Aarhus
University
Department of Computer Science

Ubiquitous Computing and Interaction Research Group

Bachelor Projects

Contact: Hans-Jörg Schulz
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Date: 14 November 2022

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

[UBI-A] How can Mixed Reality blend different spaces for collaboration?

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

We need better tools for doing work together over distance! Virtual Reality (VR) is increasing in popularity as a commercial solution for more embodied remote collaboration. Metaverse apps like Spatial (https://www.spatial.io/) are being adopted for creative meetings where people can break out of their boring Zoom windows and be together in a virtual 3D world. In VR collaboration, users are embodied as avatars, but they cannot move around in their own physical environment – only teleport around in the virtual environment. With new headsets that have Mixed Reality capabilities, collaboration experiences can combine elements from the virtual and the real world to provide a "blended" space. This enables new exciting opportunities. For instance, users can be in different rooms and sit at their individual tables, move physically around, and draw on their individual whiteboards, while seeing each other's avatars embedded in their own physical environment as if they were sitting at the same table, or drawing on the same whiteboard.

But challenges arise when users' physical rooms are dissimilar (see the example in the figure above). A few works have started to explore this [1, 2], but there are still many open research questions. How can Mixed Reality interfaces incorporate elements such as furniture and walls from multiple users' physical spaces? How can such physical elements be mapped to each other, (e.g., blending users' different physical desks as a shared Mixed Reality meeting table)? This project will explore and develop this design space of possibilities for blending spaces. The outcome will be a set of prototypes that demonstrate new techniques for blending spaces. These can be evaluated with users to study their collaborative benefits and limitations.

Related Literature:

[1] Lehment et al. 2014 "Creating automatically aligned consensus realities for AR videoconferencing" in Proc. of IEEE ISMAR. doi: https://doi.org/10.1109/ISMAR.2014.6948428

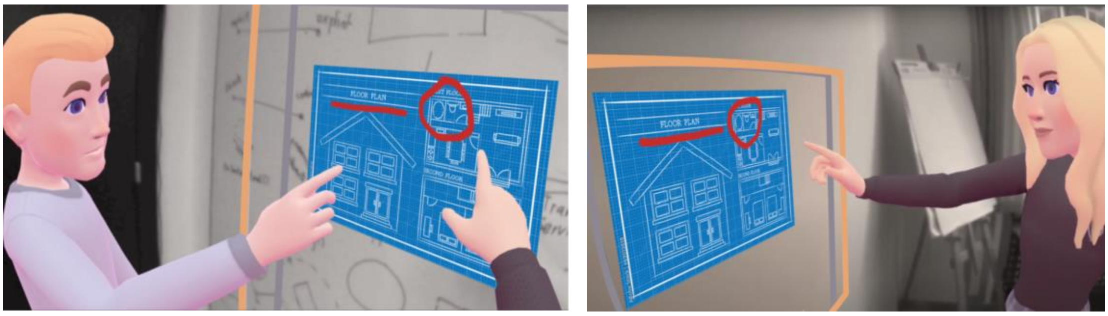
[2] Yoon et al. 2021 "A Full Body Avatar-Based Telepresence System for Dissimilar Spaces" arXiv preprint arXiv:2103.04380. url: https://arxiv.org/abs/2103.04380

[UBI-B] Remote Mixed Reality whiteboard collaboration

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

Being creative together over distance is challenging. Tools such as Zoom provide features for spontaneous creativity, such as virtual whiteboards. But, as well-stated in the Microsoft Future of Work report, "We don't yet have an awesome replacement for getting the right nerds in a room at the same time, with a whiteboard" [1]. Imagine being able to break out of your 2D Zoom window, and instead meet remotely in 3D with your friend or colleague around your own physical whiteboard, where you can freely sketch and place both physical and digital objects (such as documents, post-it notes, or even 3D models) while you generate ideas together.

