Aarhus
University
Department of Computer Science

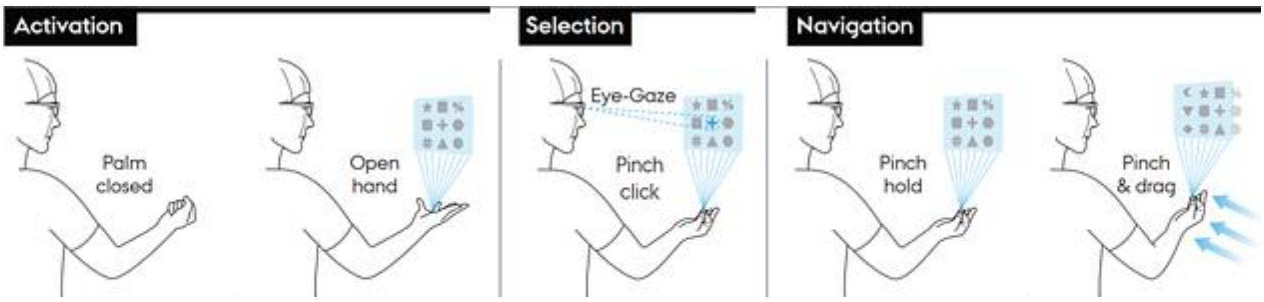
Ubiquitous Computing and Interaction Research Group

[UBI-A] Exploring Multimodal Eyetracking Interfaces and Interaction Techniques For VR/AR

(Ken Pfeuffer – ken@cs.au.dk, Hans W. Gellersen – hwg@cs.au.dk)

Smartglasses and head-mounted displays (HMDs) become increasingly prevalent, with big players like Apple, Microsoft, and Meta taking center stage in the race for the next generation of spatial computing devices and AR/VR. Most current devices show how such devices can be used in stationary places like at home or at work. This project, we aim to take a step beyond the home and explore how we can design user interfaces (UIs) that are as mobile as smartphones, for everyday situations, potentially on the go.

For example, we started to explore the interaction concept in the Figure below. Here, the user opens a "hologram" interface spontaneously, and employs their eyes in tandem with a hand gesture to rapidly access mobile applications. However, a lot of new challenges arise in this context. For example, where to place the UI window, how to interact with the content, and even what types of content may be of interest. While smartphone UIs have matured over time, 3D UIs for AR/VR, especially to afford mobility, are so far underexplored in the research field of human computer interaction. Potential questions include: how to design a music player that one can quickly engage in? How to have the counterpart of an image gallery, Instagram, Facebook, etc.? How to design a spatial browser? Some of these tools exist, however the main question here is how novel sensing technologies such as hand-tracking and eye-tracking will provide novel and efficient experiences for the user.



The potential group of students will explore user interface designs and interaction techniques in this space. Students will learn and develop skills in 3D programming by using the Unity platform. They will also gain experience with design, implementation, and evaluation with using head mounted devices (e.g., Vive Pro, Hololens 2, Oculus Quest 2).

Related Literature:

- Ken Pfeuffer, Jan Obernolte, Felix Dietz, Ville Mäkelä, Ludwig Sidenmark, Pavel Manakhov, Minna Pakanen, and Florian Alt. 2023. PalmGazer: Unimanual Eye-hand Menus in Augmented Reality. In Proceedings of the 2023 ACM Symposium on Spatial User Interaction (SUI '23).
  - Blog & videos: https://link.medium.com/soHaLGQ14Db (or here)
  - PDF: https://kenpfeuffer.files.wordpress.com/2023/10/palmgazer_sui_final-1.pdf

[UBI-B] Exploring the Layers of Mixed Reality

(Ken Pfeuffer – ken@cs.au.dk, Hans W. Gellersen – hwg@cs.au.dk)

Video passthrough MR is the latest hype in the Extended Reality (XR) space pioneered by industry players including Apple and Meta. Through the recent launches of their most advanced devices, they envision a future where everyone will be wearing one of those devices and living among virtual windows and objects filling up our vision.

