Available online at www.sciencedirect.com
ScienceDirect
Procedia CIRP 28 (2015) 155 – 160
www.elsevier.com/locate/procedia

3rd CIRP Global Web Conference

Systematic development of mobile AR-applications, special focus on user participation

C. Weidig[a*], J. C. Aurich[a]

[a]Institute for Manufacturing Technology and Production Systems, University of Kaiserslautern, Kaiserslautern, Germany.
* Corresponding author. Tel.: +49-631-205-4067; fax: +49-631-205-3304 .E-mail address: weidig@cpk.uni-kl.de

Abstract

A comprehensive, systematic planning method to design mobile Augmented Reality (AR)-applications in the range of production planning is not available. A target driven development process to match mobile AR-applications to the methodical needs of production planners is therefore proposed in this paper.
The development process will be presented with special focus on the user integration. The incorporation of production planners, their intrinsic knowledge and engineering methods needs to be considered. Therefore, the paper will introduce how user relevant aspects will be identified and considered during the application development.

Selection and peer-review under responsibility of the International Scientific Committee of the “3rd CIRP Global Web Conference” in the person of the Conference Chair Dr. Alessandra Caggiano.

Keywords: Production planning; Augmented reality; Mobile applications; User centerd; Human aspect; Requirement analysis; Tablet-PC

1. Introduction

The complexity of manufacturing, technological and socio-technical systems is increasing continuously. Due to globalization and changing market demands the product diversity is rising. Hence, the key challenges for industry nowadays are characterized by complex designs of complex manufacturing systems to enable efficient and flexible production [1]. In addition, the trend towards globalization increases the demand for seamless collaboration and real-time information exchange methods for engineers [2]. To master these challenges context aware information visualization (as for instance realized by mobile AR-applications) is proposed as a beneficial approach to facilitate the communication among engineering problems and potential solutions between manufacturing engineers [3, 4].

2. Mobile applications for production planning

2.1. Software applications for production planning

For production planning purposes, industrial companies use software tools to support their workflow in order to achieve better planning quality and reduce planning time. [5]. But to be competitive in the future, innovative mobile and cooperative engineering methods are requested [6, 7]. The usage of mobile applications is proposed to provide real-time information for employees independent from their location. Especially for factory planners potential advantages are estimated due to accessing planning data while being at the shop floor [8]. One promising type of such mobile software tools are AR applications whose core functionality is to overlay digital and real content [9, 10].

2.2. Challenges in application development

The development of mobile AR-applications (further called mARa) to support production planning is a fast evolving research field [11]. mARas are offering innovative capabilities to support production planning by overlaying digital information and real world environments as well as providing intuitive interaction means [12]. Even if research among mARas for production planning is a growing area, one main challenge is still to identify suitable content in order to support engineering processes properly. Not every

Selection and peer-review under responsibility of the International Scientific Committee of the “3rd CIRP Global Web Conference” in the person of the Conference Chair Dr. Alessandra Caggiano.
doi:10.1016/j.procir.2015.04.026

production planning task is suitable to be supported by mARas [13]. But for most available smartphone and tablet PC applications, the development was strongly pushed from the technological side [14]. The usage of these new devices is well known from private, consumer electronic perspective and therefore requested for professional usage as well [15].

For a range of prototypes a mismatch between technological circumstances and real industrial demand can be recognized [16]. This is often the result of overhasty developments which are not solving the initial problems engineers have and therefore just provide known applications and functionality on new devices. A systematic development concept that focuses on a target driven mARa development is not available [14]. Only by addressing the users' needs from perceptual and cognitive point of view, the field of application is benefiting from AR capabilities in a comprehend way [17].

To meet these challenges, the paper introduces an approach to systematically develop mARas for production planning involving the potential users.

3. Development approach for mobile AR applications

The situation in production planning research among mobile applications can be compared to a deliberation following [18] "If all you have is a hammer, everything looks like a nail." If you already knew your tool to solve problems with, which can be a hammer for instance, is it than beneficial to transform all problems into nails? Or would it be better to analyze the problem and create a tool according to the specific requirements, using a screwdriver for instance? The situation in research production planning among mobile applications can be compared to this. Is it beneficial to adapt engineering problems in a way that they can be solved by mobile applications?

