing together.

From our perspective, we have not sufficiently involved potential users, obviously because of the pandemic, but also because the gap between in-group (research and development team) and out-group (cooperating company) of potential users has not entirely been bridged. Furthermore, the motivation of the individual team leaders in the process has remained unclear. This could be also due to the limited possibility to meet the participants of the story workshops caused by the pandemic. The lack of communication with the participants and the organization’s representatives has caused some misunderstandings and irritations during the process. For example, participants often assumed the position of a customer that assesses a product, instead of feeling part of the research process. In addition, their expectations towards the design of the VR scene diverged significantly from the actual outcome.

### *B. Technological options*

We did not involve potential users in the discussion of technological options. An interactive VR scene can be realized in three ways: either by using playable characters (i. e., as a live role play) [4] [5], or as an interaction with a non-playable character controlled by a computer [6] [7], or in the form of a 360° video. The decision to use a non-playable character was taken in advance, also due to the necessities of the research proposal. However, we could have organized workshops in order to discuss the various options in terms of technology with the participants. This would have helped anyway to create a shared understanding of the training scenario and the possibilities of the VR technology. We did not realize this in the Virtual Skills Lab because in a first step we focused on co-creating the VR content, not realizing how important is would have been to involve also potential users in technical decisions. Beside the consequences of the pandemic, we lacked time and financial resources to ensure also the users’ perspective in this stage. Up to now, the gap between the experts’ specialized view on the technology and the lack of involvement and information on the side of the participants remains.

### C. Resources

For the realization of a fully participatory and co-creative research, more time and financial resources would have been necessary. In this way, more potential users from different organizations could have been involved from the beginning. Furthermore, the involvement of users in the development of the technological solution could have been realized.

Due to the Covid-19 pandemic, organizations' priorities shifted significantly, which resulted in a lacking willingness to organize participatory events like workshops and presentations. This has severely limited the possibilities to involve potential users and stakeholders in the research.

## IV. CATEGORIZATION OF CO-CREATIVE AND PARTICIPATORY ELEMENTS

Generally, the co-creative and participatory organization of research has been practiced for a few decades. 'Open Science' and 'Open Innovation' are concepts that stand for a growing community of researchers and members of the public who carry out research projects intending to involve stakeholders from diverse backgrounds that go far beyond the academic field. Hence, Open Science aims at transparency regarding the use of data and methods applied.

Still, the intensity and extent to which a research process is opened to non-experts varies. In a report on public participation in scientific research from 2009, Bonney et al. establish three categories to differentiate between a higher or lower degree of participation in such projects [8]. They define research projects as 'contributory' if they are designed by researchers and if members of the public just contribute data. In 'collaborative' projects, researchers are still responsible for the design, but involve members of the public in the refining of the design, in data analysis and the dissemination of findings. By contrast, 'co-creative' projects are such endeavors in which researchers and members of the public cooperate in the design and in all of the implementation steps.

If we apply these categories to the Virtual Skills Lab, the project can be defined as contributory and collaborative. The project is characterized by many activities in which qualitative and quantitative data are created by potential users (in the story workshops as well as in the interviews on gender and in the evaluative user experience studies), but also by experts (in the expert interviews during the requirement analysis as well as in the workshops on ethical aspects).

According to this categorization, the Virtual Skills Lab cannot be defined as co-creative as a whole, in that members of the public have not been involved in the design. However, as we have outlined above, there are co-creative and participatory elements in the design as well as in the implementation of the project. The sandpit method of the Ideas Lab, where the project idea was first conceived, has implemented a transdisciplinary dynamic that has been provoking discussions and reflections in the research group that are well comparable to the dynamic between experts and members of the public in co-creative projects as conceived of by Bonney et al. [8]. Because of the high diversity of academic disciplines, any expert of the group is at the same time a member of the public with respect to the other disciplines.

Also, the process of creating a story for the VR scene can be defined as co-creative, in that the content was developed together with team leaders who eventually decided which topic should be worked out by the screenplay writer. In addition, the cooperation between the research group and the screenplay writer can be described as co-creative. The writer joined the research group at an early stage of the project, initially assuming the position of an external service provider. Still, during the process, she began to identify more and more with the research and eventually considered herself and her work as part of the research.

Nevertheless, as already mentioned, the consortium has not succeeded to keep the borders between the in-group of the researchers and the out-group of potential users as open as it would be required in a truly co-creative process, limiting the openness of the process to contributory and collaborative activities – except for the transdisciplinary character of the research and the development of the story.

TABLE I. CO-CREATION IN THE VIRTUAL SKILLS LAB PROJECT

| Virtual Skills Lab | | |
|---|---|---|
| ***Building block*** | ***Category [8]*** | ***Method*** |
| Conception | Co-creative | Sandpit Ideas Lab |
| Requirement analysis | Contributory, collaborative | Qualitative interviews |
| Transdisciplinary implementation | Co-creative | De-central coordination, discussion and cooperation beyond specialized tasks |
| Target group involvement | Collaborative, co-creative | Workshops |
| Usabilty and User Experience | Contributory, collaborative | Qualitative and quantitative evaluation |
| Gender and Diversity | Collaborative, co-creative | Qualitative interviews, common decision on virtual non-playable character's characteristics |
| Ethics | Collaborative | Workshops |

Table I. gives an overview how co-creation was implemented in the Virtual Skills Lab project in the different building blocks. It also shows the single methods used.

## V. A MODEL FOR A CO-CREATIVE DESIGN OF INTERACTIVE VR-ENVIRONMENTS

The categorization introduced by Bonney et al. [8] considers all three types of projects as participatory and distinguishes according to the extent to which members of the public are invited to participate. It reserves the category 'co-creative' for those projects in which members of the public are involved from the stage of designing and formulating the research proposal to the various implementation and evaluation stages.

From our perspective, the term 'participatory' also refers to the various decision-making processes and methods applied during the different stages. A distinction between more or less participatory research projects could be drawn according to the extent to which non-hierarchical decision-making methods are applied and formalized in the various phases. In this sense, not only the involvement in the design and the generation of quantitative or qualitative data should be considered, but also the way decisions are taken whenever there are diverse options or alternative ways in which the respective project can be continued. Research projects can be defined as more or less participatory according to the extent to which decisions on relevant topics of the research are taken together (in a transdisciplinary team or with members of the public), and if the decision-making methods allow for openness and a non-hierarchical dialogue.

Participatory decisions can be taken at any stage of the process, starting from the project idea and conception. In our project, the content of the interactive VR scene was developed together with members of the public. The same process could have taken place regarding the technological solution. Furthermore, the whole development process could have been organized in form of continuous participatory loops. Finally, also publication and dissemination activities could be organized involving specialized researchers, as well as members of the public.

Conceiving an ideal-typical model for participatory research, we propose to introduce participatory decision-making tools right from the beginning of the process. These can be derived from the commons research [9] or from new non-hierarchical organizational models and decision tools like sociocracy or systemic consensing [10] [11]. These are valuable methods and organizational forms for an effective shaping of discussion and creation processes in which specialized and non-specialized participants are involved.

TABLE II. IDEAL-TYPICAL CO-CREATION MODEL

| **Ideal-typical Model** | | |
|---|---|---|
| ***Building block*** | ***Category [8]*** | ***Method*** |
| Conception | Co-creative, participatory | Sandpit, Systemic consensing |
| Requirement analysis | Contributory, collaborative | Qualitative and quantitative interviews |
| Transdisciplinary implementation | Co-creative, participatory | Non-hierarchical organization (e. g., sociocratic, systemic consensing) |
| Target group involvement | Co-creative, participatory | Workshops, Systemic consensing |
| Usabilty and User Experience | Contributory, collaborative | Qualitative and qualitative interviews surveys |
| Gender and Diversity | Co-creative, participatory, collaborative | Qualitative interviews, co-creative design of characters, systemic consensing |
| Ethics | Collaborative | Workshops |

Table II. shows an ideal-typical model of co-creation in a R&E project. Methods are suggested for every single building block.

In this way, the co-creative and participatory potential of the design of socio-technical information systems could be further raised. Therefore, we propose to introduce decision-making instruments like systemic consensing or the sociocratic organization of discussions for the conception of the project, the whole process of transdisciplinary implementation and especially for the involvement of target and stakeholder groups. This implies that researchers should acquire the skills necessary for moderating group processes and common decision-making, in order to be able to effectively connect the openness of scientific research with the openness of participatory approaches. In our view, it is highly recommendable for researchers engaged in co-creative research to go through training in group dynamics and the moderation of non-hierarchical decision processes. Alternatively, these competencies could be provided by external professionals.

## VI. OUTLOOK AND FUTURE WORK

Since the technology development and co-creation process of the Virtual Skills Lab project has been largely completed, the findings described in this paper will only be incorporated in the reflection on the overall project process. For future projects in the field of research and development - especially in technology development - special emphasis will be placed on co-creation with regard to technical implementation, which means involving different stakeholders, in particular potential users, in different steps of technology decisions. Not only appropriate implementation design, but also a corresponding resource planning is necessary, since co-creation in research and innovation processes is very time-consuming and thus particularly resource-intensive.

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# Towards Implementation of Ethical Issues into the Recommender Systems Design

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***Abstract*—In the last two decades, an increasing number of companies have adopted a business model based on digital services attained from user data. Accompanying these developments are not only the changes in the processes but also the attention that is brought by the society towards the effects and the constitution of these services. Moral and ethical demands are steadily rising and requests for regulation are getting louder in public discussions. In this paper, a scenario of a Machine Learning- based System (MLS), a fictional recommender system for food delivery, is used to identify potential ethical issues that occur during the composition and usage of the artifact. Based on the scenario and its real-life counterparts, suggestions of what ethical aspects can be implemented into the design of the information system are derived. This approach is used to argue that MLSs are socio-technical systems that have an impact on the system user, but also on the receiver of the MLS-based result. Hence, the focus on the social aspect of the system design needs to be put early in the development phase of such a socially aware information system.**

***Keywords- socio-technical systems; information systems design; machine learning based systems; ethical analysis.***

## I. INTRODUCTION

The pervasiveness of algorithmic systems in our daily lives is stimulating public and research debate about their potential effects on the individual behavior and also on the society as a whole. Several companies and governmental initiatives react to this development by publishing ethical principles on how their Information Technology (IT) artifacts that involve Machine Learning (ML) components are created, leading to the so called "principle proliferation" [1]. Evidently, Information Systems Research (ISR) should manifest its leading role in pursuing practices for the creation of IT artifacts that are not only technically innovative but also socially acceptable. This paper provides a contribution by presenting and discussing the outcomes of the ethical analysis of a paradigmatic case of a Machine Learning-based System (MLS) application. Here, an MLS is an Information and Communication Technology (ICT) that is composed of one or more algorithms working together and capsuled into one or more executable software components [2].

The results of the applied analysis approach lay the ground for theoretical development of a mixed method approach that is focused on ethical reasoning in ISR.

The presumption here is that ethical compliance of an IT-system is an integral part of the design process, as well as the product use. The linkage to ethical questions and the design of an IT artifact can be historically established in several ways. First of all, the core of the engineering activities, such as software engineering and IT systems design, is the solution to the design problem [3]. Since there are multiple possibilities to solve a problem, (software) engineers weight one alternative against another. The decision criteria for the design alternatives can be financial restrains, user requirements and functional fit of the alternatives. Once the chosen alternative is realized as an artifact, it will have good and bad effects. Hence, one obvious moral obligation of a (software) engineer in the role of the solution creator is to pick a design alternative that does not induce harm [3].

Thus, to create an IT system that takes into account the effects of its application on the business processes, users, as well as the affected parties, theses potential effects need to be taken into account in its design [4][5]. It is e.g., the case, when digital systems such as a recommender or a digital assistant system provide a service for its user. A service, in the physical world, as well as digital, comes with costs that are not only monetary. It entails partial loss of autonomy in the realm it is being offered as a service. A user accepts the service if the assessed amount of the autonomy loss is acceptable and thus the user provides a consent to this loss by agreeing to use the service instead of performing the offered function him- or herself. The engagement with the service can furthermore be associated by the user with loss of autonomy due to opaque processes of result generation. Social reluctance of these practices is evident. Only 19% of surveyed users of digital services believe that tech companies design their services with people's best interests in mind and 47% feel they have no choice but to sign up to services despite having concerns [6]. Identifying and complying to ethical issues in the MLS design can thus enable autonomous decisions for the user within the interaction with the service. In addition, this quality can provide a distinctive feature on the market of IT products.

Following this reasoning, the goal of this research is to identify the potential ethical issues of MLS in the example presented in Section III using the data process centered ethical analysis [7] in Section IV. Suggestions about how the identified ethical issues can be integrated into the IT system are provided in Section V. Using the offered scenario, the process and supplementary effort to include these aspects into the artifact design can be assessed by the system designer or business engineer, providing an actionable radius to create socially acceptable IT products, as well as to lay the ground for future research questions. Conclusion and outlook on the future work finish the paper.

## II. The Socio-Technical Aspects of Recommender Systems

Socio-technical systems are described by Baxter and Sommerville [7] as systems that involve a complex interaction between humans, machines and the environmental aspects of the work system. Machine learning-based systems incorporate this interaction already in their input, i.e., the data from which patterns are derived and test data sets for the mathematical models are the result of an interaction between a human in an organizational context and a business information system. Thus, their implementation into the organizational processes has an intermediate effect on the actors on the outside and inside of the organization. Specifically, in this context, socio-technical considerations are not just a factor within the systems development process, but they have to be considered at all stages of the development life-cycle.

For MLS, the development life-cycle includes the development life-cycle includes data processing. Data processing is furthermore divided into phases of data collection, data processing, model definition, model training and calculation of the results. The socio-technical factors are triggered when the MLS results are implemented into a business process, requiring a human decision or a decision that concerns human actors. To address these challenges, the ALTAI principles were established by the European Commission [8] to help evaluate a socially aware MLS design. These are: Participation, Transparency, Human Autonomy and Auditability. These principles are considered here as facilitators for the software design approach that focuses on the person affected by the software result rather than the direct user of the software.

Identifying any ethical issues that might occur during the system design is considered here the first step of the incorporation of these values into the systems design. Hence, a scenario for an MLS, a recommendation application, is described here and used to demonstrate an approach to identifying ethical issues.

## III. An Example Application: FoodApp- the Application for Meal Delivery

The FoodApp is a fictional application based on a three-sided digital platform that is implemented as a mobile app. It is a branch of a fictional large company Acima that offers on-demand individual transportation provided by freelancing drivers. To further explore the transportation market, Acima started FoodApp, a fast growing food delivery platform connecting the customer, restaurant owner and the delivery partner. It allows the customer to choose from a large database of participating restaurants and order a menu to be delivered to the customer’s address via delivery partners. The eater can choose a specific delivery partner based on the ratings of the currently available partners. The payment process is integrated into the platform as is the real-time tracing of the order delivery.

The platform business goal is the “fast and easy food delivery whenever, wherever”. To achieve this goal, an MLS, namely a recommender system, is used to provide the best food suggestions for the user in accordance to the indicated preferences and the order history. The business performance indicators for the FoodApp include the return and re-order customer rates, as well as customer number growth rates. The implemented ML-model is thus optimized to drive user’s re-ordering on the platform.

To use the FoodApp, the customer downloads it on the mobile device granting permissions for it to access the location of the device. Further, a profile including information on delivery address, name, e-mail and phone number is required. Payment methods and login to the payment provider is further required. No manual modifications concerning the data collection by the app is possible. Then, the meal preferences such as preferred cuisine or menu item need to be indicated or a meal can be chosen from the provided suggestions. The first suggestions are based on the historical frequency of the orders made within the community in the area of eater’s location. A rating system for restaurant and delivery partner performance is implemented.

The platform gains revenues from the customer via convenience charge, fixed commissions and marketing feeds from the restaurants, while providing the assignments and the payment to the delivery partners, as well as the technical infrastructure for the platform participants. The application is a key driver of Acima’s revenue and is a fast-growing meal delivery service with over 15 million users worldwide (this estimation is made based on the data from other food delivery companies such as e.g., Uber Eats).

Additionally, the platform includes an app for delivery partners that provides the possibility to accept or decline a specific delivery job, monitor the revenues, rate the restaurant’s delivery process, as well as provide directions to the restaurant and to the eater. This app is out of scope for this research.

## IV. Identifying Ethical Issues

To identify ethical issues, data process-oriented analysis [9] has been conducted. Since the core component of the FoodApp MLS converts (user) data into a food recommendation, the data process as described by [10] is referenced to structure the identification of ethical aspects. These aspects are derived using a hermeneutic approach from basic values such as human rights and are rooted in the basic principles and moral considerations of ethics and data ethics, see [1][11]. The ethical analysis looks at the data process within the system's design and identifies some of the relevant aspects, where ethical questions arise and give direction to the system's design.

FoodApp's business goal is to engage the user in the re-ordering of the food via FoodApps's digital platform. The user interacts with the app aiming for a comfortable provision of the favorite food in an efficient way. Therefore, as described above, the user is inclined to give up some autonomy within this process. Nevertheless, in the digital realm, the user is often not aware of what elements of his/her *autonomy* are jeopardized when the digital service, here food selection and ordering via a digital platform, is created [12][13].

FoodApp's user profile provides the information that is, among others, needed for the algorithms in the MLS to derive food recommendations. The user does not have any information about the exact *purpose* of the provided datasets, the *data lifecycle*, nor about who has *access* to the (possibly) un-anonymized profile or historical data and about the data state timeline, i.e., when the data are transferred or deleted. These aspects can be categorized as "*transparency* issues", since the user does not have the information about FoodApp's processes s/he might need or would like to have.

On the home screen of the FoodApp, the most frequent orders for eater's automatically identified location are presented. The user can filter the suggestions using the provided filter categories. These categories, defined by the MLS-engineers and designers, include cuisine and menu item names, as well as the ratings of the accordant restaurants. In future interactions with the FoodApp its home screen offers the meals and food items that are most frequently ordered by the eater or users that were identified to have a similar ordering behavior, thus nudging the eater to order the same or similar kind of food [14].

The ordering process is organized in a way that no extended explanations or additional information are given so that the user does not have to choose, decide or react during the interaction process. This design allows a *fast phase-out* between opening the FoodApp and ordering the food. This effect can be expected to contribute to user satisfaction and thus re-visiting the platform for the next order. Nevertheless, consequences of the provided recommendations based on historic behavior could lead to *decisional de-skilling* [5] or, in this case, potentially *homogeneous* food preferences for the eater.

The process efficiency offered by the FoodApp is also built on to the lack of decision possibilities and a limited items selection that is based on the historic and profile preferences for the user. Such an automated decision support can also potentially result in the *de-skilling of the evaluation* abilities [15] for the eater in the given context.

Additionally, the gained comfort for the user in terms of food selection and delivery has implications on the *ecosystem* of the FoodApp. The restaurant partners will be faced with the increased amount of reviews from the delivery customers, potentially forcing them to concentrate on robust packaging to ensure the sound condition of the meal for delivery. More or more robust packaging means more damage to the *environment* but potentially better ratings from the FoodApp users [16].

Furthermore, the food recommendations based on historic and similar orders might lead to the *homogenization* of the food offered and prepared in the participating restaurants, as menu items that are ordered less often might not be prepared by the restaurants anymore, potentially leading to the decreasing of the skills of the cooking staff. The individual delivery of the food orders requires reliable and efficient delivery partners. Acima relies here on its network of drivers for personal transportation that are also incentivized to transport food orders via reward programs.

Additionally, efficient and effortless process of ordering food for individual consumption can and does cause significant *environmental damage* in terms of air pollution through traffic and waste [16]. The eater rates the restaurant on the food quality and the delivery partner on the quality of the delivery. The rating is based on eaters' satisfaction with the end result, whereat the traffic situation and other eventualities are not considered. This relationship pattern also causes societal effects.

The rating of the delivery partners results in an increasing number of orders for high ranked drivers and in a reduction of delivery orders for the worse ranked drivers. This transforms the reviews into the main factor for job acquisition, and thus income, for the drivers. This type of job market is known as the *gig economy* [17]. It provides income potential for the workers while creating an interdependency between the platform customer and the gig worker. This relation seems to remain unclear for the platform customer and is often debated by the platform owners [18][19]. Consequently, the Organisation for economic Co-operation and Development (OECD) stated that digital platforms need social values to be reflected in the platform governance [19].

## V. INTEGRATING THE ETHICAL ISSUES INTO THE SYSTEM DESIGN

Based on the ethical analysis of the previous section, Table 1 provides a synthesis of the identified ethical issues. Also, an example how the identified issue can be integrated into the IT system is provided.

The recommendations are structured along the following levels: business level, User Interface (UI) and system level. While business level addresses the definition of the business model and business goals, the system level considers the systems design, including the design of the algorithms. The UI aspects can be used to balance the business goal, i.e., eater's re-ordering behaviour, and the eater's interaction expectations with the digital platform. This paradigmatic nature allows an insight into the application of the ethical analysis during the MLS design. A more detailed analysis would be needed to provide specific insights into the algorithm level.

TABLE I. ETHICAL ISSUES OF THE FOODAPP AND SUGGESTIONS FOR THEIR IMPLEMENTATION

| Ethical issues | Suggestion for implementation |
|---|---|
| No explanation on the data storage | *System/UI*: Include clear and transparent information for the user about the data storage, in e.g., in individual contracts or in general terms and conditions.<br>*System*: Develop a concept for deletion routines if the purpose of the data processing is no longer applicable. Accordant selection of the storage location. |
| No explanation on the purpose of data collection | *UI*: Provide information, e.g., via mouse hover, about the purpose of the data collected in the field, as concrete as possible<br>*System*: To collect data that are not essential for the provision of the service, provide opt-in options by asking the user directly, e.g., "Would you like to help us to improve our service by providing your automated location data?" |
| Lack of an opt-out for specific data type collection | *System/UI*: Privacy friendly default settings, e.g., opt-in function for every data item collected instead of the implementation of the "required" fields. |
| Lack of the possibility to manually adjust the collected data | *System*: Possibility to add or correct data manually, e.g., to type the address for delivery.<br>Establish a reporting system for customers if they wish to have data corrected. |
| The fact that stakeholders have access to the collected data by FoodApp | *Business*: No data exchange between other stakeholders without agreements; user can be asked if s/he wants specific data to be shared for a specific purpose with the specific partner (a reimbursement could be offered)<br><br>Implement an accordant opt-in or rewarding mechanisms for the user in the settings. |
| Data life cycle is unclear for the user | *System*: Describe the data life-cycle to the user, e.g., on the FAQ page.<br><br>Integrate an automated deletion routines after the needed data are collected; inform the user about the routine in the FAQs, provide opt-ins for further data collection if needed; implement a reward system for additional data collection. |
| Data state: Is the data anonymized before the analysis? | *System*: Make clear in FAQ that data is processed anonymously. If this is fulfilled, the GDPR does not apply for the processing.<br>Implement anonymization process via e.g., distributed data bases. If anonymization is not possible, secure data by pseudonymisation and encryption. |
| Lack of feedback from stakeholders. | *System/business*: Provide a transparent feedback system from and to every actor in the ecosystem; provide an explanation of the ratings and their effects for the actors on the FAQ. Eliminate one-sided rating mechanisms. |
| Lack of tracing of (e.g., societal) changes induced by the app. | Business: Schedule surveys regularly with eaters, restaurants and delivery partners to assess the changes induced in those ecosystems; perform simulations to define potential changes to the traffic in the delivery area; establish contact to the traffic agency; include actionable changes suggestions, e.g., provide contact to a sustainable packaging producer for the restaurant partners; make these actions transparent on the FAQ. |
| Optimizing the algorithm for user re-ordering | System/Business: Include other stakeholders such as restaurants, delivery partners and the environmental effects with similar weights into the recommendation algorithm; evaluate the systems on a regular basis.<br>UI: Provide different recommendations foci for the user, e.g., focus on preferences, focus on restaurant convenience, etc. |
| Lack of a test phase about the effects of app usage on the society | *Business*: Include a laboratory phase, where the app is tested by the users and stakeholders with evaluation of the UI, UX, legal and ethical aspects plus relevant simulations on the ecosystem e.g., food and restaurant landscapes before release. |
| Definition of the parameters for food selection by the engineers | Business/system: Include a customer survey on which categories they would like to have; change categories or filters for sorting and extend these cate-gories regularly. |
| Live roll-out of changes to the MLS, i.e., online experimentation | Business: Perform changes roll-out during the laboratory phase and simu-lation; when approved, roll-out for the whole community. |
| Usage of power resources to train the (modifications to) ML- model recommendations are based on a selection of pre-set parameters | *Business*: Change and train the model as rarely as possible, e.g., once a year.<br>UI: Provide information why the recommendation was generated and what impact the change of the parameters (e.g., delivery time) would have on the results;<br>Provide possibilities to have parameters adjusted or included into the list. |
| Lack of understanding of the rating mechanism | UI: Provide an explanation of the rating mechanism containing a relative comparison to other ratings, as well as potential consequences (e.g., in a dialog: "Your rating will decrease the number of suggested orders to this delivery partner by 0.2% per cent"). |
| Tendency of the user to accept the MLS suggestions | *UI*: Include a "surprise me" function, where a product is suggested to the eater that does not adhere to his/her top preferences; add a reminder function: "you have already ordered this meal *n* times this month. Would you like to try Y (second choice) today instead?".<br>System: Perform an assessment on how ML might impact user behaviour and present the results on the website. |
| Effects on the eco-system of the app are not clear for the user | *Business*: Make the results of the conducted surveys and traffic analysis accessible to the users on the website.<br>*System*: Carry out an impact assessment on the rights of users and also on those of the stakeholders. |

| | |
|---|---|
| Individual food delivery | *System*: Include environmental concerns into the algorithm evaluation;<br>*Business*: Provide rewards for environmentally friendly behaviour of the partners (using e-vehicles, e.g., or using environmentally friendly packaging). |
| Recommendations presentation to optimize the business goal | *UI*: Change the UI to be more intuitive for the user with the goal of finding favourite food selection. |

The suggestions provided in Table 1 are centred around mainly two aspects: providing information about every data element collected by the FoodApp, i.e., the facet of transparency, and establishing a reward system for the user in return to providing data to the company, i.e., a reward. The implementation of a reward system would implicitly make the data life-cycle more transparent for the user, as well as provide the user with more autonomy within the engagement with the service. It would also help the user to understand that the data is a resource that is traded and thus has a value.

Identified issues that go beyond the business processes might be subject to the interpretation of the regulation or the business ethics. Furthermore, due to the context of the example, some identified ethical aspects are due to the example being positioned in the platform economy and therefore are not specific for every MLS. Nevertheless, bigger negative effects such as the effects on the environment or the society are part of the social awareness and responsibility that are not (and maybe should not be) regulated, but can be supported by socially acceptable IT artefacts.