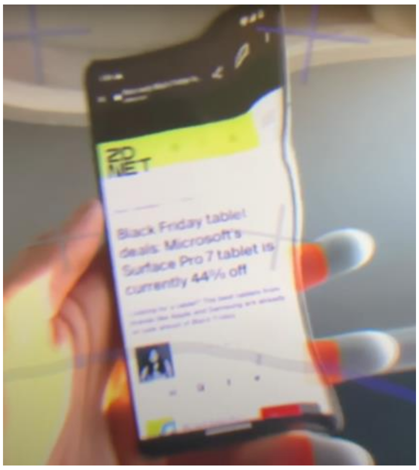
Aarhus
University
Department of Computer Science

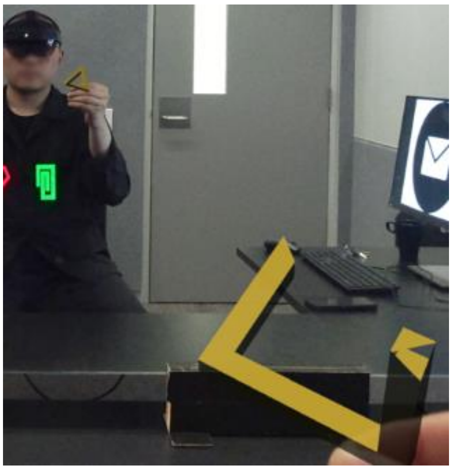
Ubiquitous Computing and Interaction Research Group

**Contact: Hans-Jörg Schulz
hjschulz@cs.au.dk**

Date: 08 November 2024

Please direct project-related inquiries to the respective contact person of the project.



However, how ready are we to jump from using screen-based devices to using MR glasses? What's the best way to move digital content from our smartphones to the MR space if we can't see them clearly anymore? How do we use MR glasses and physical screens interchangeably or together? Are we building the ultimate distraction machine or the opposite with the panoramic digitally rendered MR space? What happens when every pixel in the visible world becomes responsive to your gaze? How would we want to see our hands and bodies in MR?

In this project, you will work with the latest generations of MR devices and build interfaces that communicate across MR glasses and screen-based devices such as smartphones and laptops. Together, we will explore interesting topics including novel use of gaze tracking across different layers of reality (video-captured physical space, video-captured screens, virtual windows), adaptive rendering of digital contents with smart transitions between layers of reality, and/or novel uses of our reflected images in mirrors.

Related Literature:

- Zhou et al. 2023. Reflected Reality: Augmented Reality through the Mirror. In Proc. of IMWUT. https://qiushi-zhou.github.io/PDF/IMWUT-2023-RR.pdf

[UBI-C] Beyond Talking to the Wall: Gestures, Speech, and Touch for Visualization Dashboards (Vaishali Dhanoa – dhanoa@cs.au.dk, Gabriela Molina León – leon@cs.au.dk, Niklas Elmqvist – elm@cs.au.dk)

Dashboards or interactive visualizations linked together in a single-page display help users gain insights from data. Due to their interactive nature, they are frequently displayed in the public domain, commonly used by organizations and businesses to explore data alone or collaboratively. However, dashboards are usually created by a single author using traditional input with a mouse and a keyboard. Can we make use of different input modalities, such as touch gestures and speech commands, to provide a richer interactive experience for dashboard creation? Once the dashboard is ready, can we make the usage of the dashboard also a multimodal experience?

An analyst designing a visualization dashboard (DALL·E 2)

Contact: Hans-Jörg Schulz
hjschulz@cs.au.dk

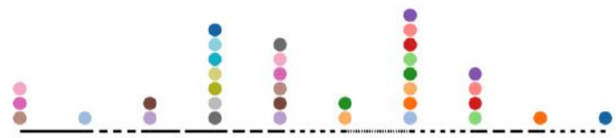
In this project, we aim to design a multimodal visualization tool (i.e., combining multiple input modalities) to support a dashboard authoring experience. The students will experiment and choose among diverse input modalities, such as touch gestures, pen interaction, speech commands, and mid-air gestures, to support multiple tasks, such as creating visualizations, adding interactive elements, and adding data and its transformations. They will develop an interactive prototype of a dashboard, most likely using Typescript, HTML, CSS, React or Vue.js, that they will test with potential dashboard users (if time allows). Accordingly, they will gain experience in designing and implementing web-based visualizations with diverse interaction technologies.