This project will explore how to use Mixed Reality, via AR/VR headsets (e.g., the just released Meta Quest Pros [2]), to enable remote creative collaboration around real whiteboards. Users can move around in their respective physical rooms, with a real whiteboard each, but see remote others as avatars. Students will develop



prototypes with interaction techniques that use the sophisticated tracking capabilities of AR/VR headsets. Techniques should aim to enable a sense of social presence that allows remote users to collaborate around a shared virtual whiteboard, which mixes virtual content (e.g., playable videos, digital documents, 3D models, etc.) with real content from users' respective physical whiteboards (e.g., real drawings, post-its, etc.). Once students have a prototype of this interactive experience, they will learn how to conduct a small collaboration experiment, user their prototype as the platform to study with users how a mixed reality whiteboard experience compares to Zoom whiteboards and/or real whiteboards.

Related Literature:

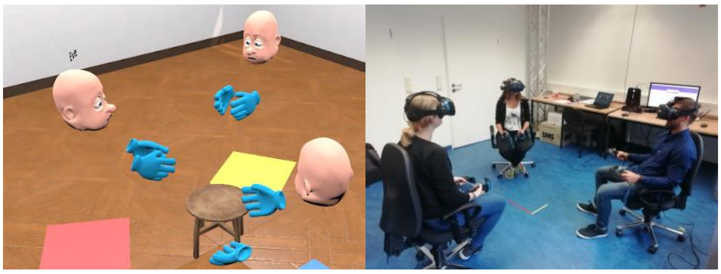
[1] Baym et al. 2021 "Collaboration and Meetings." In The New Future of Work: Research from Microsoft on the Impact of the Pandemic on Work Practices, Microsoft. url: https://aka.ms/newfutureofwork

[2] Meta Quest Pro. url: https://www.meta.com/dk/en/quest/quest-pro/

[UBI-C] Multimodality in Virtual Reality Collaboration

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

Enter VR! This project investigates how human conversation in Virtual Reality (VR) can be designed with and is affected by the inclusion of non-verbal cues. In VR, most current social applications do not support a range of non-verbal cues, e.g., user's body, eye movement, hand movement, finger tracking, or face/mouth expressions. Instead, an often-static looking avatar is employed. But what makes a virtual conversation natural? Are all modalities necessary or would a partial coverage be sufficient? How do different user representations affect our social interaction?



To investigate these questions, the main goal is to develop a multi-user multi-modal VR prototype. This includes using at least 2 headsets and synchronizing them in one virtual scene over the network. For example, implementation in Unity and using a modern VR device such as the Vive Pro or Oculus Quest 2. It is possible to develop this in a local lab space where two users sit next to each other. Optionally, users may be remotely located. Further potential tasks and follow-up projects include a comparison of multi-user conversations with different support of modalities, to assess their impact on the user experience, immersion, and "naturalness".

Related Literature:

- Auda et al. 2021. "I'm in Control! Transferring Object Ownership Between Remote Users with Haptic Props in VR". In Proc. of SUI '21, https://www.dropbox.com/s/ka63cr52tvvvmfd/_SUI_2021.pdf?dl=0

[UBI-D] Understanding haptics and touch in (remote) physical Mixed Reality

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

Enter MR! This project explores how physicality can aid collaboration in Mixed Reality. Current VR devices allow remote collaboration but are completely virtual - without info on the physical environments. This includes objects users may have (pen, drinks, etc.), the people themselves in remote collaboration (body, head, hands, gaze, ...), and the environment (e.g., table, chair, ...). By supporting such physical aspects, remote collaboration could in principle become more tangible and natural, as if sitting side by side.

To investigate these issues, the main goal is to develop a system in VR where physical objects in the environment are tracked and integrated in the VR scene. This is, e.g., possible by using markers placed on objects that are tracked by a motion tracking system. Implementation can for instance be conducted in Unity, and prototyping in a given VR headset. Further tasks can include, e.g., to investigate how these objects can be synchronised to remote users, e.g., through virtual representations, potentially over the network. A further potential task is an evaluation with users, that assesses the pros and cons of adding physicality to remote collaboration.

