

**I. IDENTIFICATION DATA**

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| <b>Thesis name:</b>           | <b>Automating Spatial Calibration of Whole-Body Artificial Robot Skin Using 3D Reconstruction</b> |
| <b>Author's name:</b>         | <b>Bohumila Potočná</b>   |
| <b>Type of thesis :</b>       | bachelor  |
| <b>Faculty/Institute:</b>     | Faculty of Electrical Engineering (FEE)   |
| <b>Department:</b>            | Department of Cybernetics   |
| <b>Thesis reviewer:</b>       | Silvio Traversaro   |
| <b>Reviewer's department:</b> | Outside CVUT, Italian Institute of Technology   |

**II. EVALUATION OF INDIVIDUAL CRITERIA**

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| <b>Assignment</b>  | <b>challenging</b> |
| <i>Evaluation of thesis difficulty of assignment.</i>  |                    |
| The assignment of this thesis was to perform taxel geometric calibration for the iCub humanoid robot skin, following the work done on the Nao robot in reference [2] of the thesis bibliography and published at the Humanoids international conference. The proposed technical work was indeed challenging and non trivial. |                    |

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| <b>Satisfaction of assignment</b>   | <b>fulfilled with minor objections</b> |
| <i>Assess that handed thesis meets assignment. Present points of assignment that fell short or were extended. Try to assess importance, impact or cause of each shortcoming.</i>  |  |
| The candidate completed most of the work required by the assignment, even if he was not able to complete the assignment, in particular he was not able to complete the point 7 of the assignment "7. Provide the taxel positions files for the skin on the iCub legs (not available at [5]). For the other skin parts, compare the performance of your solution with existing calibration [5]." |  |

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| <b>Method of conception</b>  | <b>correct</b> |
| <i>Assess that student has chosen correct approach or solution methods.</i>  |                |
| The candidate used an RGB-D camera to obtain the required data from the robot, and a state-of-art computer vision technique like CNN to extract taxel positions. This proved to be a valuable and correct approach, even if affected by problems such as false positives that the candidate was not able to completely remove. |                |

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| <b>Technical level</b>  | <b>C - good.</b> |
| <i>Assess level of thesis specialty, use of knowledge gained by study and by expert literature, use of sources and data gained by experience.</i>   |                  |
| The thesis demonstrated a good technical level. However, under some aspects the technical level could be improved, for example in the following points: <ul style="list-style-type: none"> <li>In section 4.2, there is the sentence "This whole process takes up to 10 minutes on a computer with 16GB of RAM." This is a good example of a sentence that is a bit too informal for a technical bachelor thesis. For example, it is not really a descriptive description of the computer used for the experiments just to say "16 GB of RAM", as the speed of the process most probably depends on the CPU or GPU used, not on the amount of RAM.</li> </ul> |                  |

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| <b>Formal and language level, scope of thesis</b>   | <b>D - satisfactory.</b> |
| <i>Assess correctness of usage of formal notation. Assess typographical and language arrangement of thesis.</i>   |                          |
| The thesis describes in detail and in an effective way the work done. However, in some cases the text is written quite in an informal way, making it difficult to read. For example, at the end of the Section 4.2, it is written "assuming the robot and camera are in upright position, otherwise it needs to be edited". This assumption seems to indicate that there is an assumption of a known relative rotation between the camera and the robot, that anyhow was not mentioned elsewhere in the paper. How much is this assumption affecting the results? |                          |

Furthermore, with respect to some aspects there are some typographical errors, that if fixed could improve the readability of the thesis, such as (but not limited to):

- At the beginning and in the title of Section 3.6.1, ICP is introduced as Iterative closest points, while the name used in literature for this algorithm is typically Iterative closest point, including in the referenced citation.
- In Section 4.2, there is the sentence "The output is a 3D point cloud of detected taxels + some extra points". These are formal documents, so it is better to avoid the use of "+" unless it is used in mathematical sense, and write down extensively "and" or other conjunctions.
- The usage of commas and points in the bullet point of the thesis are not consistent: in some cases they are present, in some other no. To increase readability it would be great if there was consistency.

### **Selection of sources, citation correctness**

**C - good.**

*Present your opinion to student's activity when obtaining and using study materials for thesis creation. Characterize selection of sources. Assess that student used all relevant sources. Verify that all used elements are correctly distinguished from own results and thoughts. Assess that citation ethics has not been breached and that all bibliographic citations are complete and in accordance with citation convention and standards.*

The student used some relevant sources, and the sources can be clearly distinguished from the results of the thesis. However, the used material seems to be extremely based on the material given as part of the assignment. For example, the thesis does not mention at all the work "3D spatial self-organization of a modular artificial skin" by Mittendorfer, that is instead quite related to this work. Furthermore, for some sources it seems that there is a misunderstanding on the nature of the work. In Section 2.1 it is written:

"In 2017 Kangro et al. [6] came up with a time-efficient technique to calibrate the skin surface normals using vacuum bags. When a skin part is wrapped in a plastic bag and the air pressure inside is lowered by a pump, the bag applies a known uniformly distributed force on the whole skin surface, which provides the information for calibrating each taxel simultaneously. Based on this approach, they later developed a calibration device [7]."

However [6] and [7] do not describe any kind of geometric calibration of the taxel position, but rather they calibrate a model that describe the pressure exerted on the skin given the raw capacitance measured.

### **Additional commentary and evaluation**

*Present your opinion to achieved primary goals of thesis, e.g. level of theoretical results, level and functionality of technical or software conception, publication performance, experimental dexterity etc.*

The work demonstrated an interesting approach for the geometric calibration of iCub skin, however it did not achieved fully all the original objectives, as described in the thesis itself.

### **III. OVERALL EVALUATION, QUESTIONS FOR DEFENSE, CLASSIFICATION SUGGESTION**

*Summarize thesis aspects that swayed your final evaluation. Please present apt questions which student should answer during defense.*

I evaluate handed thesis with classification grade **C - good**.



## REVIEWER'S OPINION OF FINAL THESIS

Date: 5.6.2023

Signature: