DR.SC.-01 REQUEST FOR APPROVAL OF THE DISSERTATION TOPIC[1]

GENERAL INFORMATION AND PERSONAL CONTACT INFORMATION OF THE DOCTORAL CANDIDATE

First and last name, and title of the doctoral candidate:	Jelena Šklebar, mag. ing. mech.		
Provider of the study programme:	University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture		
Name of the study programme:	Mechanical Engineering, Naval Architecture, Aeronautical Engineering, Metallurgical Engineering		
Scientist ID of the doctoral candidate:	35003330		
Approval of topic for acquiring a PhD *(please fill in appropriate box)*:	☒ within programme-based doctoral study	☐ on the basis of scientific achievement	☐ Dual doctorate (Cotutelle de these)
First and last name of mother and/or father:	Kristinka Turković		
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CURRICULUM VITAE OF THE DOCTORAL CANDIDATE

Education *(in chronological order, with most recent first)*:	1. University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, *Mechanical Engineering, Engineering Design and Product Development*, Master's degree, Croatia (2017/2018) 2. University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, *Mechanical Engineering, Engineering Design and Product Development*, Bachelor's degree, Croatia (2015/2016)
Work experience *(in chronological order, with most recent first)*:	01.01.2022. – today: Research and Teaching Assistant, Chair of Design and Product Development, Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb (teaching, research, cooperation with industry) January 2021 – December 2021: Design Engineer, STSI – Integrated Technical Services Ltd., Member of INA Group d.d. September 2019. – December 2020.: Maintenance Specialist, STSI – Integrated Technical Services Ltd., Member of INA Group d.d. September 2018. – August 2019.: Intern, STSI – Integrated Technical Services Ltd., Member of INA Group d.d.

[1] Please name file as: DR.SC.-01 – Last name and first name of Doctoral Candidate.doc
Please send the filled -out form DR.SC.-01, in electronic and written format, and signed, to the appropriate Registrar's Office.

Bibliography and active participation in conferences:	1. Šklebar, Jelena; Martinec; Tomislav; Perišić; Majda Marija; Štorga, Mario: Clustering of Sequential CAD Modelling Data. // Proceedings of the Design Society: International Conference on Engineering Design Bordeaux, France / Online: Cambridge University Press, 2023. str. 937-946 doi: 10.1017/pds.2023.94 (lecture, international peer review, full paper, scholarly) 2. Ege, Daniel Nygaard; Goudswaard, Mark; Nesheim, Ole; Eikevåg, Sindre W; Bjelland, Øystein; Christensen, Kim A; Ballantyne, Robert; Su, Shuo; Cox, Chris; Timperley, Louis; Aeddula, Omsri; Machchhar, Raj Jiten; Ruvald, Ryan; Li, Jie; Figueiredo, Sara; Deo, Saurabh; Horvat, Nikola; Čeh, Ivan; Šklebar, Jelena; Miler, Daniel; Gopsill, James; Hicks, Ben; Steinert, Martin: Virtually Hosted Hackathons for Design Research: Lessons Learned from he International Design Engineering Annual (Idea) Challenge 2022. // Proceedings of the Design Society: International Conference on Engineering Design, Bordeaux, France / Online: Cambridge University Press, 2023. str. 3811-3820, doi: 10.1017/pds.2023.382 (lecture, international peer review, full paper, scholarly) 3. Martinec, Tomislav; Škec, Stanko; Šklebar, Jelena; Štorga, Mario: Applying Engineering Design Ontology for Content Analysis of Team Conceptual Design Activity. // Proceedings of the Design Society: International Conference on Engineering Design, Delft, The Netherlands/ Online: Cambridge University Press, 2019. str. 2467-2576, doi: 10.1017/dsi.2019.253 (lecture, international peer review, full paper, scholarly)

TITLE OF THE PROPOSED TOPIC

Croatian:	Utjecaj pomoćne tehnologije za umjetnu inteligenciju na sinkrone suradničke aktivnosti računalom potpomognutoga konstruiranja
English:	Influence of AI assistive technology on synchronous collaborative CAD activities
Title in the language of the dissertation (if it is not Croatian or English)	-
Area/field/branch (if the doctoral study is performed in a branch)**:**	Engineering / Mechanical Engineering / General Mechanical Engineering (Design)