Related Literature:

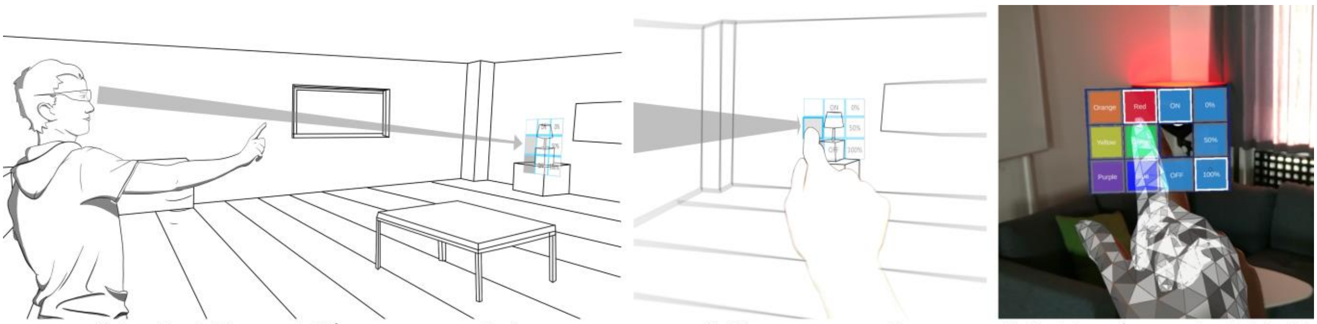
- Auda et al. 2021. "I'm in Control! Transferring Object Ownership Between Remote Users with Haptic Props in VR". In Proc. of SUI '21, https://www.dropbox.com/s/ka63cr52tvvvmfd/_SUI_2021.pdf?dl=0

[UBI-E] Eye Based Interaction in Augmented Reality

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

Enter AR! Future Augmented Reality (AR) smart glasses may replace our phones, raising many new design challenges such as how users interact without traditional mouse, keyboard, and touchscreen. In this project, we investigate how we can design the UI of AR devices using novel spatial sensing capabilities. Especially, how freehand gestures and eye tracking can be fused to provide novel types of interactions. Hand gestures alone support only a constrained limited range, however can be extended by using the eyes to point at objects of interest.

For example, we started to explore the interaction concept in the Figure below. The user invokes selection commands by aligning the index finger exactly in line with the object they look at (A-B). It can e.g. be useful to interact with context menus situated in the world using the HoloLens 2 (C).



A) Eye-Hand Alignment (3rd person perspective) B) 1st person perspective C) Prototype for a context UI in AR

The potential group of students will explore further explorations 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). Example use cases include:

Continuous input: How can a user drag & drop an object by using their eyes and hands? E.g., continuous input in the form of a line or other shape? Project tasks involve 1) design of techniques that allow continuous input with eye and hands, 2) implementation of those techniques in prototypes, and 3) user testing to get insights into their usability.

Eye-refocus interaction: Humans can instantly refocus their eyes between large distances –for example between a far-away restaurant, and the close-by hand. Could we exploit this, e.g., to transfer information across distance? In this project, students will learn how to explore a completely new interaction concept. Tasks include investigating how well such eye refocus can be tracked, and how it can be exploited for interaction with interfaces in AR.

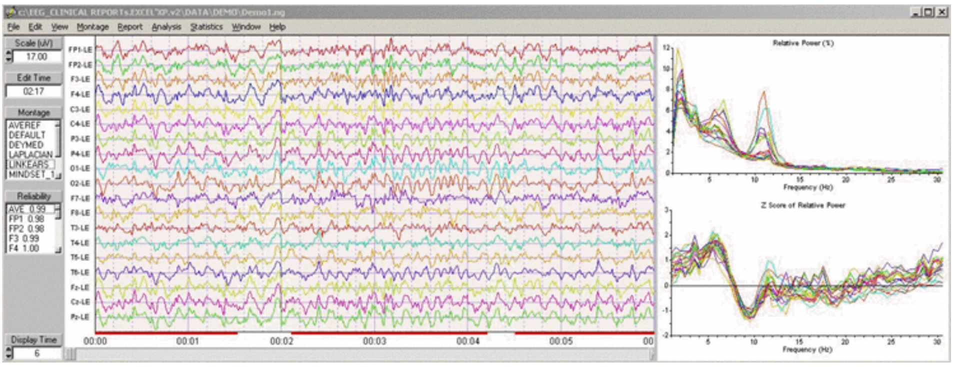
Related Literature:

- Pfeuffer et al. 2017. "Gaze + pinch interaction in virtual reality". In Proc. of SUI '17. https://doi.org/10.1145/3131277.3132180, https://youtu.be/NzLrZSF8aDM

[UBI-F] A Tool for Visual-Analytic Anomaly Detection and Correction in of EEG Data

(Hans-Jörg Schulz – hjschulz@cs.au.dk)

Electroencephalography (EEG) measures the voltage variations from electric currents in the brain. EEG data can be used to diagnose a wide range of health issues from sleep apnea to epilepsy. Anomalies in EEG data (called *artifacts*) can occur for a variety of reasons from malfunctioning sensors to patients' movements; and what qualifies as artifact depends heavily on the used EEG device and the study scenario. In practice, artifact detection is usually semi-automated with machine-learning methods performing an initial detection pass and human experts manually correcting their results. It will be your task to build an interactive visual analysis tool that integrates these two steps more tightly in a mixed-initiative approach where the running artifact detection points the user to artifacts in the data, and where the adjustments made by the user in turn reconfigure and steer the running algorithm to yield better results.



Related Literature:

- Sadiya et al. 2021 "Artifact detection and correction in EEG data: A review", Proc. of IEEE/EMBS Conference on Neural Engineering. doi: https://doi.org/10.1109/NER49283.2021.9441341
- Makonin et al. 2016 "Mixed-Initiative for Big Data: The Intersection of Human + Visual Analytics + Prediction", Proc. of HICSS'16. doi: https://doi.org/10.1109/HICSS.2016.181
- Slayback et al. 2018 "Novel Methods for EEG Visualization and Virtualization", Proc. of IEEE International Symposium on Circuits and Systems. doi: https://doi.org/10.1109/ISCAS.2018.8351688

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Date: 14 November 2022

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[UBI-G] Organic Charts – Nature-inspired Rendering for Data Visualization

(Hans-Jörg Schulz – hjschulz@cs.au.dk)

In data visualization, in particular in visual presentation scenarios, different rendering styles can be used to give otherwise common charts or diagrams a unique look & feel. The field of visualization knows a number rendering styles, such as sketchy rendering, impasto rendering, or watercolor rendering (see below).

Your task in this project is to invent and implement an organic rendering style for selected charts (preferably implicit tree diagrams) that gives a chart an organic – i.e., "amoebic" or "cellular" – look & feel that can be parametrized in its distortion of the underlying chart in a smooth manner from clear-cut & straight to amorphous & blobby. You can find some inspiration for that in the related literature.

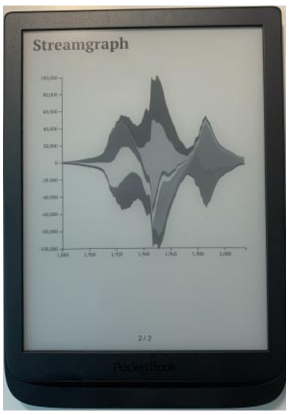
Related Literature:

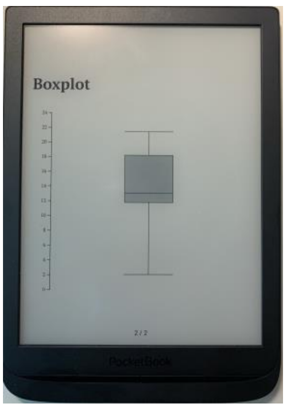
- Görtler et al. 2018 "Bubble Treemaps for Uncertainty Visualization", IEEE TVCG. doi: https://doi.org/10.1109/TVCG.2017.2743959
- Collins et al. 2009 "Bubble Sets: Revealing Set Relations with Isocontours over Existing Visualizations", IEEE TVCG. doi: https://doi.org/10.1109/TVCG.2009.122
- Hlawatsch et al. 2014 "Bubble hierarchies". Proc. of Workshop on Computational Aesthetics. doi: https://doi.org/10.1145/2630099.2630107

