MASTER THESIS PROPOSAL DECEMBER 15, 2020

Race Car Ergonomics using Digital Human Models

- a multi-objective optimization of the driver cockpit

Contacts:

Björn PÅLSSON
bjorn.palsson@chalmers.se

Mohamed TAKKOUSH
mohamed.takkoush@fcc.chalmers.se

Examiner:

Mathias LIDBERG
mathias.lidberg@chalmers.se

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FRAUNHOFER CHALMERS
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Background

The emergence of the field of human factors started in the United States after the Second World War mainly to understand process design problems from a human information processing viewpoint. A couple years later, the field of ergonomics emerged in European countries as an approach to improve biomechanical applications in the industries' workplaces and jobs [1].

While vehicle ergonomics has not been the center of attention in traditional vehicle design, it has gained more and more interest over the years. Nowadays, driver ergonomics has become of utmost importance due to the emergence of autonomous vehicles which is shaping the ways people behave while commuting. Traditional approaches in the design of a vehicle's interior have worked well for current manufacturers. However, there is a compelling industrial need for more efficient methods and tools to ensure proper ergonomics in the design of future vehicles, for the benefit of various product quality aspects as well as occupant safety. The inherited approach is to include human-centred aspects in the product and production development.

Some researchers have developed digital human models (DHM) which can be used in simulations of dynamic driving maneuvers [2]. Others rely on existing DHMs of high complexity to develop test procedures of an objective nature that explain how virtual driving test routines and subsequent driver ergonomics evaluations can be performed in a proactive manner within vehicle development processes, in accordance with lean product development (LPD) philosophies [3].

Driver ergonomics has always been down the chain of priorities in formula student teams. Designers would rely on existing chassis/monocoques to design their driver's ergonomic environment by fitting the driver in the vehicle while complying to certain set rules. Usually, drivers' feedback are the main driving factor in the design of subsequent chassis/monocoques [4]. But improvements do not have to be drastic; a simple double pendulum human model, like the one developed by Cyrén et al. is capable of capturing the fundamental motion of a driver [5], which is a major asset for taking formula student ergonomics one step further by understanding the motions and forces that a driver exhibits when maneuvering.

Aim

Given the CFS21 chassis, the aim of this thesis is to develop a multi-objective design and optimization procedure of the driver cockpit based on static and dynamic postures of the CFS21 driver on a race track. The outcome of the work should be a well thought out design process and recommendations for the development of CFS22.

Scope

The scope of the master thesis is to be tailored towards the preference and competence of the selected student(s). However, the thesis project is expected to be among the lines of:

- Developing a knowledge in driver ergonomics and the design procedure of a race car's cockpit interior for static and dynamic driver postures.

- Utilizing DHM technologies to enhance the quality and efficiency of vehicle design and development processes.
- Performing fast, objective, and automated simulations of virtual driving test routines.
- Assessment and analysis with simulation tools.
- Identify and solve design issues in a virtual environment.
- Leading a multi-objective optimization procedure for driver cockpit development.

Tasks

The tasks for the master thesis are divided into 4 work packages:

Work Package 1: Fundamentals of Vehicle Ergonomics

- Basic modeling of driver posture/ergonomics in MATLAB to represent anthropometric and behavioral diversity from the 5^{th} percentile female to the 95^{th} percentile male.
- Define basic ergonomics requirements and geometric constraints based on the cockpit interior and formula student regulations.

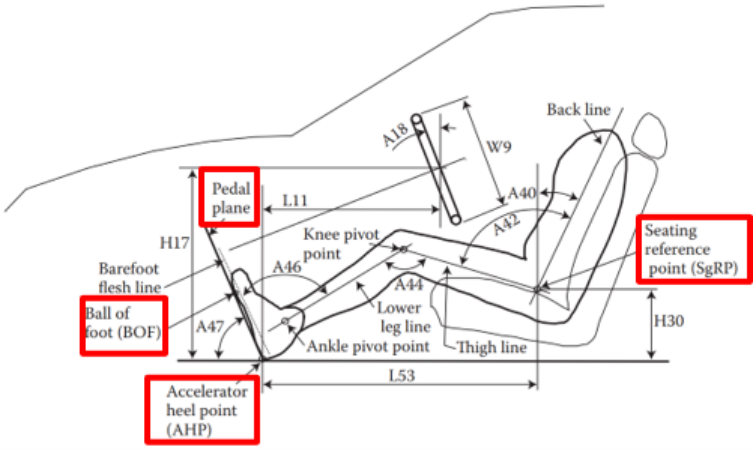

FIGURE 1: Interior package reference points and dimensions [1].