Related Literature and Inspiration:

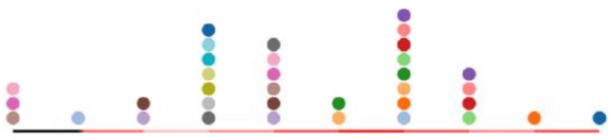
- Tamara Munzner. 2014. Visualization Analysis and Design. CRC Press.
- Vaishali Dhanoa, Andreas Hinterreiter, Vanessa Fediuk, Niklas Elmqvist, Eduard Gröller, and Marc Streit. 2024. D-Tour: Semi-Automatic Generation of Interactive Guided Tours for Visualization Dashboard Onboarding. IEEE Transactions on Visualization and Computer Graphics.
- Gabriela Molina León, Anastasia Bezerianos, Olivier Gladin, and Petra Isenberg. 2024. Talk to the Wall: The Role of Speech Interaction in Collaborative Visual Analytics. IEEE Transactions on Visualization and Computer Graphics.
- Bongshin Lee, Petra Isenberg, Nathalie Henry Riche, and Sheelagh Carpendale. 2012. Beyond Mouse and Keyboard: Expanding Design Considerations for Information Visualization Interactions. IEEE Transactions on Visualization and Computer Graphics.

[UBI-D] Accordion-based Time-Series Visualization (Niklas Elmqvist – elm@cs.au.dk)

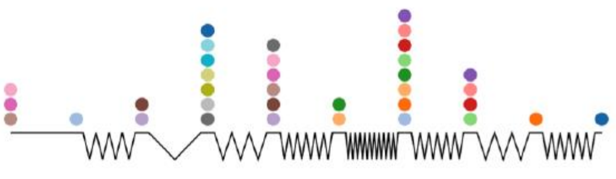
Time series data is everywhere–from stock markets to social media trends to climate measurements–but viewing this data effectively remains challenging when interesting patterns occur at different time scales. This project explores an approach to interactive time-series visualization inspired by the accordion metaphor, building on pioneering visualization work on accordion drawing (PRISAD) and time-series exploration (LiveRAC). The core idea is to adaptively compress and expand different regions of a timeline while guaranteeing that important data points remain visible, much like the folds of an accordion can compress or stretch while maintaining its structure.



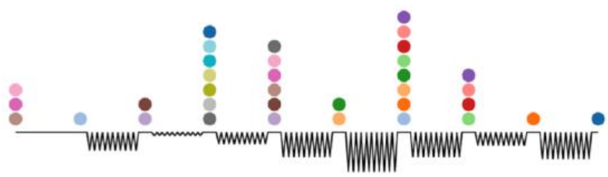
(c) Stipples (STP)



(d) Transparency (ALP)



(e) Coils w/ numbers (CLN)



(f) Coils w/ amplitude (CLA)

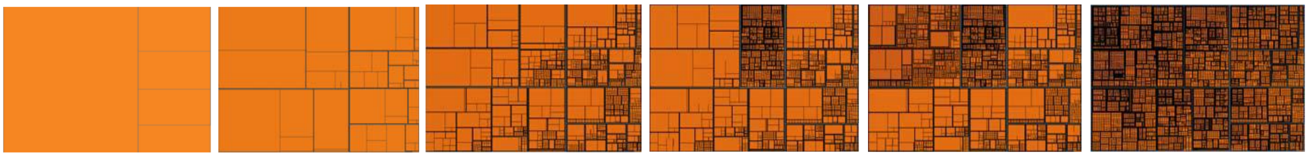
This project will involve developing an interactive visualization system that allows users to dynamically explore time series data through fluid zooming and flexible compression. The system will support both continuous compression for less important regions and complete breaks for irrelevant periods, with clear visual cues to help users understand scale changes. While our initial focus is on temporal data, we'll explore extending these techniques to handle multiple dimensions of data compression. This project offers opportunities to work with modern web technologies for interactive visualization while tackling fundamental challenges in data visualization and human-computer interaction.

Related Literature:

- James Slack, Kristian Hildebrand, and Tamara Munzner. Partitioned Rendering Infrastructure for Scalable Accordion Drawing. Information Visualization, 5(2), p. 137-151, 2006.
- Peter McLachlan, Tamara Munzner, Eleftherios Koutsofios, Stephen North. LiveRAC - Interactive Visual Exploration of System Management Time-Series Data. Proc. Conf. on Human Factors in Computing Systems (CHI) 2008, pp 1483-1492.