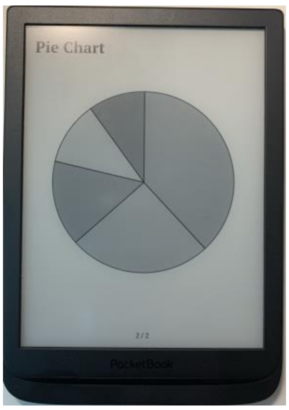
[UBI-H] Interactive Table of Contents Visualization on eReaders

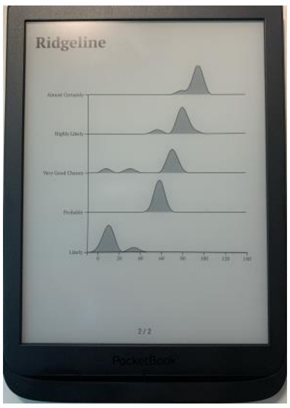
(Hans-Jörg Schulz – hjschulz@cs.au.dk)

Even in the age of e-books, we still rely on very simplistic forms to provide tables of contents to the readers. This is usually in the form of an indented list, potentially with clickable entries that take the reader directly to the indicated position in the book. But modern eReaders compatible with the ePub 3 standard can do so much more – for example, they are able to run JavaScript embedded in ebooks. In previous work, we have already been able to get the visualization library D3.js working on eReaders by injecting it into epub-files (see below). It will be your task to expand on this work and make use of it for inventing a modern, visual-interactive form of tables of contents to be used for e-books.







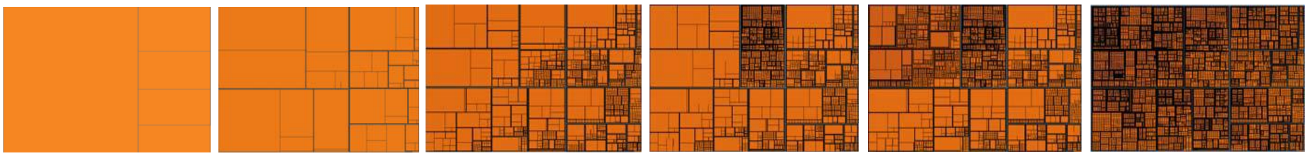


Related Literature:

- I.Talavera 2022 “Exploring the possibilities of Data Visualization in e-inks displays and the EPUB format”. AU-CS Project Report. (available upon request by contacting hjschulz@cs.au.dk)
- Bostock et al. 2011 “D³ Data-Driven Documents”, IEEE TVCG 17(12). doi: https://doi.org/10.1109/TVCG.2011.185 (see also https://d3js.org)

[UBI-I] Progressive Visualization Techniques (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 fill some of these gaps and to propose – e.g., Progressive Line Charts, Progressive Area Charts, Progressive Chord Diagrams, Progressive Icicle Plots / Sunbursts, Progressive Venn Diagrams, Progressive Tag Clouds, or Progressive Cartograms.

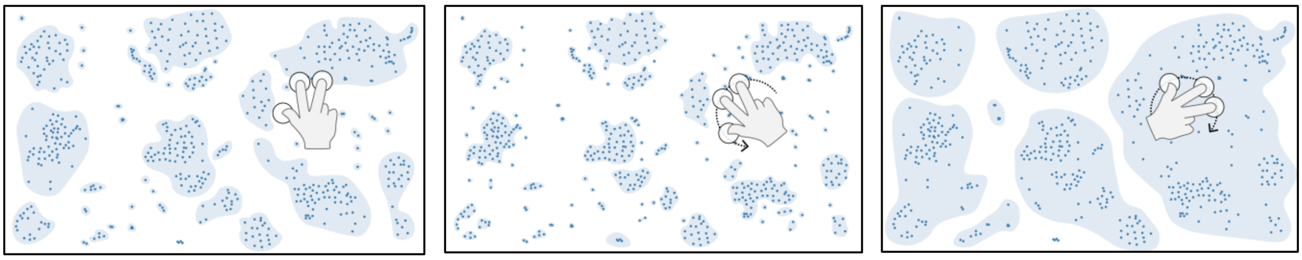
Related Work:

