DisMoSim: Hybrid Collaboration in Mechanical Engineering

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Abstract
This position paper describes a research project with a concrete manifestation of hybrid collaboration in the realm of distributed modeling and simulation in mechanical engineering. An envisioned use case is introduced, consisting of two remotely connected teams, each working on an interactive surface to collaboratively create and manipulate a synchronized model of a car chassis. Consequently, the five most important key challenges concerning tool design and characteristics of hybrid collaboration are discussed.

Author Keywords
distributed model simulation; hybrid collaboration; partially distributed teams

Introduction
In order to meet the growing complexity of modern products in vehicle, machine or plant construction, these products are increasingly being broken down into subsystems or modules. The virtual development of the entire system (including modeling, simulation and optimization) is currently typically performed by one person in a solitary work process. This leads, for instance, to the following issues: Because most common software products do not allow synchronous collaboration, the complex and error-prone task of modeling relies on individuals and can lead to inefficient communication and redundant workflows. The simulation

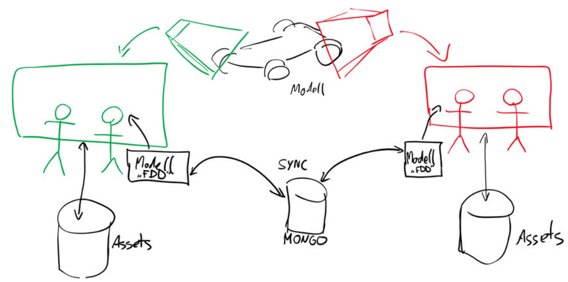

Figure 1: A typical *hybrid collaboration* use case in the research project DisMoSim. Two co-located pairs work together remotely to collaboratively design a model.

of the overall model usually also takes place only at one location, which inevitably results in privacy problems when passing on models between the companies involved. In addition, the data exchange is usually not standardized and is often solved ad hoc and, therefore, inefficiently. From this, the motivation of the research project Distributed Modeling, Control, and Simulation of Cyberphysical Systems (DisMoSim) is derived: The decentralized reality of today's development processes from modeling to simulation to the optimization and verification of cyber-physical systems is dealt with in this project and supported with new software tools. Thereby, the goal is the design, the prototypical implementation and the evaluation of new digital tools and algorithms to support collaborative development in different locations. In the field of 3D modeling, new operating and visualization concepts support more effective and efficient teamwork in and between companies. Multi-touch and pen-based inputs on large displays or mobile devices allow seamless group work in the same place ("co-located") or in distributed teams ("remote"), but place a special emphasize on partially distributed teams engaging in *hybrid collaboration* (see Figure 1). New algorithms for the coupled simulation of the subsystems ensure the know-how protection for model and data exchange between OEMs and suppliers. The adaptation of standardized web technologies guarantees a uniform and efficient data transfer. The achievement of all these goals is underpinned by a concrete test scenario. The distributed modeling, simulation, control and optimization will be demonstrated on a complete vehicle. We expect that DisMoSim creates an infrastructure that enables our institution to assist industry partners with follow-up projects to implement the vision "Industry 4.0", especially in the areas of vehicle, machine and plant construction. The findings will be used in existing and new interdisciplinary courses on "Modeling and Simulation of Cyber-physical Systems".

In this position paper, we reflect on the collaborative modelling and simulation aspects of DisMoSim, and do not elaborate on the technology-centered aspects which are part of the greater project scope.

Use Case

A typical use case we envision is depicted in Figures 1 and 2. A partially distributed team of two co-located pairs is remotely connected via two Microsoft Surface Hubs and works together on a model of a car chassis. The teams use 3D representations of the model that can be manipulated, among other interaction techniques, with the help of pen input and touch gestures. Furthermore, mobile devices can be used to create additional workspaces and territories (e.g., personal or storage territories). However, all devices show the current, synchronized model state.

Key Challenges

This section describes the main challenges we envision to arise from the nature of hybrid collaboration we identified in the related research project DisMoSim.