[UBI-E] Agent-based Progressive Charts (Hans-Jörg Schulz – hjschulz@cs.au.dk)

Progressive Visualization is a chart drawing paradigm, where not all data is shown at once – possibly after a lengthy layout computation – but instead added bit by bit to a chart so that it “evolves” from a rough sketch to the final polished visualization. A few progressive visualizations techniques are already known, such as Progressive Treemaps (see image below), Progressive Parallel Coordinates, or Progressive Scatterplots / Dotmaps.



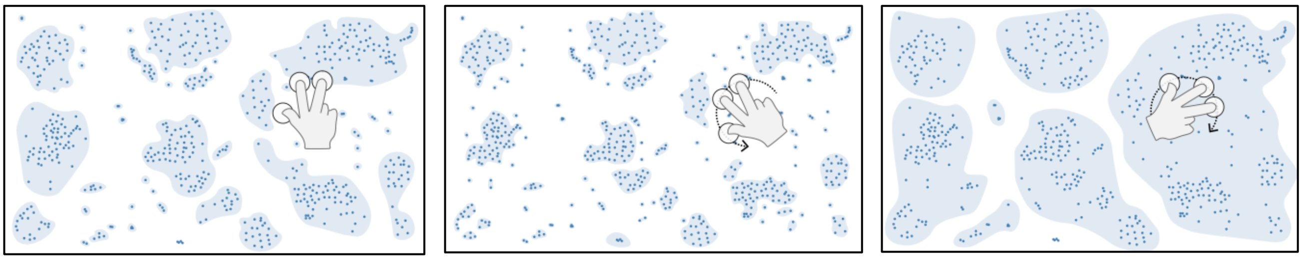
Yet for a variety of other charts, it is still open how to integrate such a progressive visualization paradigm with them and their usual layout algorithms. In this project, it is your task to try a new approach to progressive visualization and to use agent-based approaches to create suitable candidates for progressive line charts or progressive tree diagrams. The idea behind this is to place a number of autonomous agents in/on the dataset and let them progressively build-up the visualization – instead of funneling chunks of data through a monolithic visualization pipeline.

Related Literature:

- Rosenbaum et al. 2009 “Progressive Presentation of Large Hierarchies Using Treemaps” in “Advances in Visual Computing”, Springer. doi: https://doi.org/10.1007/978-3-642-10520-3_7
- Rosenbaum et al. 2012 “Progressive parallel coordinates”. Proc. of IEEE PacificVis. doi: https://doi.org/10.1109/PacificVis.2012.6183570
- Angelini & Santucci 2013 “Modeling Incremental Visualizations”, Proc. of EuroVA. doi: http://doi.org/10.2312/PE.EuroVAST.EuroVA13.013-017

[UBI-F] Multitouch Interaction for Data Analysis (Hans-Jörg Schulz – hjschulz@cs.au.dk)

In data science and data mining, keyboard and mouse interaction dominate the field. This presents a bottleneck, as human intentions have to be funneled into the “Morse code” of clicks and drags in graphical user interfaces or be typed out in a command line. To expert users, this bottleneck imposes interaction costs that may make working with a computer tedious, but not impossible. To novices and laymen, though, this bottleneck may become an insurmountable hurdle. It will be your task to remove mediating interaction devices and menu structures, so as to manipulate and transform data more directly with one's own hands. To that end, you will develop touch gestures for complex operations like clustering or dimensionality reduction that strive to be as intuitive as the now universal pinch gesture for zooming in or out of images.



Example: 3-finger tap&hold gesture to initiate a clustering. Rotate gesture left to yield smaller clusters. Rotate gesture right to yield larger clusters.

Related Literature:

- Chakraborty and Stuerzlinger 2021 “VizInteract: Rapid data exploration through multitouch interaction with multi-dimensional visualizations”, in Proc. of Human-Computer Interaction – INTERACT, Springer. doi: https://doi.org/10.1007/978-3-030-85613-7_39
- Nielsen et al. 2016 “Scribble query: Fluid touch brushing for multivariate data visualization”, in Proc. of Australian Conf. on Computer-Human Interaction. doi: https://doi.org/10.1145/3010915.3010951
- Schmidt et al. 2010 “A set of multitouch graph interaction techniques” in Proc. of the ACM Intl. Conference on Interactive Tabletops and Surfaces (ITS). doi: https://doi.org/10.1145/1936652.1936673

[UBI-G] Seamless music streaming room to room (Niels Olof Bouvin – bouvin@cs.au.dk)

This project explores network communication, mobile and server development, personal presence, identity, and preference, as well as collaborative spaces, and integration with and data mining of streaming services. The goal is to develop one of two scenarios, both involving music.