3.1. Underlying consideration

The intention of the development approach initially introduced in [14] and extended in this paper, is to structure the development of mARas in the scope of production planning in a target driven way. The target thereby is not to exploit a solution at the maximum technological feasibility, but to develop an application which fits the real demand coming from engineering methods. Therefore, gaps at the methodic level need to be identified and supported by specifically tailored mARas. In addition the genuine, new capabilities mobile devices offer need to be considered in a beneficial way. By the sole adaptation of desktop based software systems, the initial software functionalities are often only re-used considering the lower computing power of mobile devices. Such approaches often neglect the full range of mobile device interaction means and mobility capabilities and therefore do not exploit the full potential, such devices can provide for solving production planning problems.

Moreover the extension of everyday-tasks of production planners (e.g. layout planning) should be supported by comprehensive mARas. To structure the development process of mARas, an approach based on this intention is under development [14]. The core idea of this approach is visualized in Figure 1.

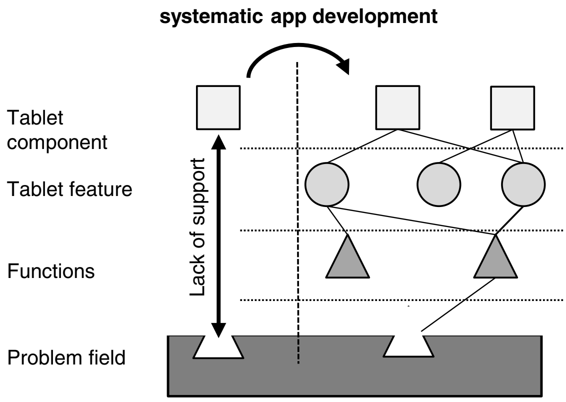

Fig. 1. Initial idea of the development approach [14]

Following [14] a direct mapping between hardware components of mobile devices (so called Tablet components) and the Problem field of the users (which is production planning for this approach) can hardly be achieved (Figure 1). To converge these two domains adaptations on both sides need to be made. Tablet components, as technical parts, need to be described with regards to the features they can provide. So can Tablet components be assembled and combined to realize Tablet features. For instance Tablet components like cameras, CPUs and position sensors can be connected to realize Tablet features like registration for mARas. In contrary the socio technical Problem field must be detailed out by specific Functions which are needed to support methodical needs. For instance can the demand of comparing planned factory layouts with existing local constraints, result in the required Function of overlaying real and digital data in mARas. At this level of requirement description a mapping between Tablet feature and Functions can be enabled by the developed approach [14].

3.2. Mobile application concept at a glance

Based on the core idea a systematic and structured development approach for mARas in the range of production planning is proposed. This Mobile application concept describes the development of mARas, beginning from user demand and technical constraints. The Mobile application concept is a systematic approach to identify all requirements from engineering methodical perspective and technical perspective (hardware, but also software aspects are considered) by a joint method. In addition to the requirement description also the process for execution of the approach is considered. Following the Mobile application concept will be introduced.

The Mobile application concept consists of three major parts (Figure 2). The central part is the App requirement analysis. Thereby the requirements of users on the mARas are analyzed and systematically identified. As result of the App requirement analysis a comprehensive requirement list is provided which serves as an input for software programming afterwards. The Mobile application concept involves several predefined checklists and supportive measures to facilitate the requirement analysis. Hence the App requirement analysis itself is subdivided into two main aspects to structure the analysis. Here an overview is given, whereas more details among the App requirement analysis are provided in section 3.3.

On the one hand the requirements are gathered from methodical point of view. This Methodical description is summarizing all demands coming from the production planning methodology. Based on investigations on the Problem field the Cognitive aspects of users working on the initial engineering problem are identified. This includes requirements coming from the problem purpose (e.g. required information, focused objectives) and the users working situation as well (e.g. number of stakeholders involved). The Cognitive aspects are direct results of the user needs, derived from methodical gaps and the working procedure the user is conducting (e.g. the factory planning process) [14].

