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ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

SUPERVISOR'S OPINION OF FINAL THESIS

I. IDENTIFICATION DATA

Thesis name:	Retargeting Infant Movements to Baby Humanoid Robots
Author's name:	Ondrej Fiala
Type of thesis :	bachelor
Faculty/Institute:	Faculty of Electrical Engineering (FEE)
Department:	Department of Cybernetics
Thesis supervisor:	Doc. Mgr. Matej Hoffmann, Ph.D.; Valentin Marcel, Ph.D.
Supervisor's department:	Department of Cybernetics

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment **challenging**

Evaluation of thesis difficulty of assignment.

The thesis was challenging in the sense that it required abstract knowledge on geometrical transformations for the mastering of kinematic representations and their transfer to humanoid poses but also because it required the ability to transfer joint angles into two very different simulation platforms Mujoco and Gazebo and for different humanoid shapes (dummy, iCub, MIMo, and fetus). Additionally, the thesis required some understanding of the physics engines to simulate contacts and touch activation and the graphical renderers for the robot eyes. Moreover, the student had to get acquainted with infant biomechanics – proportions and constraints of small babies.

Satisfaction of assignment **fulfilled**

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.

The assessment is totally fulfilled with an addition of an extra humanoid shape (the fetus simulator) which has its own tactile sensors. The theoretical points were well understood and properly treated and the proposed practical solutions meet very well the assignments.

Activity and independence when creating final thesis **A - excellent.**

Assess that student had positive approach, time limits were met, conception was regularly consulted and was well prepared for consultations. Assess student's ability to work independently.

The student was autonomous and managed to consult the supervisors when required. Additionally, he provided very good visualization content to be used for the team's presentations of current research at conferences. Moreover, two of the target platforms required communication with external research centers (Frankfurt Institute of Advanced Studies; University of Tokyo), which the student perfectly managed.

Technical level **A - excellent.**

Assess level of thesis specialty, use of knowledge gained by study and by expert literature, use of sources and data gained by experience.

Tthe work is in line with state of the art formalization of 3D pose representations for humanoids. Filtering and analysis of motion where also justified using expert literature. Additional knowledge obtained from the retargeting on iCub, MIMo, and fetus simulator has been gathered, compared and synthesized in the thesis.

Formal and language level, scope of thesis **A - excellent.**

Assess correctness of usage of formal notation. Assess typographical and language arrangement of thesis.
The notations in the thesis are clear and pertinent, and reflect the knowledge on the state of the art. The thesis is well arranged and the student has made a very important pedagogical effort to describe his work. The combination of formal mathematical notation, schematics, block diagrams and photos/videos is appropriate and of highest standard.

Selection of sources, citation correctness **A - excellent.**
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 sources selected by the student are pertinent state of the art methods and are well cited and the presented work is well placed in the literature.

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.
All the goals of the thesis have been achieved with the addition of an extra humanoid platform: the fetus simulator. The thesis provides a detailed and sound groundwork for any additional projects on the subject. The text is very didacticl and well documented. The student dealt very well with the difficulty of handling multiple simulation platforms.

III. OVERALL EVALUATION, QUESTIONS FOR DEFENSE, CLASSIFICATION SUGGESTION

Summarize thesis aspects that swayed your final evaluation.

Overall, the thesis is of excellent quality both on the technical level, with solid results obtained, and nice visualizations for the different simulation platforms while being well documented.
The thesis provides a "first-person baby simulator" where movements of actual babies can be mapped onto different robot platforms, with the possibility of collecting visual and tactile inputs. This technology will be key in furthering our understanding of infant development.

We evaluate the handed thesis with classification grade **A - excellent.**

Date: **8.6.2023** Signature:

THESIS REVIEWER'S REPORT

I. IDENTIFICATION DATA

Thesis title:	**Retargeting Infant Movements to Baby Humanoid Robots**
Author's name:	**Ondřej Fiala**
Type of thesis :	bachelor
Faculty/Institute:	Faculty of Electrical Engineering (FEE)
Department:	Cybernetics
Thesis reviewer:	Hoshinori Kanazawa
Reviewer's department:	School of Information Science and Technology, The University of Tokyo

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment **extraordinarily challenging**

How demanding was the assigned project?

This project is so difficult due to several factors including the variance in shapes, the complexity of capturing the movement, the lack of suitable simulators, and the scarcity of prior research in the field.

Fulfilment of assignment **fulfilled**

How well does the thesis fulfil the assigned task? Have the primary goals been achieved? Which assigned tasks have been incompletely covered, and which parts of the thesis are overextended? Justify your answer.

The author has been able to realize retargeting, which was set as the goal, through the definition of joint movements and the utilization and modification of multiple models. Furthermore, he has made progress to implement both visual and tactile perceptions through the addition of sensors.

Methodology **correct**

Comment on the correctness of the approach and/or the solution methods.

In terms of motion transfer, the author has accurately defined each joint, both mathematically and practically, thereby achieving notable success in minimizing errors during the transition. There also could be potential areas for improvement, specifically regarding the sizing of the model, as well as adding the joints of the hand and ankle.

Technical level **A - excellent.**

Is the thesis technically sound? How well did the student employ expertise in the field of his/her field of study? Does the student explain clearly what he/she has done?

Yes, the necessary techniques towards the goal are properly employed. The author also addresses inevitable issues that arise during the process. He demonstrated clear explanations of their methods, particularly in chapters 3 and 4.

Formal and language level, scope of thesis **B - very good.**

Are formalisms and notations used properly? Is the thesis organized in a logical way? Is the thesis sufficiently extensive? Is the thesis well-presented? Is the language clear and understandable? Is the English satisfactory?

The English used throughout the thesis meets a satisfactory standard. The author has effectively employed clear and understandable language, ensuring his ideas and methodologies are communicated in a way that is easy to follow. Additionally, technical terms are accurately applied, demonstrating a deep understanding of the subject matter.

Selection of sources, citation correctness **B - very good.**

Does the thesis make adequate reference to earlier work on the topic? Was the selection of sources adequate? Is the student's original work clearly distinguished from earlier work in the field? Do the bibliographic citations meet the standards?

Yes, while there is scant research on the retargeting of infant movement, the author adequately references the technical prior research necessary for its achievement. The computation methods required at each step are also sufficiently cited.

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THESIS REVIEWER'S REPORT

Additional commentary and evaluation (optional)

Comment on the overall quality of the thesis, its novelty and its impact on the field, its strengths and weaknesses, the utility of the solution that is presented, the theoretical/formal level, the student's skillfulness, etc.

This thesis possesses high novelty in that it enables retargeting towards robotic models of infant movements, an area not previously explored. Though not explicitly stated, the approach taken in this research holds great potential for application in clinical measurements of infants and developmental psychological experiments. The approach taken is fundamentally correct, and the completed animations indicate a reasonable degree of success, with an error angle of about 10 degrees in the joint movements of infants, which would be considered within practical use.

III. OVERALL EVALUATION, QUESTIONS FOR THE PRESENTATION AND DEFENSE OF THE THESIS, SUGGESTED GRADE

Summarize your opinion on the thesis and explain your final grading. Pose questions that should be answered during the presentation and defense of the student's work.

The grade that I award for the thesis is **A - excellent.**

The thesis aimed to achieve retargeting of infant motion, which is highly challenging due to factors such as shape variance, complex motion capture, lack of suitable simulators, and limited prior research. The author undertook an impressive and demanding endeavor. The author demonstrated ingenuity by defining joint movements and modifying multiple models, including the implementation of visual and tactile perceptions using sensors. In terms of motion transfer, the author defined joints mathematically and practically, minimizing errors. There would be room for improvement in filters, model size, and hand and ankle joint adjustments. Future work suggests size customization for each infant to enhance performance. Also, the estimation of vision and touch through retargeting shows promise for medical applications and developmental psychological research.

I have several questions/comments on this thesis.
Q1: You calculated error angles as the accuracy of the motion transfer, which only becomes zero when the shape of the target model matches the shape of the actual infant. Similarly, differences in performance by model reflected differences by shape. These problems can be improved by resizing the model as described in future work, but problems probably remain with the modelling of the torso due to its flexibility. Is there any idea for solution to this?

Q2: In Figure 5.2, you have utilized frequency filters as noise removal for joint angles. However, there is a potential for further improvement in the filtering for time-series 3D position of each joint before calculating joint angle, as well as incorporating the despiking method like described in Patel et al.'s study (Fig2) [A wavelet method for modeling and despiking motion artifacts from resting-state fMRI time series. *Neuroimage*, 2014]. Have you considered using these methods, and if not, would it be worth exploring its effectiveness?

Q3: The touch and visual extraction using models is highly applicable and impressive. However, it would be beneficial to have validation for each of these methods. Do you have any ideas for validating the touch and visual?

Q4: The author argued "Our focus is not on the precise location of the end effector, as our goal is to simulate the motion and sensory perspective of infants of different ages.", which makes sense. However, considering the reproducibility of infants' visual and tactile sensations, would it be important to ensure accuracy specifically for the endpoints that affect target sensation? Could incorporating inverse kinematics for these endpoints be a useful approach to achieve greater accuracy in simulating visual and tactile experiences in the future work?

Date: **6.6.2023** Signature: