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Benefits and Challenges of Participatory Design in Agriculture: The Example of the FieldMApp

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Using the example of the development and testing of the FieldMApp, a digital application for capturing and characterizing agricultural low-yielding areas within acreages during farmers' operational field management, the paper highlights the benefits and challenges of participatory design approaches to product development. The article is based on and extends our findings presented as a poster at the Austrian Citizen Science Conference in June 2022.

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1. Introduction

In the AgriSens – DEMMIN 4.0 project, an approach for mapping agricultural low-yield areas is currently developed. The FieldMApp, a mobile application (app), is intended to enable the documentation of the location, extent and causes of low-yield areas during the operational management of fields by farmers. Integrated with remote sensing data, the data collected by means of the app provide an important basis for decision-making, for example for the use of agrochemicals. The recording and characterization of low-yield areas is a prerequisite for a resource- and environmentally-friendly management of arable land as part of sustainable production processes. Right from the beginning, the development and testing of the FieldMApp is done in close cooperation and co-creatively by farmers and scientists.

Why is it promising to early on and actively involve potential users in the creation process of a software product? By doing so, the specific requirements and expectations of customers are incorporated into new products right from the beginning, meaning the value proposition of a product is put to test at an early stage. This avoids costly undesirable developments and increases the chances of success for new products. Co-creation also bundles knowledge, creativity and expertise of different stakeholders and thus accelerates the design and development phase of products [1]. Thus user-centered and co-creative approaches to the development of new products are therefore common practice [1, 2]. In terms of the FieldMApp, the close exchange and cooperation between farmers and scientists ensures that the FieldMApp will be a technology that meets the needs of farmers and is beneficial to them.

This article shows the different requirements and expectations of the project participants with regard to the functionality and practicability of the application. It also demonstrates how the different perspectives, ideas and requirements of the project participants affected the design of the FieldMApp. In particular, it addresses necessary trade-offs in terms of data quality and the effort required for data collection, and demonstrates the crucial role of knowledge transfer and exchange at eye level for the development of viable digital innovations.

2. Participatory development of the FieldMApp

The development of the FieldMApp followed three phases: (1) the analysis of requirements and relevant factors to consider when developing the app (section 2.1), (2) the development and implementation (section 2.2) as well as the evaluation of the mapping strategy (section 2.3).

2.1 Analysis of requirements and key influencing factors

Even before the development of the FieldMApp, it was necessary to understand **basic requirements and conditions** for data acquisition and the joint app development process. This concerns the requirements for the data to be collected and the conditions for data acquisition, as these represent significant influencing factors for data quality. Through a systematic analysis of these aspects, preliminary discussions with farmers, on-site inspections and supervision of farmers during cultivation, essential requirements and conditions could be derived. With regard to the joint development process, it was important to understand the target group "farmers", their expectations and their confines concerning the participation in the development process. It quickly became apparent that several target groups had to be considered in the development of the FieldMApp. In addition to the operator, the current user of the FieldMApp app, the company management had to be considered. While operators rather look at the effort of data acquisition, company managers focus on the resulting economic added value from the FieldMApp use. For both groups, their daily workload offers very limited scope for involvement in the development of the app. Key requirements in terms of the data acquisition were that using the FieldMApp should not interfere with the operator's main task of cultivating the field, and that the cultivation is carried out along regularly arranged tractor tracks.

In advance of the app's development, important **technical, ecological and human factors influencing data quality** had to be determined as well. The data collection strategy implemented in the app must take these factors into account in order to later ensure a high data quality. Major influencing factors that have been identified are: (1) the positional accuracy of the equipment, (2) the viewing angle of the driver, as it influences distance estimation, (3) the delayed perception and reaction speed of the driver at a typical operating speed of 8-15 km/h, (4) the complexity of the work task, (5) possible interference of the operator by his major work task, or the work environment, (6) the motivation of the driver, and finally (7) the frequency of occurrence of low-yield areas and their size. Our analysis showed, for example, that drivers generally listen to music over a loudspeaker in the cab while working, which is a poor prerequisite for a speech recognition solution.

2.2 Development and implementation of the mapping strategy

In the **development of the mapping strategy** for the recording of the low-yield areas by the farmers, a compromise was required between detailed mapping (data quality) and the effort of data entry by the farmer. Additionally, the concept of farming along lanes had to be integrated (see requirements in section 2.1). Three strategies were conceived: (1) recording the bounding boxes of low-yield areas (bounding box model), (2) recording a single point at a time, located in each low-yield area (point model), and (3) dividing the field into equidistant zones parallel to the tractor tracks and record start and end points of low-yield areas within the zones (zone model). The zone model represented the best compromise between effort and theoretical mapping accuracy. After consulting farmers, this mapping strategy was further adjusted. Although the original design provides a relatively accurate estimate of the location and size of the low-yield areas, from the farmer's side, the survey requires high concentration and effort. As a compromise proposal, the farmer indicates start and end of low-yield areas for several affected zones together instead of doing this individually per zone. Although this approach is at the expense of the level of detail of the recorded low-yield areas, it considerably reduces the effort required for data entry on the part of the farmer.

The **implementation of the mapping strategy** preferred by the farmers mainly comprised the development of a graphical user interface (GUI) of the FieldMApp for data acquisition, tailored to the needs of the farmer. The basic design idea behind the interface was to display the farmer's environment, i.e., field and tractor tracks and the position of the agricultural machine, one-to-one in the FieldMApp in order to enable easy transfer of the observed low-yield areas via the FieldMApp GUI. The GUI design was developed in an iterative, participatory process. Various design drafts for the GUI were created in the form of consecutive interactive mockups. These were tested by farmers and gradually improved with their own design suggestions. In particular, farmer feedback improved orientation in the field and reduced the number of steps required to record the low-yield areas. Estimating the distance relative to the tractor track proved to be particularly challenging during data recording. A solution for a consistent reference point (for all machinists) was found together with the farmers in their direct working environment. The segment boundaries of the spayers and applicators were used for the distance estimation relative to the track. These serve as landmarks for the zone boundaries shown in the FieldMApp. The position of the toolbar frame was chosen as the reference for recording the location data of the low-yield areas.

2.3 Evaluation of the mapping strategy

Testing of the implemented mapping strategy and its evaluation in terms of manageability and achieved data quality was initially carried out independently of the farmers by the project staff. This was carried out under idealized conditions (test drives in a car at constant, maximum operating speed of agricultural machines, predefined location and cause of the low-yield areas to be recorded, no parallel cultivation). This was necessary to reduce the time required for farmer participation (see requirements in section 2.1) and to first identify and correct any fundamental shortcomings of the FieldMApp. After successful functional testing and minor improvements to the FieldMApp's GUI a practice test with farmers under real conditions was performed. In the process, the farmers proved to be extremely supportive and patient. The data collected during the field test is currently evaluated.

3. Conclusion

The development of viable and accepted digital innovations in the context of sustainable production processes requires attentive listening, genuine interest in farmers' concerns, exchange at eye level, openness and appreciation. This creates the necessary trust for an open and mutual transfer of knowledge and information as a basis for understanding each other's needs and requirements.

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