[UBI-G1] A home with speakers in each room

As the user comes home, their music transitions seamlessly from their phone (or other music player) to the loudspeakers in the home. As the user moves from room, their music follows them, so that it is not playing where they are not. If the home is not a single residency, the system keeps track of where the inhabitants are and adjusts the playback accordingly. The music is of course always in sync throughout the home. If there are multiple people, the system can combine their playlists and personal preferences into a shared playlist. Guests can be granted temporary access to affect the playlist.

[UBI-G2] A public place with one speaker and a communal playlist

There is one speaker system and thus only one playlist. The people present can make suggestions to the playlist, and others can in return vote or influence what is going to played next. People who have demonstrated good taste according to the room (upvoted songs) are given higher weight and influence. If no-one is voting, the system automatically plays music that matches the collective taste of those present.

Both projects involve developing a sensor platform that can reliably detect presence through, e.g., Bluetooth LE beacons, ultrasound sensors, or camera input. The sensed data is used to create a context sensitive system combined with what can be gathered from the users’ online music profiles. Finally, the playback requires synchronization across different devices. From a concrete scenario, students will gain experience and understanding of Ubiquitous Computing fundamentals as well as advanced topics, distributed programming, and Web integration with existing services.

[UBI-H] Educational machine learning with the micro:bit

(Niels Olof Bouvin – bouvin@cs.au.dk, Karl-Emil Kjær Bilstrup, Magnus Høholt Kaspersen)

Note: This bachelor project takes place within the context of Center for Computational Thinking & Design (https://cctd.au.dk) at AU.

This project explores physical computing, machine learning education, and web-based development, focusing on expanding the educational potential of the ml-machine.org platform. The goal is to enhance the platform's capabilities by incorporating additional sensor inputs beyond the current accelerometer-based classification, enabling richer learning experiences and more diverse machine learning applications.

The project builds on ml-machine.org's approach of allowing learners to create classification models through direct interaction with sensor data. By integrating new sensor types (such as sound, light, magnetometer, or moisture sensors) available for the BBC micro:bit, students can explore more complex classification scenarios and real-world applications. This expansion creates opportunities for learners to understand how different types of sensor data can be combined and processed for machine learning tasks.

Key technical challenges include:

- Designing an intuitive web-interface for collecting and visualizing multi-sensor data streams
- Developing appropriate feature extraction methods for different sensor types
- Creating meaningful educational scenarios that demonstrate the value of using different sensors
- Ensuring real-time processing and feedback remains smooth with multiple data streams
- Maintaining the platform's accessibility while increasing its complexity

The project involves both technical development and educational design aspects. The project could:

1. Research and implement effective ways to represent multiple sensor streams in the web interface
2. Design and evaluate example scenarios that showcase the educational value of different sensor combinations
3. Develop appropriate visualization techniques for various sensor types
4. Study how learners interact with and understand multi-sensor machine learning concepts
5. Consider scalability and performance implications of processing multiple sensor streams

Through this project, you will gain experience with physical computing, web development, machine learning concepts, user interface design, and educational technology. The project combines hands-on technical implementation with consideration of learning theory and user experience, making it suitable for those interested in both technical and human aspects of computing.

Related Literature:

- Karl-Emil Kjær Bilstrup, Magnus Høholt Kaspersen, Marie-Louise Stisen Kjerstein Sørensen, and Marianne Graves Petersen. 2022. Opportunities and Challenges of Teaching Machine Learning as a Design Material with the micro:bit. In Adjunct Proceedings of the 2022 Nordic Human-Computer Interaction Conference (NordiCHI '22 Adjunct). Association for Computing Machinery, New York, NY, USA, Article 45, 1–6. https://doi.org/10.1145/3547522.3547689
- https://ml-machine.org, https://github.com/microbit-foundation/cctd-ml-machine
- https://createai.microbit.org, https://github.com/microbit-foundation/ml-trainer

[UBI-I] Expanding the interaction with large language models (Marianne Graves Petersen – mgraves@cs.au.dk, Magnus H. Kaspersen, Karl-Emil Kjær Bilstrup)

This bachelor project takes place within the context of Center for Computational Thinking & Design (https://cctd.au.dk) at AU.