Work Package 2: Ergonomics Design Procedure

- Develop a design procedure using optimization in MATLAB and a simplified DHM to reach a feasible design for the driver's static posture.
- Perform advanced simulations in Adams Car to understand how the driver posture/kinematics is changing in braking and cornering.
- Estimate the envelope (range, reachability) of driver inside the monocoque using advanced simulation tools (i.e. Adams, CATIA).
- Embed Adams simulations in the developed design procedure in an iterative/optimization approach.

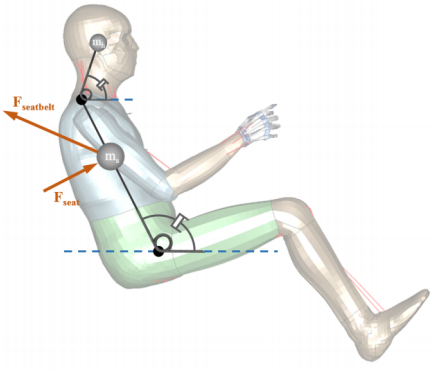

FIGURE 2: A simplified occupant kinematic model; a 3D pendulum representation of a vehicle occupant [5].

Work Package 3: Vehicle-driver Force Interaction

- Study the effect of suspension/steering system design on the driver's force/-muscle activity and ergonomics.
- Use the DHM for studying the required steering forces and pedal forces during maneuvering and accelerating/braking.
- Estimate restraint (belt) forces on the DHM.
- Estimate lateral forces on the driver's neck and suggest design changes to minimize those forces.

Work Package 4: Assessment and Extended Targets

- Perform ergonomics assessment using the IPS ergonomics tool IMMA [6].
- Perform testing and instrumentation on the CFS2021 race car to measure dynamic forces on the driver and seat while maneuvering.

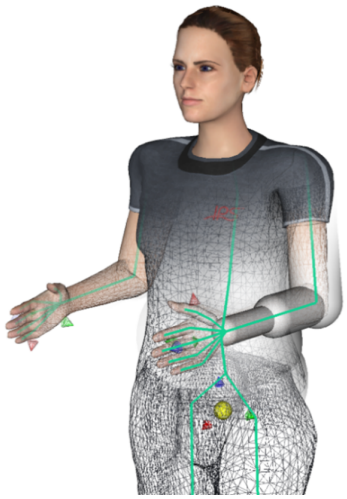

FIGURE 3: A biomechanical model of the IMMA manikin skeleton with manikin meshes from Poser [6].

Student Profile

- We are looking for students that are highly motivated and have a genuine interest in vehicle ergonomics and dynamics as well as in mechanics and kinematics.
- Master's degree students in: Mathematics, Applied Mechanics, Systems, Control and Mechatronics or similar.
- The student(s) preferably has a history with MATLAB and knowledge in multibody simulation software like Adams.
- Communication skills are an important asset.

Status

- Period: 1 Semester, 30 hp credits
- Starting date: January 2021
- Number of students: suitable for 1-2 students

Location

- Due to COVID-19 considerations, the work is to be carried out remotely. Offices at FCC might become available based on the developments of the pandemic.
- Meetings to be carried out online or in person at FCC depending on availability.
- Presence at the premises should follow COVID-19 protocols.

Application

- Attach your CV and cover letter stating your interest within the given area and your thoughts and credentials.
- Attach your master's and bachelor's academic records.
- Send the application to the contact persons and examiner. Make sure to title your email "Application for Race Car Ergonomics using Digital Human Models".
- Selection process will be ongoing.

References

[1] V. D. Bhise, *Ergonomics in the automotive design process*. CRC Press, 2011.

[2] L Hanson *et al.*, "A digital human model for the simulation of dynamic driving maneuvers," in *DHM2020: Proceedings of the 6th International Digital Human Modeling Symposium, August 31-September 2, 2020*, IOS Press, vol. 11, 2020, p. 269.

[3] D. Högberg, P. R. Castro, P. Mårdberg, N. Delfs, P. Nurbo, P. Fragoso, L. Andersson, E. Brolin, and L. Hanson, "Dhm based test procedure concept for proactive ergonomics assessments in the vehicle interior design process," in *Congress of the International Ergonomics Association*, Springer, 2018, pp. 314–323.

[4] Z. Ahmad, A Abinandhan, and R. Sen, "Determination of ergonomics for formula student vehicle," *International Journal of Engineering Reseacrh and Technology*, vol. 6, no. 3, pp. 404–407, 2017.

[5] O. Cyrén and S. Johansson, "Modeling of occupant kinematic response in pre-crash maneuvers a simplified human 3d-model for simulation of occupant kinematics in maneuvers-a simplified human 3d-model for simulation of occupant kinematics in maneuvers," M.S. thesis, 2018.

[6] *Intelligently moving manikin*, `http://www.fcc.chalmers.se/focus-areas/engineering-industry/imma/`, Accessed: 2020-12-01.