The term of socially acceptable IT has been introduced to describe a system that considers and integrates ethical requirements into its design. The added effort but also the value of the implementation of the suggestions of the ethical considerations in Table 1 could lead to socially acceptable IT products and thus a realization of a socio-technical IT systems. To ensure the remaining and homogeneous quality adherence, inter-company assessment mechanisms, i.e., ethical quality audits, could be put in place.

## VI. Conclusion

Here, a scenario of a fictional food ordering platform that uses an MLS for item recommendations was used to perform an ethical analysis of an MLS. This scenario was chosen as a realisation of a socio-technical system that incorporates the system designers, users and stakeholders affected by the system design and process implementation.

The results showed that users of digital services need to be integrated into the design of a socio-technical system as they may have expectations that rely on the ethical awareness of the company and thus need to be implemented into the workflow. The examples of how to address these issues demonstrated that changes in the UI, system design but also in the business model can be realistically made to accommodate these challenges. Hence, designing socially acceptable socio-technical IT systems can be a chance to find a niche on the growing and competitive market of consumer-oriented digital services.

Although the provided approach needs validation and verification in a rea-life environment, it can already be used by the designers and architects of information systems, business developers considering a data-based business model, as well as ISR scientists as it shows how ethical aspect can be incorporated into the context of IT design. Future work will aim at establishing the criteria for the definition of the quality requirements for the social acceptable IT, evaluation of the suggested measures, as well as developing methods for the assessment of the effort of their implementation.

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# Considering Business Process Complexity Through the Lens of Textual Data

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***Abstract*— Organizations are challenged by a growing Business Process complexity as a result of new technologies and continuously generated data flows of various types and volumes. These are likely to result in the organizational performance decrease and loss of control. While textual data is reasonably considered one of the most typical data types in organizations, the mainstream of Business Process complexity research is driven by software complexity approaches, whereby textual data remains discarded. In our work, we explore the potential of textual data generated by the process participants from a linguistic perspective and suggest a textual data-based process complexity concept. We illustrate our proposition with the real-world IT ticket processing scenario and identify IT ticket complexity based on the IT ticket description texts provided by the customers. Our findings evidence sufficient prediction quality and positive influence of linguistic features on the prediction quality.**

***Keywords-Business Process Management; Process Complexity; Natural Language; Text Understanding; Linguistics.***

## I. INTRODUCTION

The overused concept of process complexity and strategies to solve this complexity gain new interest due to the rapid penetration of new technologies into Business Process Management (BPM) and resulting dynamics. The focus of BPM as a discipline has traditionally been on the modeling of organizational processes. Hence, the research on complexity is also mainly driven by this perspective [1]. The major complexity approaches in BPM, i.e., complexities of process models, event logs, work- and control flows, have been derived from the software complexity based on the graph-theoretic measures suggested by McCabe in the 1970s [2]. The observation demonstrates a strong focus on the technical artifacts prevalent in the BPM community. In these approaches, the social component expressed through *the textual data massively generated by the business process (BP) participants in the process execution* remains dismissed.

With the maturity of Natural Language Processing (NLP), the attention of BPM research and practice shifts towards textual data. Despite that, the efforts dedicated to analyzing textual data have been mainly directed to support modeling activities [3].

Recently, the studies considering both perspectives of natural language generated by process workers and process logs generated by information systems have started to appear, paving the way to further research. Hence, Fan and Ilk [4] suggest a text analytics framework for automated communication pattern analysis using conversation logs and natural language. In [5], the authors propose enriching Information Technology (IT) ticket resolution logs with the topical phrases extracted from comments to capture the underlying process interactions.

On a positive note of such research directions and in line with “humanistic” enrichments of BPM in general and process mining in particular [6], we suggest inquiring into the potential of natural language generated in the processes and showcase our work from the unconventional viewpoint on process complexity based on natural language.

The remainder of this extended abstract is organized as follows. Section II reflects the approaches used in our work as well as research methodology. Section III provides an illustrative application case. Finally, Section IV discusses the results and gives a short outlook.

## II. OVERVIEW OF APPROACHES

In the present work, we propose to use textual data generated by BP participants as a valuable source of information allowing to identify the complexity of the process. Linguistics is the discipline concerned with the study of human language, its structure, usage, and history [7]. Traditionally, linguists define textual complexity in terms of the text readability, understandability, or comprehensiveness which is prevailingly based on the average sentence length and the proportion of complex words [8]. Whereas we partially make use of this traditional linguistic understanding, i.e., text understandability for the reader, we aim to extend and adapt it to the BPM context.

In doing so, we consider the three levels of text understanding typically differentiated by the linguists [9] which can potentially indicate the BP complexity: (i) *objective knowledge* (the who, what, where questions), (ii) *subjective knowledge* (opinion, sentiment), and (iii) *meta-knowledge* (what can be learned about the text other than its contents, mainly about its author).

Our research methodology is based on a *three-fold triangulation*. *First*, we follow literature review process to determine and structure our approach as well as define the NLP techniques to be used in the study. *Second*, expert knowledge of both researchers and practitioners is used to adapt these techniques to the BPM and application case context. *Third*, we perform experiments applying our approach to a real-world process to demonstrate its practical value and evaluate the results.

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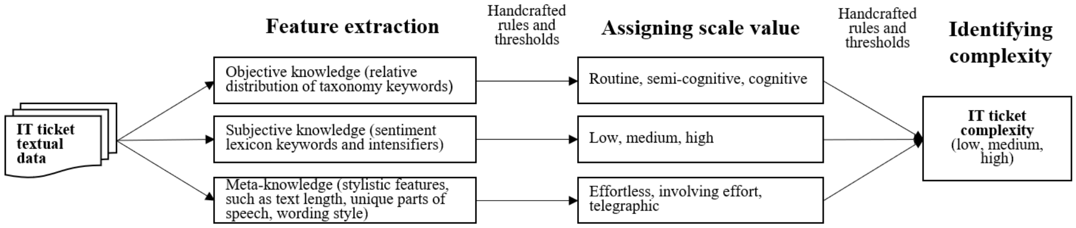


Figure 1. Experimentations

Hence, according to the three above mentioned knowledge types, we use common NLP techniques and adapt them to the BPM context. Thus, we propose domain-specific taxonomy and taxonomy keyword-based pattern matching algorithm to extract *objective knowledge* and estimate *cognitive (mental) efforts* including professional contextual experience of the BP worker necessary to understand the task / process at hand and successfully execute the task / process [10]. The taxonomy contains four basic elements of a BP text: (1) *Resources* (nouns indicating the specificity of BP elements), (2) *Techniques* (verbs of knowledge and information transformation activity affecting *Resources*), (3) *Capacities* (adjectives describing situation specificity of *Techniques*), and (4) *Choices* (adverbs determining the selection of the required set of *Techniques*). These four elements extracted from the BP text are then organized according to the three following levels: (i) routine, i.e., daily, activities, (ii) semi-cognitive, i.e., including some non-routine BP elements, activities, and (iii) cognitive activities demanding much mental effort and involving complex problem-solving [10]. These levels of routine, semi-cognitive, and cognitive also serve as a scale to formalize the objective knowledge extraction and measure the cognitive efforts.

