Skoltech
Skolkovo Institute of Science and Technology

Thesis Changes Log

Name of Candidate: Daria Trinitatova

PhD Program: Engineering Systems

Title of Thesis: Development of a wearable interface with multimodal haptic feedback for intuitive VR-based teleoperation

Supervisor: Associate Professor Dzmitry Tsetserukou

The thesis document includes the following changes in answer to the external review process.

I would like to thank the reviewers for their valuable and important comments, which contributed to the overall improvement of the content and formatting of the thesis.

Professor Clement Fortin

- ***Comment: I suggest to include a high level summary of her findings at the end of chapters 2, 3, 4 and 5 where she could present her expert assessment at the end of each important section.***
- Response: Thank you for this suggestion. Following your advice, a brief summary has been added to each chapter.

- ***Comment: I have included minor comments in the manuscript which must be carefully reviewed for minor grammatical errors.***
- Response: Thank you for notifying about the typos, I corrected them and have proofread the thesis.

Professor Tatiana Podladchikova

- ***Comment: Please unify writing of chapter titles, for instance "Directions of Future work", either all words start from the capital letter, or only the first one. The same for thesis subtitles, for instance "Forward Kinematics calculation".***
- Response: Thank you for your observation. The format of section titles is now unified.

- ***Comment: Conclusion (Chapter 6) presents a brief conclusions separately for each chapter, would be benefitting to add a paragraph of conclusions that unite the outcomes and implications of all thesis with emphasis on novelty and the results achieved for the whole work.***
- Response: The main outcomes and contributions are presented in the section *6.2 Contributions and conclusion*.

- ***Comment: The abstract would benefit from adding supporting accuracy metrics to prove that the suggested novel approach works.***
- Response: Thank you for your suggestion. I included more details about the conducted studies in abstract.

Professor Andrey Somov

- ***Comment: I recommend to clearly state in Abstract what problem do you address in your thesis, what is novelty of your research, and mention your key achievements.***
- Response: Thank you, I tried to reformulate the abstract to make it clearer.
- ***Comment about Background section***
- Response: In Chapter 2, I added a conclusion in which I summarized the review of the state-of-the-art works conducted. In addition, the research gaps for the studied scientific topic were formulated in the Chapter 1, which I addressed during the thesis work.
- ***Comment: In my opinion, there is too much stress on 'development' in the titles of sections.***
- Response: Thank you for pointing this out. I eliminated the word "development" from the section titles.

Professor Fei Chen

- **Comment: Chapter 2: In section 2.1, it would be beneficial to have figures illustrating the different tactile sensors for fingertips and palms. Figure 2-1 only shows a few examples of mechanical stimulation devices for fingertips, while other technologies are mentioned without visual aid. This applies to tactile sensors for other body parts as well. In short, a comprehensive figure showcasing all techniques and designs would help readers understand their pros and cons more intuitively.**
- Response: The figures in the Chapter 2 illustrates different types of haptic devices that provide different type of stimulation. I added a more detailed description to the captions to the figures.

- **Comment: What is the relationship between DeltaTouch/FiDTouch and the Glove? Figure 5.3 should be introduced earlier.**
- Response: vDeltaGlove is a wearable modular interface for providing multimodal haptic feedback to the hand. The proposed approach to interface design include development of a system that combines three submodules, namely, a DeltaTouch palmar haptic display, a FidTouch haptic display for the finger pad, and a hand tracking glove. Each of the designed submodules can be used as an independent device or in combination to provide the user's hand with a full range of haptic feedback. I added the illustrative figure with all developed modules at the end of Chapter 3.

- ***Comment: Is Fig. 3-11 supposed to be non-symmetric, given that it is a map of a human palm?***
- Response: Fig. 3-11 illustrates the spatial contact pattern recognition results averaged over all users. According to the obtained results, the recognition of patterns was not symmetrical.

- ***Comment: More details could be added regarding the remote control of the robot arm, and***
- ***position-position/position-velocity modes. Are both controllers activated alternately online?***
- Response: Using the developed VR framework, the robot can be controlled either through position-position or position-velocity control scheme. The control scheme can be switched online during the teleoperation process. I added an additional description of control principles to the section 4.4. In addition, I prepared the illustration figure of robot control principle (Fig. 4.2).

- ***Comment: What does "multimodal" haptic feedback refer to?***
- Response: The term "multimodal" feedback meant that a combination of skin stretch feedback on the palm of the hand and vibrotactile feedback on the fingertips was used during the teleoperation.

Professor Yuhua Jin

- ***Comment: Several points related to haptic device design, evaluation of haptic feedback latency, and adding additional modalities were suggested to be discussed during the thesis defense.***
- Response: Thank you for the suggestion. I will try to point out all the topics mentioned during the defense discussion.