Рег. №: 3-2773/23.08.2024г.

POSITION

on a dissertation work for the acquisition of an educational and scientific degree "doctor" (PhD)
Author of the dissertation: Eng. Lili Tsvetanova Pavlova
Dissertation topic: "Visualization of electronic battlefield with elements of augmented reality"
Member of the scientific jury: Assoc. Prof. Dr. Dimo Todorov Dimov
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from the Institute of Information and Communication Technologies (IICT) of the BAS
(pursuant to order No. 418/16.07.2024 of the Director of the Defense Institute "Professor Tsvetan Angelov", Sofia, notification letter No. 3-2341/18.07.2024 to the Director of IICT-BAN).

A dissertation of 165 pages including 5 tables, 58 figures, 111 referenced titles, 2 sections of appendices (29 pages), abstract (40 pages), CV of the dissertation candidate, on paper and e-media.

1. *Relevance of the problem developed in the dissertation*:
Augmented Reality (AR) is from the field of Realistic Image Synthesis and emerged as a theory and practice in Informatics about 30 years ago. Essence: A suitable virtual plug-in is added to the real-world model. The best known are applications in museum activities (for virtual reconstruction of artifacts), in design works (for visual evaluation of a future object in a real environment) and others, and last but not least in the military sphere (for supporting the management of troops, from the -large units to separate combat groups and combatants) in a combat environment, through AR of the "electronic battlefield" type (the name was introduced in this dissertation). The military application of AR is developing intensively in many countries around the world. The relevance of this dissertation is for the Bulgarian army and defense with a view to adaptation and upgrading to existing army communication and information systems.

2. *Degree of knowledge of the state of the art*:
The state of the art in the field under consideration (military-applied aspects of AR) is well described and purposefully interpreted in the three chapters of the dissertation. Chapter 1 is a goal-oriented overview of the research object - development of a model of an advanced electronic battlefield with basic components - visualization and augmented reality, with a subsystem for identifying an object of interest (from the battle order and military infrastructure objects) in the field of view of an observer using inertial sensors. Most known systems are based on Microsoft's HoloLens device. For the Bulgarian army, the known and experimentally accessible information and control (C2) systems, FICIS and C2PC, are indicated. It is believed that there is a "Tactical Database" developed for them. An advanced electronic battlefield model is proposed with specific data flow from the existing databases of these C2 systems to the hardware part of field mobile systems with AR. Two object identification methods are considered -- optical marker tracking and markerless one (via GPS geolocation).
Chapter 2 examines the structure and functional features of the proposed AR extension for military C2 systems, including types of databases (DBs), local, central/coalition DBs (mainly relational DBs) and respective methods of accessing them. Software gateways are also considered as a universal approach for relative compatibility and exchange between different DBMSs used in the military. For the AR experiment, a test environment consisting of a base computer (BC), a virtual machine (VM) and a mobile computer (MC) was created.
Chapter 3 details the proposed AR for an extended electronic battlefield. The main and "not yet fully resolved issue is related to the identification of the object in the field of view of the mobile device". The problem is known in Informatics, and in this case it is loosely related to the method for markerless identification, which is mainly considered in the dissertation. To increase the reliability of MC's inertial sensors (accelerometers, gyroscopes and magnetometers, each equipped with 1 to 3 sensors), known data fusion (error reduction) methods such as complementary filter and Kalman filter are applied. Emphasis is on Kalman filtering, but a non-filtering variant is also developed for the experimental benchmarking. A total of 111 publications are referenced, mainly after 2010, most of them

internationally visible. Obviously, the PhD student knows very well the theory and practice in the field of the dissertation topic.

3. *Correspondence of the chosen research methodology*:
The chosen research methodology is based on known methods and approaches, algorithms, techniques and tools from informatics for AR and software engineering (AICS, DBMS, system and application programming). Various other methods -- for segmenting visual objects, 3D computational geometry, filtering, and more -- are also included. The dissertation work was developed in the last 4-5 years, in the order of the description by chapters. The main approach of the research is software one, of the "trial - error" type, i.e. everything positively evaluated and/or experimentally confirmed is included; which is the natural approach to problems of the type addressed in the dissertation.

4. *Scientific and/or scientifically applied contributions of the dissertation work*:
The dissertation lists a total of 7 contributions, 5 scientific and applied ones and 2 applied ones. The lack of a "purely" scientific contribution is not a disadvantage for dissertation-type research -- applied research with experimental software development. The specified contributions are well described and correspond to the text of the dissertation and the attached 4 publications to it. *I accept the contributions in substance*, with the following 2 recommendations to their description:
- First and second scientific and applied contributions can be combined (i.e. 1st contribution can be excluded) !
- Contributions should be supported with references to an article on the dissertation and/or with a conclusion (paragraph) from the text of the dissertation itself (for easier follow-up).

5. *Evaluation of publications on the dissertation work*:
Four publications on the dissertation have been declared. These are not presented in the review package, but were provided upon request. Only 1 of the publications (the one in English) is available on the Internet. The remaining 3 reports are in Bulgarian, in specialized forums, military and/or security ones. Article [19] ((co-authored with the PhD student, in press) is referenced in the text of the dissertation, but not announced as a dissertation publication (?). I believe that the presented publications sufficiently cover the research and experiments carried out on the topic of the dissertation.

6. *Opinions, recommendations and notes*:
An undeniably good and above all useful dissertation. It is written in a nice style, clear and concise. My editorial notes are provided here to help refine the thesis if necessary, for example:

1) Some unknown abbreviations: NBC battalion, OMP (p. 59); CP (p.60), and ACEC2 (p.60) can be interpreted as (=ACE + CC) (?)

2) Indications (3.8) and (3.9) are confused (?)

3) Fig. 3.4 has insufficient resolution (unreadable :)

What do next expressions mean:

(p.100) "Expressions (3.12, 3.13) are an extended form of that shown in [73]" !?!

(p.102) "complementary sensor": "In the measurement update step, the KF uses the values from the measurements of another complementary sensor" ?

(p.119) "test point" is a bit confusing, "target point" would be more adequate?

A few questions:

(1) Why the "gimbal lock" problem (p.98) is bypassed. Perhaps it is expected that the AR system will not be used near the poles (of the planet). Do similar situations exist when the MC is accidentally rotated at the moment of initial initialization?

(2) App. 2.1 "C2PC Computer System", why is it so long since it is also described in Chapter 1 (?)

(3) App. 3.6. "Source code for determining angular variance": why is variance calculated based on min() and max(), but not on mean() ?

(4) Why is a minimally circumscribed rather than a maximally inscribed sphere, which is more precise used when estimating the limit for robust markerless identification (?)

(5) Is it expected to implement the results in the dissertation as intended -- in the automation and management of the army. Is dissemination of the results planned in other areas, for example, in the construction and design activity in the country (?).

7. *Conclusion*: The presented dissertation meets the requirements of the Law on the Development of the Academic Staff of the Republic of Bulgaria and deserves a positive evaluation. I propose to award the educational and scientific degree "doctor" (PhD) to Eng. Lili Tsvetanova Pavlova in the professional field 5.2. "Electrical Engineering, Electronics and Automation".

Date: 23.08.2024
Sofia

JURY MEMBER:
/ Assoc.Prof. Dr. D. T. Dimov/