To extract *subjective knowledge* and assess *attention efforts* needed to be paid to particular BP elements and BP as a whole, we develop a domain-specific business sentiment lexicon and lexicon keyword-based pattern matching algorithm extended by semantic and syntactic rules and formalize it on the ordinal scale of low, medium, high [11]. Business sentiment [11] is suggested as an instrument to measure those business-related emotions implied by the BP text author and indicating urgency or importance of the task / process at hand.

To obtain information regarding *meta-knowledge* and *reading efforts* (readability) needed to comprehend the text, we use stylistic patterns [12] expressed with a number of stylistic features, such as text length, unique parts of speech, and wording style [12]. We measure the readability on the ordinal scale of effortless, involving effort, and telegraphic, the latter indicating the texts written in the shortest possible way, as a rule, by professionals to professionals already knowing the specific professional jargon. Meta-knowledge is a naturally distinct type of knowledge. As defined above, objective and subjective knowledge is about extracting information contained in the text. Meta-knowledge indicates the latent information about text quality, i.e., information about the text author [9]. The text quality will likely be determined by the author's professionalism, competence, and stress level. Obviously, a well-written explanation of task / process facilitates timely and successful execution. On the contrary, poorly written explanation will complicate the work.

In the end, as shown on Fig. 1, it is suggested to aggregate the three extracted and formalized on the mentioned scales knowledge types to a BP complexity measured on the scale low, medium, high.

## III. ILLUSTRATIVE APPLICATION CASE

To evaluate the suggested concepts, we use an IT ticket processing scenario of an IT Information Library (ITIL) [13] Change Management (CHM) department of a telecommunication company. As BP textual descriptions, we use customer requests for changes in IT infrastructure products or services of the company reaching CHM workers in a free text form, as a rule, per e-mail. For the evaluation purposes, we obtained two data sets with the textual customer requests comprising 28,157 and 4,625 entries correspondingly. Preprocessing and extraction of the knowledge types were conducted using Python 3.4. To obtain application case specific scale values for each of the knowledge types as well as IT ticket complexity (see Fig. 1), the handcrafted rules and thresholds were developed based on the qualitative (using the values manually assigned by the CHM workers) and quantitative (using historical ticket data in case of BP complexity identification) evaluation process implemented in the Microsoft Office Excel 2016 application. This rule-based approach evidenced the BP complexity prediction precision of approximately 65%.

## IV. DISCUSSION AND CONCLUSION

In this study, to showcase those meaningful insights inherent in the BP textual data, we proposed that the three types of knowledge, i.e., linguistic levels of text understanding, can potentially indicate textual data-based BP complexity. We tested this proposition using the real-world ITIL IT ticket processing scenario and developed the rule-based approach demonstrating 65% precision [14]. In our further work, we experimented with the semi-supervised machine learning using the suggested linguistic features as IT ticket text representation and available 90 labels with the assigned IT ticket complexity to train the classifiers and predict the complexity [15]. Based on the comparative analysis of various classifiers and text representation approaches, i.e., TF-IDF in our case, we managed to confirm the positive influence of our linguistic features on the prediction quality. In future work, we aim to compare the textual data-based and process mining-based process view, specifically in terms of complexity identification, and derive and analyse discrepancies and commonalities between these two views.

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# Towards Comprehensive Safety Assurance in Cloud-based Systems

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***Abstract*—When a system malfunctions or a required service is not provisioned in a timely manner, this can lead to human injuries or fatalities. Increasingly, safety-critical system operation relies on offloading of functions into the cloud, including real time ones. For this reason, the cloud-based systems that are involved must exhibit a high degree of dependability. Thus, to determine a system's dependability, a comprehensive safety assurance process is needed to allow integration in a development process allowing iterative improvement to tackle complexity and changing requirements. Based on the principles of adaptivity and flexibility we propose a 3-leveled safety analysis process for building up a necessary resilience against disruptions and failures of various scale, nature and operation context dynamism. A multilevel genuine combination of traditional and contemporary safety methods is a key to provide necessary system resilience in a cloud. The right composition, expected yield and applicability of methods that will be best suited for cloud context is a subject of our research.**

***Index Terms*—Safety; Resilience; Dependability; Cloud-based; CPS; RTS; IoT.**

## I. Introduction

An ongoing evolution towards an increasingly integrated world comes along with modern Cyber-Physical Systems (CPS) applications paving the way of an ubiquitous automation in the current digital transformation. Contemporary cloud-systems already serve a myriad of services of different purposes in smart cities, agricultural domains, vehicular systems, industrial automation, health-care, robotics, etc [1]. Such applications have certain dependability requirements that need to be fulfilled. Cloud-offloaded functions are scattered across different entities and exhibit dynamic and composite context of operation. They are subject to continuous internal (e.g., algorithmic faults) and external disruption (e.g., connectivity changes) [2]. The developed system must be able to absorb these adverse alterations whilst satisfying its design goals and timeliness requirements for critical Real-Time System (RTS) applications. However, dynamics of operation, complexity and often limited resources [3] pose particular challenge to system's reliability, hence requiring an elaborated resilience assurance strategy [4].

Dependability is the capability to avoid failures that are more frequent and more severe than what is deemed acceptable and ability of a system to supply trusted and available services. There are many dimensions that should be considered when analyzing whether a cloud-based solution is dependable, such as availability, reliability, performability, maintainability. At the same time, there are different ways to implement a dependable system, for instance using fault tolerance algorithms and redundancy techniques [5]. Some of the proposed dependability measures could turn out to be inefficient in a dynamic cloud-based environment, some might provide insufficient coverage or even conflict with other measures diminishing the deemed safety gain [6]. In the end, the system must be performant, whilst providing sufficient level of safety that does not overly burden resource-constrained nodes. Satisfying these requirements in a dependable manner remains largely underexplored. A comprehensive safety assurance process is missing. Although there are some processes proposed for cloud computing and fault tolerance in networks, they do not tackle the problem systematically [7].

In this paper, we propose a 3-leveled comprehensive safety assurance process for resilient and efficient system architectures development that embraces the aspects of design-time as well as run-time assurance aiming to provide high safety coverage of a system. We explain what each level of the process is focused on, its main purpose, methods are meant to be utilized to provide an insight on how it can be applied. The rest of the paper is structured as follows. Section 2 outlines the related work in this area. Section 3 presents the discussion on a proposed comprehensive safety assurance process hierarchy, main steps and validation approach. Section 4 concludes the paper and gives a future outlook.