PROPOSED OR POTENTIAL MENTOR(S)

(name the second mentor in case of interdisciplinary research or if there is another reason for more than one mentor)

	First name and last name, and title:	**Institution, country:**	**E-mail:**
First mentor:	Prof. Mario Štorga, PhD. M.E.	University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Croatia	mario.storga@fsb.hr
Second mentor:	-	-	-

MENTOR'S COMPETENCES – list of up to five relevant works published in the last five years

First mentor:	1. Horvat, Nikola; Kunnen, Steffen; Štorga, Mario; Nagarajah, Arun; Škec, Stanko: Immersive virtual reality applications for design reviews: Systematic literature review and classification scheme for functionalities. // Advanced engineering informatics, 54 (2022), 101760, 21 doi:10.1016/j.aei.2022.101760 2. Smojver, Vladimir; Štorga, Mario; Zovak, Goran: Exploring knowledge flow within a technology domain by conducting a dynamic analysis of a patent co-citation network. // Journal of Knowledge Management, 25 (2021), 1367-3270 doi:10.1017/pds.2021.480 3. Martinec, Tomislav; Škec, Stanko; Perišič, Majda Marija; Štorga, Mario: Revisiting problem-solution co-evolution in the context of team conceptual design activity. // Applied Sciences, 10 (2020), 18, 6303; doi:10.3390/APP10186303 4. Lukačević, Fanika; Škec, Stanko; Perišić, Marija Majda; Horvat, Nikola; Štorga, Mario: Spatial perception of 3D CAD model dimensions and affordances in virtual environments. // IEEE access, 8 (2020), Access-2020-40098, 18 doi:10.1109/ACCESS.2020.3025634 5. Martinec, Tomislav; Škec, Stanko; Horvat, Nikola; Štorga, Mario: A state-transition model of team conceptual design activity. // Research in engineering design, 30 (2019), 1; 103-132 doi:10.1007/s00163-018-00305-1
Second mentor:	-

TOPIC OUTLINE

Summary in Croatian *(no more than 1000 characters with spaces):*	Proces konstruiranja u svojoj osnovi sastoji se od suradnje konstruktora koji svojim vještinama i znanjem kroz različite aktivnosti doprinose razvoju tehničkih sustava. U tom kontekstu, nove tehnologije kao što su suradničko računalom potpomognuto konstruiranje (CAD) i umjetna inteligencija imaju ključnu ulogu. Konkretni utjecaj pomoćne tehnologije za umjetnu inteligenciju na suradničke CAD aktivnosti još nije dovoljno istražen. Zbog toga, cilj ovog istraživanja je razviti teorijski model kojim će se objasniti utjecaj pomoćne tehnologije za umjetnu inteligenciju na sinkrone suradničke CAD aktivnosti. Istraživanje nastoji razviti metodu za mjerenje utjecaja pomoćne tehnologije za umjetnu inteligenciju na te aktivnosti, s ciljem olakšanja procjene konačnih efekata. Očekivani doprinosi ovog istraživanja uključuju spoznaje koje će biti korisne za organizaciju i upravljanje suradničkim CAD aktivnostima uz podršku pomoćne tehnologije za umjetnu inteligenciju.
Summary in English *(no more than 1000 characters with spaces):*	The engineering design process is inherently a collaborative endeavour, involving multiple designers who contribute their skills and knowledge through various design activities to develop technical systems. In this context, emerging technologies like collaborative CAD and AI assistive technologies play a vital role. However, the specific impact of AI assistive technologies on collaborative CAD activities remains unexplored. This research, therefore, aims to develop a theoretical model to understand how AI assistive technologies influence synchronous collaborative CAD activities. Additionally, the study seeks to create a method to measure the impact of AI assistive technologies on these activities, ultimately facilitating an evaluation of their effect on synchronous collaborative CAD activities. The expected contributions of this research include insights that will inform the organization and management of AI-assisted collaborative CAD activities.