On the other hand requirements coming from the technical point of view are considered as well. As second subdivision of the App requirement analysis, the Technical description is therefore dealing with the demand on software and hardware level, but also more generic interaction means [14].

As result of the App requirement analysis all requirements from different perspectives on the mARa are gathered. The requirements are stated in two complementary Part requirement lists, one containing the methodical requirements and one containing the technical requirements (Figure 3). They will serve as input for the software programming which is the following step in the development of mARa. But before forwarding the requirements to software programmers, one additional process steps needs to be elaborated. Out of the Part requirement lists the Functional software specification of the targeted mARa needs to be derived. Therefore, the Part requirement lists are merged to form a joint requirement list on which the Functional software specification can set up. Merging the Part requirement lists is done based on a predefined process. Some elements of the Part requirement lists are directly linked to corresponding counterparts on the opposite list. So, methodical needs on requested information are complementary to technical needs which are facing on access to databases, for instance.

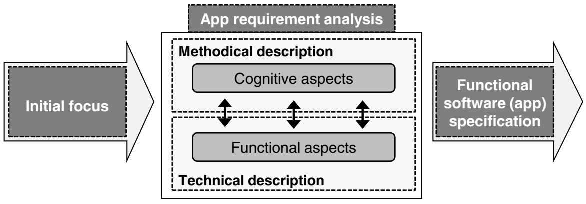

Fig. 2. Mobile application concept

For merging the requirements two major rules are important. First, the requirements are analyzed regarding consistent correlations. If Methodical and Technical description match each other they should be applied to the joint requirement list. Out of complementary requirements proper specifications for the final Functional software specification can be outlined. The second rule to follow is the analysis of contradictions within the Part requirement lists. It is important to identify which requirements exclude each other. Following solutions to subsequently avoid or solve such contradictions can be developed. Otherwise, if no arrangement can be found, a final prioritization is performed to define which requirement is the leading one. The transfer from the joint requirement list into the Functional software specification will be further facilitated using methods and processes from Software Requirement Specification (SRS). The Functional software specification is the final result of the Mobile application concept, on which the software deployment can set up.

As shown in Figure 2 there is a process step prior to the App requirement, the Initial focus. This step is required to identify general Problem fields in which the implementation of mARas may lead to beneficial solutions. The engineering methods and the challenges associated must not be outlined in detail before executing the App requirement analysis, but the Problem field must be determined in a way that mARas can contribute to a major extend. Hence the Initial focus tries to assure that a solution, based on mARas, can be potentially found for the considered Problem field and not end in an empty solution space.

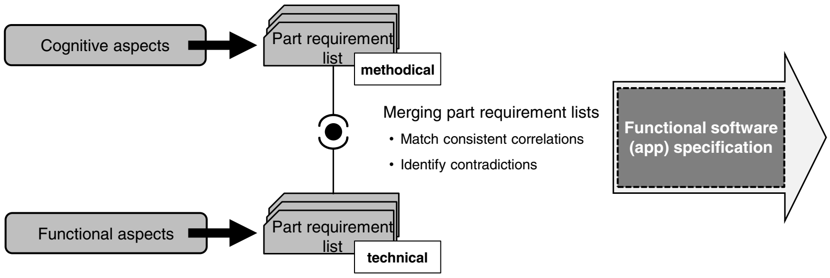

Fig. 3. Merging part requirement lists

The idea is to specify the general Problem field in a way that mARas can potentially close existing gaps and contribute to a solution by really new functionality. Therefore, four prerequisites need to be fulfilled by the specific Problem field. (1) 'Go-to-Gemba' (go to "the real place") claims that the objective cannot be d while sitting in the office. The problem must be directly connected to already existing locations or objects the user can physically visit and interact with (e.g. existing workshop areas, already existing product parts). Only if this prerequisite is fulfilled the usage of mobile devices makes sense at all. (2) 'Digital data partially available' is claiming that the engineering method requires the consideration of information that is available through digital data and physical object in parallel. One core functionality of mARas, which is overlaying of digital and real content is only beneficial to engineering methods, if digital and real content is existing and comprehending each other. For problems which are completely described by virtual models, a mARa is not providing any benefit, for instance. (3) 'Software gap' is claiming that there is no solution out of the Digital Factory available to solve the problem. The development of new mARas is only beneficial if no suitable software tool is already existing. (4) 'Communication / validation problem' is claiming that the initial production planning problem should deal with coordination and decision making challenges. The Mobile application concept is focusing on the user to a large extend. Therefore, the integration of the user and its interaction with others users is a main focus of the concept. Furthermore, several editor tools already available are necessary which are sophisticated for model creation (e.g. CAD-tools, factory planning tools). The Mobile application concept is not aiming to develop competitive solutions against these matured tools.

