Peer review of the dissertation

Thesis topic: End-User Cobot Programming in Augmented Reality

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The presented dissertation investigates the possibilities of using augmented reality for programming robots by end users who have no or very modest knowledge of programming languages. Augmented reality currently has some hardware limitations, especially for hands free work, on the other hand it seems that the software is ready for the implementation of applications. Programming robots is a qualified job, which will have to be delegated to a larger number of less skilled workers as more robots become available in companies. The topic therefore seems to me to be very topical and socially necessary, yet it is only very limitedly explored.

The dissertation contains a number of sub-studies, so it is possible to conclude that the problem is viewed comprehensively, and a number of possibilities and aspects are explored. The thesis has a really broad scope. The finding of a "research gap" for further follow-up research is either directly supported by the previous research itself or follows directly from it.

In the introductory chapters the author defines the motivation for the research, which is supported by initial research, defining basic concepts and the actual pilot research. Chapter 4 then defines the main aim of the thesis, which is divided into four reasonably designed objectives. At this point, the main research question or even hypotheses could also be defined (some hypotheses are defined later in the sub-research). This chapter could also summarize the limits of the solution (for which companies and operations the solution is suitable, supported software and HW, etc.).

As already mentioned, in the following chapters the PhD student then presents concrete possible solutions, which he verifies using standard and valid scientific methods (e.g. SUS, NASA-TLX, statistical data processing, etc.). There are presented mostly smaller studies with low N, but the number of probands is balanced by the number of additional alternative studies.

The author presents his own ARCOR and ARCOR2 systems, among others, within these listed studies. In both cases, new and comprehensive engineering solutions are presented that are correctly based on scientific evaluation. ARCOR2 is described in terms of software architecture in the paper, whereas in the case of ARCOR the description is only superficial. The author's involvement in the development of these environments is not clearly evident, hence the frequent occurrence of "we" in the thesis. In the case of a collective work, the partial contributions should be defined in the scope of dissertation.

Chapters that contain studies more or less replicate published or to be published articles. Those have been (or are likely to be) published in relevant mostly impacted journals. Each chapter more or less follows the structure of a scientific article (research, methodology, results, discussion, conclusion). This, however, results in a dilution of the literature research into subchapters. In my subjective opinion, it would probably be better to clearly separate the literature research and implementation parts of the thesis. All the experiments carried out in the studies described are measured using appropriate methods and are also properly validated and interpreted. Comparison of the results with the work of other authors is lacking within the discussion sections.

Chapter 11 then provides a reflection towards meeting the partial pre-declared objectives and sets the direction for further work. At this point, it would be useful to make a summary of the studies described and, if necessary, to summarise the theses that emerge from the research presented.

Formally, the work is of a high standard. I have only a few minor comments:

- Chapter 2.3 - the claim that VR uses HMDs can be disputed.
- The term SAR should be explained before first use, it should also be in the list of abbreviations
- Fig 3.2 - the term magic wand is not used in the text (probably a 6DOF device)
- Fig 5.7 is part of the literature research chapter, yet it is probably a part of practical part
- Chapter 5.3 - it would be useful to add a diagram of the functionality. For example, it is not clear why a second KINECT is used.
- Chapter 6 - at the beginning it would be better to introduce the study that follows
- Chapter 7.5 explains SUS and NASA-TLX. These tools were used earlier in the thesis, they are explained at this point

The strengths of the thesis are: the comprehensive view of the problem, the number of sub-studies performed, the completely new approach, the use of modern methods and modern hardware. The weakness of the thesis is the discussion part within the particular studies and missing of the overall summary (i.e. the description of the overall contribution to the theory).

Realization of this work was certainly very time consuming, not only with respect to the complexity of the developed software, but also with respect to the experiments performed. A total of 161 relevant sources are cited.

In the Scopus database the PhD student has 9 records with a total of 62 citations (H-Index 5) and in the WoS database there are also 9 records with 42 citations (H-Index 4). This indicates intensive successful scientific work during the doctoral studies. The publications are related to the topic of the dissertation. Parts of the thesis have been published; some are under review. This fact and the overall level of the dissertation testifies to the high scientific erudition of the doctoral candidate.

On the basis of the analysis of the thesis, the assessment of the formal and scientific level, the correctness of the theoretical and applied solutions, the opponent concludes that the thesis meets the general requirements set for dissertations. The dissertation under review meets the following generally accepted requirements for the award of the academic degree of Ph.D. After successful defence of the thesis, I recommend that the Ph.D. degree be awarded to the candidate.

Question:

What are the practical implications of the studies? Will your solutions be implemented in practice? If not yet, what are the obstacles?