Introduction and overview of research conducted hitherto *(suggested length: 7000 characters with spaces)*

Engineering design is a complex and multifaceted process, transforming initial requirements and problem descriptions into technical system representations [1]. The process involves various design activities that collectively lead to the development of a product. The engineering design process extends beyond individual designers' capabilities and is fundamentally a social process, relaying on the collaborative efforts of multiple designers. Each contributor brings unique skills and knowledge to achieve a common goal [2]. This approach to design is known as collaborative design, which spans all stages of product development, from conceptual to detailed design [3].

Computer-Aided Design (CAD) plays a pivotal role in supporting these design processes. CAD allow designers to create digital representations of design (CAD models) and test products virtually before physical manufacturing [4]. This technology has become integral to most engineering design activities. Moreover, the advent of collaborative CAD enables multiple designers to work to the same CAD file synchronously, irrespective of their location [4].

CAD has garnered significant research attention due to its ability to address common collaboration challenges such as cloud-based synchronous editing, seamless file-sharing, and the visibility of design changes [4] As a result, the literature on collaborative CAD activities have mainly focused on the process and problems in collaborative CAD, analysing both behavioural and outcome aspects.

The behavioural facet encompasses elements inherent to CAD and collaboration, such as productivity [5], CAD modelling styles [6] and their sequential nature [7] considering design space and types of CAD user actions [8]. On the collaboration side, factors such as communication and coordination [6], contribution [8], or the sensitivity of number of individuals collaborating [9] are examined. Outcomes are assessed in terms of completeness and consistency [5] or the quality of CAD models relative to design requirements [10]. Different working styles in collaborative CAD, such as synchronous (each designer collaborating in CAD can edit a CAD model simultaneously) or shared (designers collaborating share one control of the CAD interface and model) approaches, have also been explored [5]. Considering synchronous working style, literature has yielded contrasting results, with some evidence suggesting that synchronous collaborative CAD enhances efficiency and the quality of CAD work [11] while others found it does not align with higher performance [12]. Although these studies provide insights into the various elements that are influenced by synchronous collaborative CAD activities, being primarily descriptive, they lack a comprehensive approach to thoroughly understand these elements, including a lack of support to measure, assess, and analyse them.

Artificial Intelligence (AI) is increasingly recognized in engineering design [13]. Its application in design spans from conceptual [14] to detailed design [15] phases, enhancing efficiency, accuracy, and overall productivity. AI is defined as the ability to interpret data and learn from it [16]. It uses this knowledge to achieve specific objectives and potentially augment or replace humans in specific activities [17]. It operates in two operational modes: reactive and proactive. In a reactive mode, AI responds to requests or inputs prompted by a user, giving designers an active role. On the other hand, in the proactive mode, AI initiates actions without direct user prompting, considering the designer as a passive source of feedback. In both cases, AI engages in problem-solving and process-focused activities [18].

AI is more than just a tool for designers; it plays a vital role in supporting them within various tasks and activities [19]. This is primarily achieved through AI assistive technology, a socio-technical system involving a designer with specific goals, tasks needed to achieve those goals, and technology (software, hardware, and data) a designer interacts with to carry out tasks [20]. Literature on AI assistive technology [21] in design has primarily focused on evaluating its impact on the design process [22] or design effectiveness [23], but lacks research on collaboration in design, especially in the context of collaborative CAD. In the context of collaboration in CAD, studies have mainly focused on analysing the influence of AI assistive technology by comparing AI-assisted teams with non-AI-assisted ones, mainly through evaluating design outputs. Thus, Zhang's [24] research suggests that AI assistance may initially hinder high-performing teams but benefit low-performing ones, whereas Song [23] further supports the advantages of AI assistance in design team members' collaboration, showing enhanced team agility. However, while research highlights the potential advantages of AI assistive technology for both individual designers [25] and teams, there remains a need for a more holistic approach in understanding its impact within the context of collaborative CAD activities.