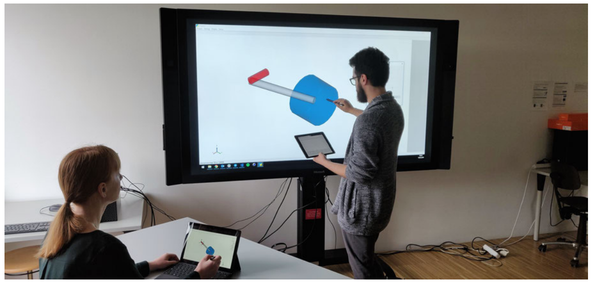

Figure 2: One team in the exemplary *hybrid collaboration* use case in DisMoSim. Two co-located collaborators work together remotely with others to collaboratively design a model.

Key Challenge 1: Real-time Collaboration
For distributed simulation and modeling, it is essential to create an illusion of synchronous collaboration. Feedback has to be provided in a (real-)timely manner, the system has to remain responsive at all times (even when there is a lot of processing going on in the background), which is challenging because the same state has to be presented to all (also distributed) collaborators. Another aspect lies in the question which conflict management mechanism looks most promising to resolve arising interaction conflicts. Several mutual exclusion principles (e.g. to lock currently selected components for all but the collaborator who first selected them) would perfectly solve interaction conflicts, but are not a valid option because of the nature of some modeling tasks. For example, collaborator 1 at location A might virtually hold component X in a 3D space while collaborator 2 at location B turns the same component X around. This is a very common task in mechanical engineering and should, therefore, be also allowed in DisMoSim's simulated environment.

Key Challenge 2: Awareness
Furthermore, it is essential to convey to the collaborators a sense of who does what and where at the moment. This knowledge is called Awareness or more specifically Workspace Awareness when it concerns a common workspace in a collaborative tool (see, e.g., the seminal work by Gutwin & Greenberg [2, 3]). Many collaborative writing tools, such as Google Docs[1] or Overleaf[2], use remote cursors to signal to collaborators where their counterparts currently have positioned their cursors. Similarly, the viewport of other collaborators can be hinted in the UI to show what others currently see. However, these concepts are usually not transferable directly to the 3D space and are thus not tried and tested to the same extent.

Key Challenge 3: Different Forms of Presence
The concept of social presence plays a major role in collaborations that have a remote portion in them and was an important subject in prior research dealing with partially distributed teams (see [1]). There are many different options to consider, such as establishing a shared audio space that can be selectively enabled or disabled, or video feeds of the different collaborators, or even using more abstract representations of them. The design space in this area is large and has to be solved with the help of experiments using realistic tasks and conditions.

Key Challenge 4: Input Techniques
Another important challenge to consider is the use of different input techniques. In the 3D space, touch gestures are not as widely known and adopted by a majority of users in comparison to conventional 2D interfaces. There is some common ground with input techniques used in virtual reality applications, however, the lack of immersion into the 3D

[1] https://www.google.com, last access May 2, 2019.
[2] https://www.overleaf.com, last access May 2, 2019.

space in our use case makes it more difficult for users to readily adopt these techniques. Furthermore, a common input challenge of co-located collaboration is also important to consider here: The mapping between a system interaction and its originator. This is mostly a problem with touch input on a large shared UI, where the system cannot readily distinguish between the different users' interactions. With the use of pens, this can be alleviated, but comes at the cost of less natural gestures compared to touch.

Key Challenge 5: Territoriality
Scott et al. showed that different territories are typically used and needed by users in co-located collaboration [5]. They identified personal, group, and storage territories in co-located tabletop collaboration. Recently, Neumayr et al. [4] discussed that these territories also seem to play an important role in hybrid collaboration. In DisMoSim's use case, we envision to support personal or storage territories on mobile devices and use the Surface Hub as a group territory.

An example for the use of a personal territory in DisMoSim would be to work in a trial-and-error approach by starting a long-lasting operation, such as the calculation of a model simulation. It is conceivable, that other collaborators would not want to notice this or that the operation's originator would not want to share such a preliminary operation with others. This could be done by letting users selectively share operations but caution has to be exercised to prevent a desynchronisation of the shared model.

Conclusion

In this position paper, we described an envisioned use case of the research project DisMoSim that shows a manifestation of hybrid collaboration practice. By the special nature of hybrid collaboration, there are many challenges to address, concerning, e.g., the interaction, workspace awareness, or presence of remote users. We reflected on the main challenges we identified so far but are aware that this list could and should be easily extended over the course of the project and the accompanying research endeavors.

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