- 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
- Huron et al. 2013 “Visual sedimentation”, IEEE TVCG. doi: https://doi.org/10.1109/TVCG.2013.227
- Angelini & Santucci 2013 “Modeling Incremental Visualizations”, Proc. of EuroVA. doi: http://doi.org/10.2312/PE.EuroVAST.EuroVA13.013-017

[UBI-J] Developing Multitouch Interaction for Data Analysis (Marius Hogräfer – mhograefer@cs.au.dk & 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.

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



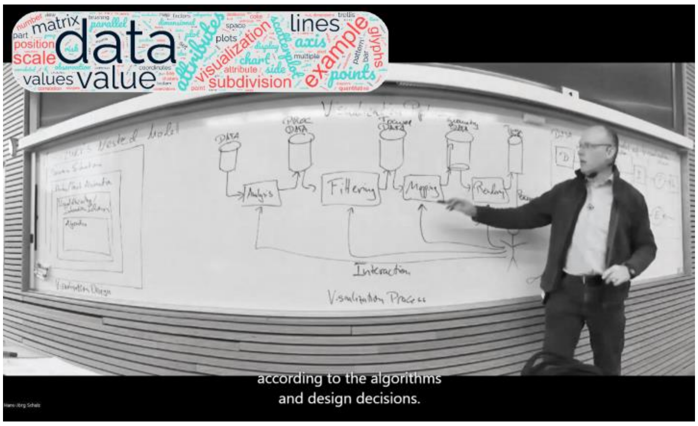
Example: 3-finger tap&hold gesture to initiate a clustering. Rotate gesture left to yield smaller clusters. Rotate gesture right to yield larger clusters.

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-K] Visualizations from Video Subtitles (Hans-Jörg Schulz – hjschulz@cs.au.dk)

Many videos, my lectures included, come with English subtitles that are either created automatically or manually. These subtitles are not only important for hearing-impaired viewers, but they also help students with low proficiency in English to read along. In addition, Panopto allows for free-text search in the subtitles, so that students can effectively navigate even 3 hr-long lecture videos when preparing for an exam. But the display of the subtitles is so far reduced to a rather traditional rendering of text on top of the video. In this project, you are to explore more visual ways to augment the video with graphics being derived from the subtitles – either by embedding the visualizations in the video or by embedding video snippets into a visualization – to make in particular lecture recordings even more useful.



Related Literature:

- Cao & Cui 2016 “Introduction to Text Visualization” Atlantis Press / Springer. doi: https://doi.org/10.2991/978-94-6239-186-4
- Kucher & Kerren 2015 “Text visualization techniques: Taxonomy, visual survey, and community insights” in Proc. of IEEE PacificVis. doi: https://doi.org/10.1109/PACIFICVIS.2015.7156366
- Brath 2020 “Visualizing with Text” CRC Press. doi: https://doi.org/10.1201/9780429290565
- Hofmann & Chisholm 2015 “Text Mining and Visualization” CRC Press. doi: https://doi.org/10.1201/b19007

Contact: Hans-Jörg Schulz
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[UBI-L] Comparative Analysis and Visual-Interactive Merging of Video Subtitles

(Hans-Jörg Schulz – hjschulz@cs.au.dk)

When preparing subtitles for videos, my lecture videos included, one runs into the problem that none of the available services for automated captioning get the speech recognition quite right. This in turn leads to a lot of manual overhead when trying to correct the subtitles, so that search features using them work as expected.

Ground Truth: Why is the Mercator projection such an important map projection, even though it's so bad for visualization purposes? Or any angle-preserving projection for that matter – with the Mercator projection being just the most prominent among them?