3.3. Structure of the App requirement analysis

To fully understand the Mobile application concept a deeper look at the App requirement analysis, as central part of the approach, is necessary. The gathering of requirements is supported by a systematical classification of potential requirement classes. Requirement classes contain several checklists and concise methods to guide the requirement analysis for specific focus areas. Therefore, each requirement class contains a set of characteristics of requirements which can be chosen for the mARa. This ensures that all major requirement sources are respected during the analysis. The Methodical and Technical description are assembled out of nine requirement classes (Figure 4) which are described below.

The requirement analysis for the Methodical description considers three requirement classes (1) 'Methodical needs', (2) Perceptual needs' and (3) User needs'. In each requirement class one key question is outlined and a systematical method is built beneath the key question to structure characteristics of requirements for each requirement class. The Methodical description at all is dealing with the Cognitive aspects which are related to engineering methods and the user's workflow. Each of the three requirement classes specify one aspect out of the Methodical description in detail. (1) The Methodical needs are dealing with the information users need to investigate and analyze the engineering problems. Here the core subject to be worked on (e.g. specific workshop area, specific product) as well as the related information (e.g. process plans, design information) are defined. (2) Next requirement class, the Perceptual needs address the way the required information is visualized to the user. For some information, like CAD-data, means for visual perception are well established. For other information, like process plans, visualization must be considered with special attention. In addition, information coming from digital sources and information coming from the real environment must be merged and suitable visualization concepts need to be developed. (3) As third requirement class the User needs complete the Methodical description. This requirement class deals with the interaction means users request to work properly with the information provided. Depending on the requested level of interaction (e.g. displaying digital content, interact with information, manipulate planning states) different requirement characteristics can be defined which are describing the users' intention on the digital content.

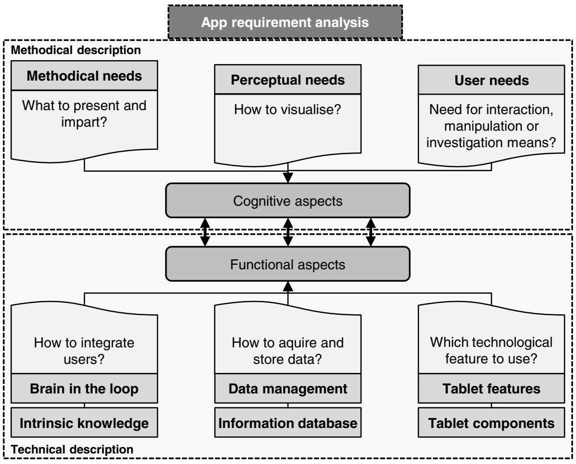

Fig. 4. Structure of the app requirement analysis (based on [14])

The Technical description is composed of six requirement classes. Here, always two requirement classes complement each other, so that three key questions are outlined, just as for the Methodical description. The six requirement classes are dealing with the Functional aspects of mARas. In our sense not only the hardware and software elements are considered, but also features which can be achieved by proper combination of technical elements. Under the scope of (4) Intrinsic knowledge and (5) Brain in the loop requirements are classified that deal with the inclusion of multiple users and their know-how into the decision making process. The central points that need to be analyzed are the requirements which need to be fulfilled to allow a cooperative problem analysis. Therefore, the user group will be analyzed on their temporally (e.g. synchronous or asynchronous) and spatially (e.g. collocated or dislocated) constellation. Established problem solving strategies and creativity techniques are providing technical constraints as well. As counterpart to the requested information on the Methodical description are the requirement classes (6) Information database and (7) Data management dealing with the technical access on information. Here the scope and content of information is not the major focus, but the access and provision of data. The requirements are typically coming from CAx-Systems and PLM/PDM-Systems which are containing major input data for mARas. Identification of the basic conditions to transfer existing data is the key task. The (8) Tablet components and (9) Tablet features in the end finalize the Technical description. Here the technological features from hardware and functionality perspective are considered. Based on the already gathered requirements, needed features are identified to realize the users' needs on interaction and visualization.