## II. Related Work

This section draws attention to related work of other authors that emphasize the lack of a structured approaches for safety assurance in emerging cloud-based systems suggesting the arising problems, possible ideas on approaching them and shed the light on relevant scientific tracks to study.

The need for a new safety assurance approach is largely dictated by evolution of Internet of Things (IoT) systems. Christos Tsigkanos et al. discuss a road-map [4] for a resilient IoT defining a structure of 4 maturity levels with various degrees of dependability requirements assurance. They discuss such challenges as resilience in a decentralized adaptive edge-centric system, nodes heterogeneity, components coordination for failure robustness, run-time assurance. Instead of traditional self-contained safety mechanisms, they assert that resilience must be built into every core IoT component and thereby unveil the track for future research in this direction.

One step further, they postulate a crucial requirement for any type of an emergent solution - formally analyzable and verifiable models to enable reasoning, starting from the early stages of design to models at run-time. Obtaining assurances on reliable requirements satisfaction in an environment that may adversely change at the system's run-time operation is seen as one of the major obstacles.

The importance of a safety process for complex cloud-based systems is emphasized by a new paradigm in edge-centric cloud-based services - Fog computing. Zeinab Bakhshi et al. present a roadmap [6] for dependability research in this area by bringing inherent system heterogeneity into perspective as a new challenge. Writing about the gap in fulfilling dependability requirements, they claim current approaches differ significantly from each other in terms of the types of faults and errors they address and the method applied leaving the resilience assurance an open question. They admit that relying only on traditional methods and approaches used before to assure safety might be highly inexpedient or even infeasible. They list several important trade-offs that become of paramount importance for novel applications in cloud-based systems, such as resource utilization and fault tolerance or reliability and timeliness. This leads to conclusion that novel cloud-based application will require a range of safety-to-performance Key Performance Indicators (KPIs) as a part of the development process for finding the right balance in each specific case.

Striking the right balance in presence of many challenges in dynamic contexts of cloud-based systems is further discussed by Jose Moura et al. [2]. They stress the importance to pay more attention to the scenario of multiple threats simultaneously affecting the normal operation of a fog system. Therefore, they urge studying diverse operational aspects not only at system run-time but initially at its design, including the protection of the physical infrastructure against weaknesses recently reported. Each resilience-enhancing measure should be validated on whether it inflicts negative effects on the system operation before adopting it stressing the importance of the simulation-oriented practices.

Worth to mention a formalized and easy to grasp definition of a bimodal resilience philosophy for cloud-based CPS aptly described by Somali Chaterji et al. [8]. They outline a roadmap for resilient CPS defining two distentions of thinking about it: *resilience-by-design* and *resilience-by-reaction*. The former encompasses various design and development techniques, the latter refers to techniques that are invoked at run-time only. Resilience-by-design makes the system robust against what can be predicted from existing knowledge, it remains blind to future events though. Resilience-by-reaction in contrast allows recovering after the occurrence of any disruption without over-fitting during the system's design engineering. They propose to use those in a genuine balance as a part of one process and in accordance to the specific operating conditions and application requirements to achieve maximum resilience minimizing residual risk to permissible minimum.

The main focal point of our work is to identify the ways to leverage existing former and modern techniques to propose a process with a cohesive methodology to be able to find such a mixture and build the system that can maintain resilience in the face of disruption, especially in the absence of a central control.

## III. Safety Assurance Process

Bringing locally-driven distributed system functionalities into the cloud leverages a great advantage of centralized processing and orchestration. This process fosters self-organization of the original system yielding greater efficiency and flexibility of operation. This, however, increases focus on operational aspects of a such system. Cloud-based system has distinctive characteristics, such as heterogeneous software stacks, often consists of resource-constrained units shared dynamically among other users, laggy or intermittent connectivity between the nodes, its functional devices are often spatially distributed in a composite environment that alters with a diverse rate of change, etc [6]. Enforcing dependability of such system operating in stringent RTS time constrains under emergent cloud environment largely remains the challenge for today's systems. Unlike traditional systems where failures are caused by faults in a specific component of a deterministic system, in cloud-based systems, inherent complexity and unpredictability of the ever-changing environment, aggravated by timeliness requirements, is the main reason of non-sufficient safety measures provisioning [9]. A reference process is therefore important to manage the growing complexity of development activities for cloud-based systems. First of all, such a process must define a clear sequence of procedural phases, their purpose, boundaries and possibly constituent technical methods to enable its implementation. Altogether, the composed process must begin already in the early development stage [4] for safety requirements derivation to influence functional system design choices which have great impact on the overall safety outcome, i.e., the ability of the system to be safe per se. The underlining structure for such process is presented on Figure 1 and can be seen as pyramid-like process targeting different scale of the dependability problems starting from the most fundamental at the bottom

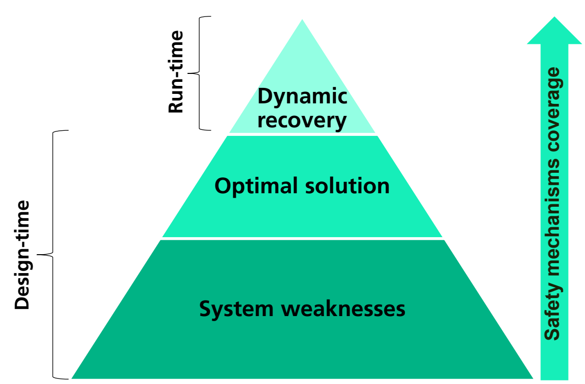


Fig. 1. Underlying structure for the dependable system architecture development (simplified form)

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and ending with more sophisticated and research intense at the top. The lower two levels are proactive and confined within design-time domain methods, whereas the third is reactive and consists of run-time domain methods.

### *A. Composite Approach in Risk Reduction*

*1) "Level 1 - System weaknesses":* It is possible that initial architecture is functionally deficient and contains missing or wrong elements and interfaces. A big aggregation of hazards of a similar root is called *weakness* and this must be addressed before any other minor hazard. This level aims at intercepting large-scale problems of a systematic design nature ensuring full functional sufficiency, i.e., provides the requirements to create a robust system architectural backbone. This level assumes usage of qualitative techniques, such as HAZOP [10] with custom Guide-phrases, STAMP/STPA [11], FMEA [12] and others to provide systematic constellation of failure modes and their consequences onto preliminary architecture draft. The further steps assume proper risk assessment steps (e.g., Hazard Analysis and Risk Assessment(HARA)) to rank the hazards and split them into safety and performance problems.

*2) "Level 2 - Optimal solution":* In many cloud-based systems, there are many alternatives of defining system operation using various physical and virtual realizations. In order to find the best possible solution, many functional allocations, resource utilization schemes and connectivity scenarios must be evaluated. Through iterative comparison of various compositions, the most optimal (as defined by system goals) utilization pattern is found providing necessary safety, performance and scalability requirements compliance. This level assumes usage of quantitative techniques based on simulation testbeds or Model-Based Dependability Analysis (MBDA) tooling [13] (eg. OSATE [14]) with numeric data for building composite error models.

*3) "Level 3 - Dynamic recovery":* Not all problems can be effectively resolved using only proactive methods. This is particularly true for cloud-based systems, where overloading its constrained edge nodes excessively with redundancy techniques will consume plenty of resources diminishing the performance gain making the whole system highly inexpedient in use or even subject to malicious intrusions due to added vulnerabilities. This level is aiming at developing an adaptive detection and recovery counter-reaction at run-time against foreseeable and unforeseeable degradation based on monitored attributes across the system [9]. Operation environment and system contextual factors are thoroughly investigated to identify what attributes must be monitored and how to react thereon. This level assumes usage of simulation testbeds and actual cloud-based systems to collect data for that purpose.

### *B. Detailed Process Outlook*

A detailed stepwise procedure of the aforementioned process application is described on Figure 2. A list of performance and safety goals serves as the initial input for the process (step 0) that shapes the entire design. In line with given confidentiality policy, the goals define the tasks and qualities of the system as well as potential hazards and risks. They are used to derive the system requirements (step 1), starting from the top-level tasks that define the overall system architecture and main sub-components. Systematic analysis identifies (step 2) failure modes and system weaknesses in order to refine the requirements (step 3). This is done by suggesting proper countermeasures that are carried out until the level of weaknesses is satisfactorily low. This process, called weakness-driven requirements refinement, helps identify flaws, such as safety hazards, failures, security threats or breach of performance thresholds. Countermeasures are then integrated at the subsystem level. The system requirements limit the options of the configuration space model (step 4), a set of tools to (semi-)formally describe, analyze, and collect information about the system. An integral, yet distinct part of this approach is a safety model, which can be used to carry out safety-oriented analysis and set limits to performance-related optimizations. The models can be instantiated (step 5) and narrowed down in order to further analyze selected weaknesses, among other things. Exploration of the configuration space (step 6) provides a set of solutions. These are essentially system configurations that meet the requirements, from which optimal system configurations are identified and evaluated. Requirements compliance is only one aspect of the success. Detailed analyses and simulations must be used to validate the solutions (step 7) and demonstrate that they fulfill the initial goals of the system and ensure dependability. Validation also allows fault forecasts to be provided and helps to identify critical scenarios. If validation identifies new weaknesses, suitable countermeasures are applied. The system requirements can then be refined for the next iteration. An essential result of the design process is monitoring and recovery concepts, which can be integrated into the operating system. By monitoring properties defined by the requirements (step 8), the state of the system can be determined. If necessary, recovery plans defined by optimal solutions (step 9) for the identified contexts can then be triggered. More advanced concepts and prototypes, including necessary monitors and recovery mechanisms, can help in constituting the system's self-awareness - its ability to determine its own state and its environment - to detect faults and identify possible actions.

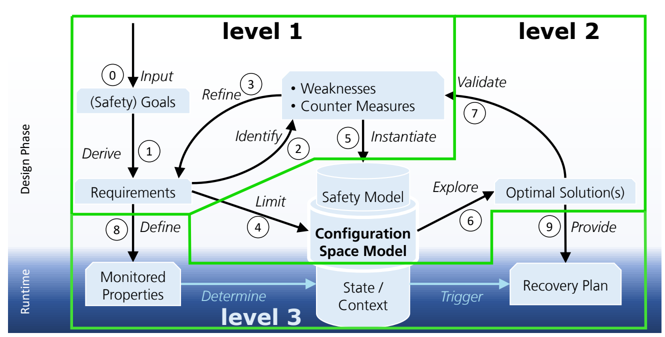


Fig. 2. Underlying structure for the iterative design and evaluation process of the dependable system architecture (detailed form)

### C. Validation Approach

To examine adaptive countermeasures alongside other proactive safety mechanisms being built-in earlier, the system operation is adjusted from one extreme to another with a concurrent fault injection. Thereby, one can verify the effectiveness of devised interoperating countermeasures for a given safety-critical scenario to further evolve the safety backbone. Since each application or use-case can have different safety and performance requirements, a *safety-to-performance ratio* must be provided as an insight to track the impact upon environmental and system alteration to strike the desired magnitude in the operation envelope. The particular definition(s) of the *safety-to-performance ratio* is specified individually depending on the use-case and KPI of interest and it mostly depends on finding the right balance between design-time and run-time methods. Additionally, the system countermeasures must be tested progressively with each new process level executed (bottom-up manner) to track the yield of each level as compared to their holistic combination. Relative and absolute scales of high-level safety and performance KPIs (e.g., for automotive domain: collisions, safety distance violations, average velocity, maneuvers executed, etc.) must be used to track the progress gain. For a system to be testable, the minimal thresholds of given KPIs must be defined for selecting required system analysis iterations as well as to ensure their minimal necessary fulfillment at the end of the process. Hence, not only optimal safety-to-performance compromise is found but also significance and applicability of selected safety methods is explored for each individual use-case. Ultimately, this will foster a development of optimal process implementation finding out what methods, in what proportion, to what extent yield the best results in each given case in a cloud environment.

## IV. Conclusion and Future Work

In order to achieve resilience in a cloud-based system, understanding and systematically managing dynamic behavior and distributed operations is the key. Hence, all elements of the architecture design process must be accompanied by appropriate safety activities aforehand. Each system design should involve applying an iterative approach to refine the safety goals in coordination with new design decisions. At each level of refinement, assumptions made in the design are explicitly stated and analyzed, so that they may also be later validated. The ultimate system to be safe must incorporate not only robustness aspects covering foreseeable events, but also resilience to cope with unforeseeable evens as well. In this paper, we analyzed the importance of the having a comprehensive process that could address the safety problems of a different scale in a systematic manner. We presented our vision of the 3-leveled process by defining and discussing the aim of each level and the possible methods that could be utilized therefor. We advocate the need of leveraging traditional methods with sophisticated simulation practices within one process in a right proportion and selection to provide the maximal safety coverage to deal with the problems of different scale throughout the entire system development. Thereby, resilience is built into system from a very early phase. We suggest to track a safety-to-performance ratio for optimal decision making when choosing the alternative countermeasures compositions balancing design and run-time mechanisms. Moreover, we underline the importance of adapting the process to particular use-case by exploring applicability and gain of each of its levels' methods. Only a genuine combination of different safety techniques alongside with a cyclic relevant properties monitoring can lead to sufficient safety coverage provisioning in complex and highly dynamic cloud-based systems. Development, testing and refinement of the reference process is an active ongoing activity. Future work will encompass discussions on the application of the proposed process with safety analysis strategies' efficiency evaluation for cloud-based applications.

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