Adobe Premiere: Why is the Mercator projection such an important map projection even though it's so bad? [..] Vocalization purposes or any angle? Preserving Jackson for that matter. The Mercator projection being just the most prominent among the.

Panopto: Why is the market objection something important map projection, even though it's so bad for realization purposes? Or any angle preserving Jackson, for that matter, the Mercator projection being just the most prominent among the.

Youtube: Why is the Makita projection such an important map projection even though it's so bad for visualization purposes or any angle preserving rejection for that matter the Mercator Projection being just the most prominent among them

It will be your task to build an interactive visual interface that allows users to compare different SRT subtitle files for the same content to find the most reliable one for the content at hand. In addition, it should allow to merge the different SRT files into one that resolves contradicting occurrences either by "majority vote" or interactively by clicking on the desired word, if one of the services recognized it correctly.

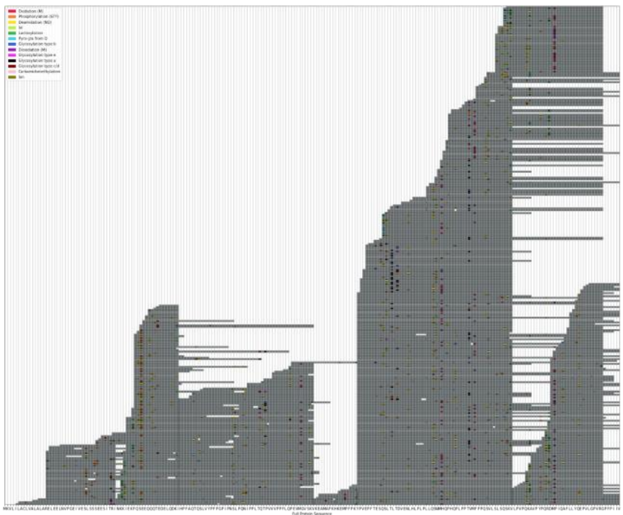
Related Literature:

- Yousef & Jänicke 2020 "A Survey of Text Alignment Visualization", IEEE TVCG 27(2). doi: https://doi.org/10.1109/TVCG.2020.3028975
- Birnbaum 2015 "Computer-supported collation with CollateX". url: http://collatex.obdurodon.org

[UBI-M] Statistical Visualization for Mass Spectrometry Data

(Hans-Jörg Schulz – hjschulz@cs.au.dk)

Modern Mass Spectrometry yields a vast amount of data. Not all of which are statistically significant. That doesn't mean, though, they are not of interest. Current tools like the Perseus software platform can be used to compute a range of statistics on Mass Spectrometry data to provide insight into each data item's relevance. Yet, its output is not shown in a visual-interactive way, so that the domain experts themselves could take a look at what parts of the data exhibit which levels of relevance and determine, for example, suitable cut-off thresholds for the data.



Your task in this project will be to close that gap by computing suitable statistical results over Mass Spectrometry data and making it available in a visual-interactive form. This can mean to either display the results of the statistical analysis directly, but also to indirectly take the statistics into account when displaying the Mass Spectrometry data itself – e.g., for scaling or color-coding the data. This way, we may be able to reduce the visual clutter that results from showing all resulting data with the same importance, for example by de-emphasizing the data that are of lesser statistical significance and emphasizing those that are of more significance.

This project will be done in close collaboration with researchers from AU's Dept. of Food Science, who will be using your resulting visualization software for their research.

Related Literature:

- Choi et al. 2014 "MSstats: an R package for statistical analysis of quantitative mass spectrometry-based proteomic experiments". In Bioinformatics Vol.30, pp.2524–2526, https://doi.org/10.1093/bioinformatics/btu305
- Hall et al. 2016 "Formalizing Emphasis in Information Visualization", In Computer Graphics Forum Vol.35, pp.717.737, https://doi.org/10.1111/cgf.12936
- Perseus software platform: https://maxquant.net/perseus/

[UBI-N] 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-N1] 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-N2] 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.