Each requirement class itself has an inner structure beneath in which the potential requirements are classified to facilitate the gathering of requirements for a specific use-case. The purpose of this paper is to give a complete overview on the Mobile application concept, hence a detailed introduction of each requirement class cannot be given, but will be provided in future publications.

3.4. Execution of the development approach

The App requirement analysis provides a comprehensive list of potential requirements for developing mARas. By filling out the requirement classes a complete set of specific requirements can be gathered for a certain use-case without neglecting essential aspects. But to achieve this objective the App requirement analysis needs to be overlaid by a systematic execution procedure which involves the end user and guides the gathering process.

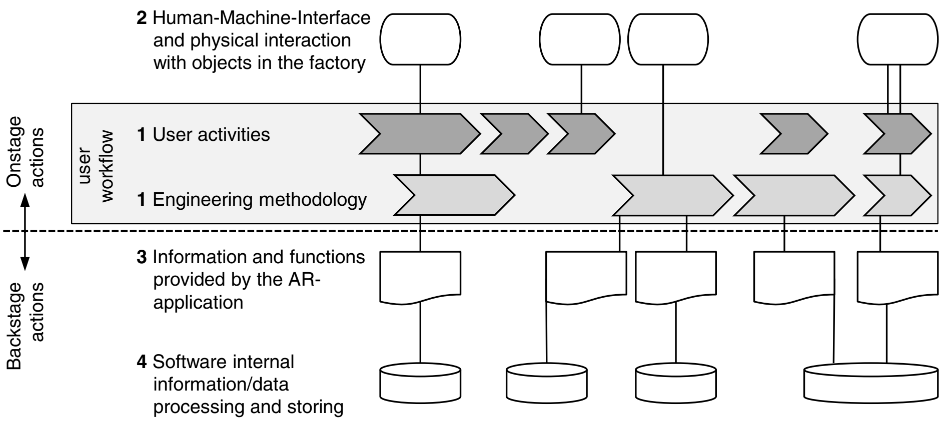

Fig. 5. Execution procedure of the app requirement analysis

The proposed execution procedure (Figure 5) falls back on the requirement classes and uses the proposed requirement description. But in contrary to the requirement classes, which are structured according to Cognitive and Functional aspects, is the execution procedure oriented towards the usage of the mARa. As shown in Figure 5 the execution procedure is blueprinting the whole engineering method, the user interaction with the mARa and the underlying software-internal information processing. By forecasting the typical engineering workflow the identification of all relevant functionality which is needed during the usage of the mARa is enabled.

4. Conclusion and Outlook

The Mobile application concept introduced in this paper allows a structured and systematic analysis of requirements for mARas in the range of production planning. Thereby the integration of the user into the development process is ensured by the specific gathering of users' needs and the user-involved blueprinting of the final workflow already during the requirement analysis. Out of this approach the target driven development of mAras can be initiated to close specific gaps at engineering methods by mobile functionality and new, interactive means.

To evaluate the approach, development initiatives for industrial use-cases need to be elaborated. The method shall be applied to extract specific requirements out of use-cases from the shop floor level, which will serve as input for software developers to tailor mARas according to factory worker's needs.

In preparation for implementation test, the requirement classes of the App requirement analysis will be further detailed out and concise methods will be defined to facilitate the gathering of requirements. In addition the execution procedure will be validated based on use-cases.

Acknowledgements

The research leading to these results has received funding from the European Community's 7th Framework Programme under grant agreement VISIONAIR n°262044. The VISIONAIR project (www.infra-visionair.eu) creates a European Infrastructure for Visualization and Interaction based Research

References

[1] ElMaraghy, W., ElMaraghy, H., Tomiyama, T., & Monostori, L. (2012). Complexity in engineering design and manufacturing. CIRP Annals - Manufacturing Technology, pp. 793-814. doi:10.1016/j.cirp.2012.05.001

[2] Chryssolouris, G., Papakostas, N., & Mavrikios, D. (2008). A Perspective on Manufacturing Strategy: Produce more with less. CIRP Journal on Manufacturing Science and Technology, 1, pp. 45-52.

[3] Spence, R. (2007). Information Visualization: Design for Interaction. Barcelone, Spain: ACM Press.

[4] S. Makris, G. Pintzos, L. Rentzos, G. Chryssolouris, Assembly support using AR technology based on automatic sequence generation, CIRP Annals – Manufacturing Technology, Volume 62, No. 1, pp. 9–12 (2013)

[5] Ebbesmayer, P., Gausemeier, J., Grafe, M., & Krumm, H. (2001). Designing Flexible Production Systems. Proceedings of the 2001 ASME Design Engineering Technical Conference and Computers and Informations. Pittsburgh, USA.

[6] Landherr, M., Neumann, M., Volkmann, J., Westkämper, E., & Bauernhansel, T. (2012). Individuelle Softwareunterstützung für jeden Ingenieur. Zeitschrift für wirtschaftlichen Fabrikbetrieb, 107(9), pp. 628-631.

[7] Fraunhofer Gesellschaft (eds.). (2011). Cloud4E Trusted Cloud for Engineering. Stuttgart, Kaiserslautern: Fraunhofer-Allianz Cloud Computing.

[8] Bracht, U., & Sontag, T. (2013). Smarte Fabrikplanung - Digital Factory goes mobile. wt Werkstattstechnik online, 103(4), pp. 356-362.

[9] Dong, S., Behzadan, A., Chen, F., & Kamat, V. (2013). Collaborative visualization of engineering process using tabletop augmented reality. Advances in Engineering Software, pp. 45-55.

[10] Sutherland, I. (1965). The Ultimate Display. Proceedings of the 3rd IFIP Congress, (pp. 506-508). New York, USA.

[11] Bracht, U. (2013). Die Digitale Fabrik - Vision und durchgängiger Einsatz. Konferenz für Durchgängige Anlagenplanung. Nürnberg, Germany.

[12] Azuma, R., Baillot, Y., Behringer, R., Feiner, S., Julier, S., & MacIntyre, B. (2001). Recent Advances in Augmented Reality. IEEE Computer Graphics and Applications, 21(6), pp. 34-47.

[13] Nee, A., Ong, S., Chryssolouris, G., & Mourtzis, D. (2012). Augmented reality applications in design and manufacturing. CIRP Annals - Manufacturing Technology, 61, pp. 657-679. doi:10.1016/j.cirp.2012.05.010

[14] Weidig, C., Menck, N., & Aurich, J. C. (2013). Systematic Development of Mobile AR-Applications Supporting Production Planning. In M. Zaeh (Ed.), Proceedings of the 5th. International Conference on Changeable, Agile, Reconfigurable and Virtual Production (CARV 2013) (pp. 219 - 224). Munich, Germany: Springer. doi:10.1007/978-3-319-02054-9_37

[15] Schuhmann, M., Klimant, P., Kollatsch, C., & Wittstock, V. (2013). Modulares framework zur entwicklung von Augmented-reality-Anwendungen. In R. Neugebauer (Ed.), Proceedings of the 2nd Conference on Research andd USe of VR/AR Technologies of the Professorhip for Machine Tools and Forming Technology at the Chemnitz University of Technology - VAR² 2013 - Extend Reality (pp. 115-124). Chemnitz, Germany: Wissenschaftliche Scripten.

[16] Pentenrieder, K., Bade, C., Doil, F., & Meier, P. (2007). Augmented reality-bassed factory planning - an application tailored to industrial needs. Proceedings of the 6th. International Symposium on Mixed and Augmented Reality (ISMAR 2007), (pp. 1-9). Nara, Japan.

[17] Livingston, M. (2005). Evaluating Human Factors in Augmented Reality Systems. IEEE Computer Graphics and Applications, 25(6), pp. 6-9.

[18] Maslow, A. H. (1966). The Psycology of Science. Maurice Bassett Publishing