Therefore, the proposed research seeks to explore the underexplored domain of synchronous collaborative CAD activities, focusing on the integration of AI assistive technology. In this context, AI-assisted collaborative CAD involves using collaborative CAD as a key support tool for design, with AI assistive technologies seamlessly integrated into the workflow of synchronous collaborative CAD. While the current literature on CAD activities [23], [24], [26] has utilized AI assistive technology in various capacities, the proposed study aims to investigate the impact of reactive AI assistive technologies on collaborative CAD activities. The goal is to develop a theoretical model that illustrates how AI assistive technology impacts collaborative CAD activities. Accompanying this model will be a methodology designed to quantify this impact. The focus of the research will be on identifying and understanding the various factors influenced by AI assistive technology, and how these factors affect designers collaborating in CAD environments. This model and method will help in evaluating AI assistive technology's role in enhancing key aspects of synchronous work in collaborative CAD environments.

Objective and hypotheses of research[2] *(suggested length: 700 characters with spaces)*

The objectives of the research are to:

1. Develop a theoretical model to understand how AI assistive technology influences key aspects (such as efficiency, accuracy, creativity, or learning) of synchronous collaborative CAD activities.
2. Develop a novel method for measuring the influence of AI assistive technology on synchronous collaborative CAD activities.
3. Conduct a validation of the role of AI assistive technology in enhancing synchronous CAD activities, focusing on specific metrics of newly developed method.

The hypothesis of the research is:

The integration of AI assistive technology leads to measurable improvements in key aspects of synchronous collaborative CAD activities.

Material, participants, methodology and plan of research *(suggested length: 6500 characters with spaces)*

[2] The sequence of listing the objective and hypotheses depends on the area of research.

The purpose of the research is to evaluate the influence of AI assistive technology in collaborative CAD activities, addressing the gap in understanding this influence and how to measure it. A prerequisite is a thorough theoretical understanding of synchronous collaborative CAD activities, their elements, and the means to assess them, particularly focusing on the influence of AI assistive technology. The research approach integrates Design Research Methodology (DRM) [27], Design Science Research framework [28] and the principles of Experimental Design Research [29], structured in four main stages: research clarification, descriptive study I, prescriptive study, and descriptive study II.

<u>Research clarification</u>

In the initial stage, an extensive exploration of existing literature on synchronous collaborative CAD activities and the use of AI assistive technology within these context is conducted. This stage is pivotal to gain a comprehensive understanding of the current state-of-the-art in these domains while identifying gaps in the existing research. The literature reviews are primarily directed toward establishing a theoretical foundation within the context of collaborative design, synchronous collaborative CAD activities, and AI assistive technologies. it delves into a variety of theories, models, and concepts relevant to mentioned phenomena.

The focus here is to conceptualize and operationalize collaborative CAD activities, identifying their key elements and factors influencing them. In addition, methods and tools for measuring and analysing these phenomena will be explored. This comprehensive review of existing experimental frameworks, guidelines, and protocols, spanning disciplines like engineering, psychology, human-AI teaming and human-computer interaction (HCI), aims to refine research goals, questions and hypotheses.

<u>Descriptive study I</u>

Following the research clarification, the second stage significantly expands upon the knowledge base established through the systematic literature review. This phase aims to deepen understanding by delving into more specialized literature and executing preliminary experimental studies. The objective is to further affirm the application of AI assistive technology in synchronous collaborative CAD activities and to identify factors it influences.

This stage also involves assessing the suitability of various metrics, methods, methodologies, and tools for measuring the influence of AI assistive technology in synchronous collaborative CAD activities. A combination of quantitative and qualitative research methods will be employed, including subjective elements such as self-assessment scales, self-report questionnaires, and interviews, as well as performance-related approaches like the analysis of CAD log files, CAD modelling strategies, the degree of AI assistive technology utilization, and task completion time. The preliminary studies will be conducted at the University of Zagreb's Faculty of Mechanical Engineering and Naval Architecture (FMENA), using the available equipment of the Chair of Design and Product Development (CADLab). Participants in these studies will include both experienced engineering practitioners and engineering design students from FMENA, offering a comprehensive perspective that accounts for varying expertise of the individuals involved.