This project investigates different interface approaches for interacting with large language models (LLMs). While most current LLM interfaces are minimalist and text-based, often resembling command-line/messaging interactions, a GUI could offer new ways to structure, visualize, and control interactions with LLMs.

The project poses the question, *how might GUI elements improve the user experience of LLMs?* You should explore, e.g., how GUI might support making complex interactions more accessible and visually structured. Using APIs such as OpenAI or Hugging Face, you will develop a web-based platform that helps users engage with LLMs in new ways. The interface could allow users to build and manage prompts, track conversation flow, and view model responses in real-time. You will critically examine how to present and manage LLM-generated content to aid users in more effectively steering and understanding AI-driven conversations.

Novel interaction patterns for LLM conversation

- Graphical user interface design for LLMs
- Real-time integration with LLM APIs
- Implementation of interactive prototypes
- User testing and evaluation

The project combines elements of human-computer interaction, interaction design, and LLMs. You will gain experience with interface design, prototype development, and user evaluation while contributing to our understanding of how different interaction modalities can support LLM interaction.

[UBI-J] Expanding the educational interfaces of generative AI (Marianne Graves Petersen – mgraves@cs.au.dk, Magnus H. Kaspersen, Karl-Emil Kjær Bilstrup)

This bachelor project takes place within the context of Center for Computational Thinking & Design (https://cctd.au.dk) at AU.

These projects investigate different interface approaches for teaching and understanding generative AI (GenAI) concepts such as image generation and large language models. Current interaction techniques and GenAI platforms aim to be as frictionless as possible. However, for education, adding friction might provide new learning opportunities and demonstrate the inner workings of a technology. The goal with these projects is to design graphical (GUI) and tangible (TUI) user interfaces in an educational context, exploring how different interaction techniques can support learning about key concepts in GenAI.

[UBI-J1] Interactive Web Platform for Learning about GenAI

This project asks the question, how can we design a GUI that scaffolds understanding GenAI? This project centers on creating a web-based platform designed to visualize and explain fundamental processes within GenAI. The project should use existing GenAI APIs such as OpenAI or Hugging Face and focus on exploring the design of the interface for such systems in an educational setting. This project requires you to think critically about how to present abstract AI concepts visually, using clear representations and accessible tools to guide users through the complexities of generative AI.

[UBI-J2]: Tangible Interface for Learning about GenAI

This project asks, how can a tangible user interface (TUI) make otherwise intangible aspects of GenAI graspable and understandable. You will design and implement a tangible interface that makes abstract AI concepts concrete through physical manipulation. This could involve physical controls for parameters, tangible representations of data or model states, and immediate physical feedback. Key aspects include mapping AI concepts to physical interactions, designing tangible controls, and creating meaningful feedback mechanisms.

Both projects could consider:

- Learning objectives for GenAI
- User interface design for different interaction techniques and modalities
- Real-time integration with GenAI APIs
- Methods for providing meaningful feedback
- Implementation of interactive prototypes
- User testing with students or other learners

The project combines elements of human-computer interaction, educational technology, and AI systems. You will gain experience with interface design, prototype development, and user evaluation while contributing to our understanding of how different interaction modalities can support AI education.

Related Literature:

- Magnus Høholt Kaspersen, Karl-Emil Kjær Bilstrup, and Marianne Graves Petersen. 2021. The Machine Learning Machine: A Tangible User Interface for Teaching Machine Learning. In Proceedings of the Fifteenth International Conference on Tangible, Embedded, and Embodied Interaction (TEI '21). Association for Computing Machinery, New York, NY, USA, Article 19, 1–12. https://doi.org/10.1145/3430524.3440638
- Karl-Emil Kjær Bilstrup, Magnus Høholt Kaspersen, Niels Olof Bouvin, and Marianne Graves Petersen. 2024. Ml-machine.org: Infrastructuring a Research Product to Disseminate AI Literacy in Education. In Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems (CHI '24). Association for Computing Machinery, New York, NY, USA, Article 272, 1–16. https://doi.org/10.1145/3613904.3642539
- Luke John Connelly. The Engine Room. https://maskinrummet.github.io