<u>Prescriptive study</u>

The third phase of the research methodology build upon insights gained from the Descriptive study I. It involves developing a theoretical model of AI assistive technology's influence on synchronous collaborative CAD activities. This model will represent the current understanding and include the key elements and identified influencing factors. It serves as the foundation for developing a method to measure and potentially improve AI assistive technology's influence on synchronous collaborative CAD activities. Furthermore, this model and the method will be crucial in evaluating AI assistive technology's effect on enhancing synchronous collaborative CAD activities in the subsequent research stage. The gained understanding of the existing situation will be utilized in designing experimental studies for model and method validation. Designing the experimental studies will include defining the experimental setup, and combining exiting frameworks for data collection, processing, and analysis, such as the MUCAD-CLF framework [8] for the analysis of previously mentioned CAD-inherent elements or established methods to analyse the collaboration-inherent elements such as coordination or communication [30].

<u>Descriptive study II</u>

The final stage focuses on validating the theoretical model through experimental studies, exploring the relationship between the use of AI assistive technologies and collaborative CAD. This validation aims to control influencing factors and analyse their effects on the proposed phenomena. The insights gained here will be pivotal in evaluating the influence of AI assistive technology in collaborative CAD activities.

Apart from validating the theoretical models, this stage includes validating the developed method and assessing the effects of the identified influencing factors. The results of this validation will illuminate the advantages and disadvantages of the proposed method, offering insights into potential refinements. Moreover, the validation of the effects of identified influencing factors will determine if the developed method can effectively contribute to the improving the evaluation of the influence of AI assistive technologies on collaborative CAD activities. The ultimate goal of this stage is to confirm or reject the main research hypothesis by comparing the research results with empirical data and identifying significant factors in the context of AI assistive technologies in synchronous collaborative CAD activities.

In conclusion, the outcomes and datasets obtained will potentially be analysed using AI methods like machine learning and deep learning to support and automate the execution of collaborative CAD activities.

Expected scientific contribution of proposed research *(suggested length: 500 characters with spaces)*

The scientific contributions of the proposed research are:

1. A theoretical model to understand how AI assistive technology influences key aspects of synchronous collaborative CAD activities.
2. A novel method for measuring the influence of AI assistive technology on synchronous collaborative CAD activities.

List of literature cited *(no more than 30 references)*

[1] A. Chakrabarti and L. T. M. Blessing, An Anthology of Theories and Models of Design: Philosophy, Approaches and Empirical Explorations, 2014. doi: 10.1007/978-1-4471-6338-1.
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Total cost estimate of proposed research *(in kuna)*

50 000 EUR

Proposed sources of funding for research

Type of funding	**Title of project**	**Project leader**	**Signature**
National funding	Resources of the DATA-MATION project (Croatian Science Foundation)	Prof. Mario Štorga, PhD. M.E.	
International funding	Resources of the DETAILLs project (ERASMUS)	Prof. Mario Štorga, PhD. M.E.	
Other types of projects	Resources of the Chair of Design and Product Development at UNIZG-FMENA (collaboration with industry, international DESIGN conference organization)	Prof. Mario Štorga, PhD. M.E.	
Self funding	Erasmus+ Traineeship (Application by candidate)		
Session of the Ethics Committee at which consent was given to the research proposal[3]	-		

[3] Fill out only if needed

Agreement of the mentor and the doctoral candidate to request for topic approval

I declare under responsibility that I agree with the topic whose approval is requested.

Signature

Prof. Mario Štorga, PhD. M.E.

Signature

Jelena Šklebar, mag. ing. mech.

STATEMENT

I declare under responsibility that I have not submitted a request for approval of an identical dissertation topic at any other university[4].

Zagreb, 11. 12. 2023.

Signature

Jelena Šklebar, mag. ing. mech.

Official stamp here

[3] Fill out only if needed
[4] Not required in case of dual doctorate (*Cotutelle de these*)