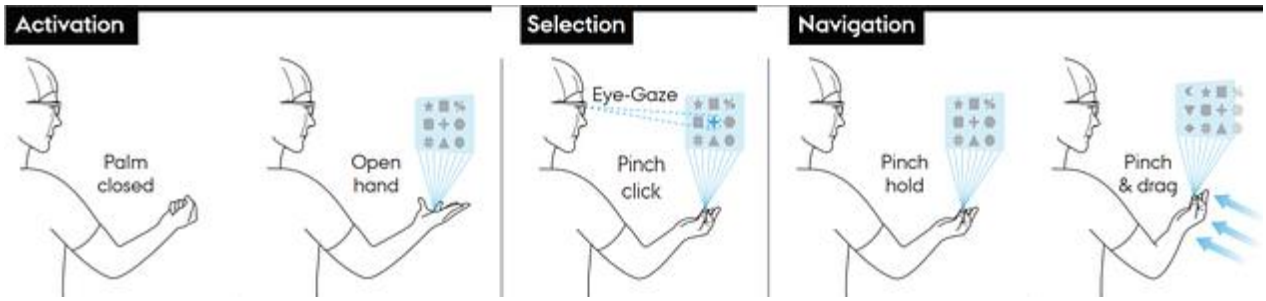
## [UBI-A] Exploring Interfaces and Interaction Techniques in Mobile Augmented Reality

**(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:

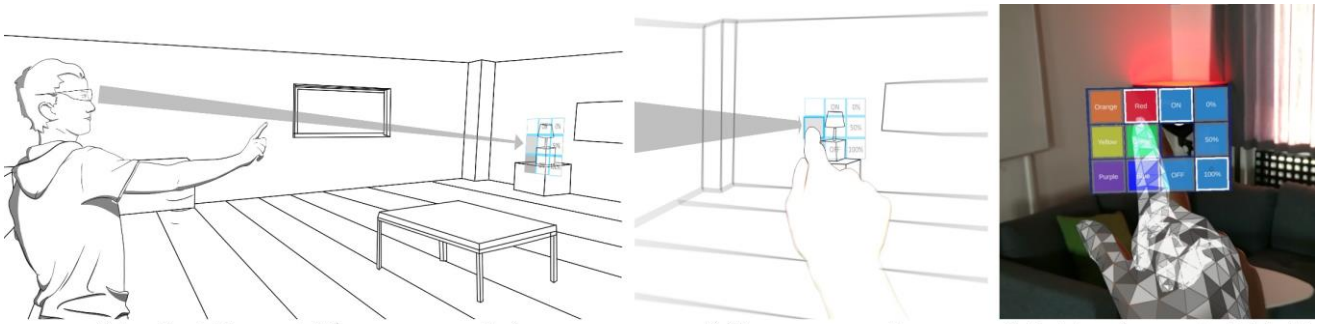
- Ken Pfeuffer, Jan Obernolte, Felix Dietz, Ville Mäkelä, Ludwig Sidenmark, Pavel Manakhov, Minna Pakanen, and Florian Alt. 2023. PalmGazer: Unimanual Eye-hand Menus in Augmented Reality. In Proceedings of the 2023 ACM Symposium on Spatial User Interaction (SUI '23).
    - Blog & videos: https://link.medium.com/soHaLGQ14Db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

## [UBI-B] Internet of Things (IoT) in Augmented Reality

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

Future Augmented Reality (AR) smart glasses may replace or complement 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 appliances such as a clock, TV, and other objects in the environment can be controlled via AR devices. Hereby, the focus is less on a hardware link to actual IoT objects, but rather on the UI design and the interaction with the devices enabled by HCI software.

For example, at home, people can be situated in various places across time – be it on the couch, a kitchen, around other people, at a dining table, and so on. At the same time, IoT appliances such as a clock, TV, kettle, lights are located all around the spaces of the user. How can a user interact from any place with any object, using e.g. only their "future" smartglasses? The below example is one technique we explored in prior work. It allows to spawn a menu at a Philips Hue Lamp, and then control the color, brightness, and other properties.



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 concepts and applications 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:

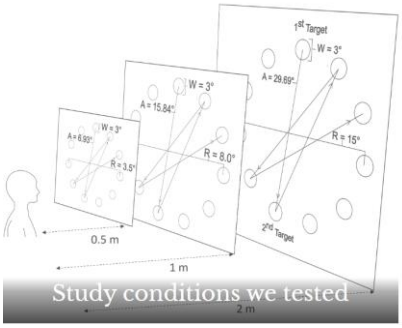
- Mathias N. Lystbæk, Peter Rosenberg, Ken Pfeuffer, Jens Emil Grønbæk, and Hans Gellersen. 2022. Gaze-Hand Alignment: Combining Eye Gaze and Mid-Air Pointing for Interacting with Menus in Augmented Reality. Proc. ACM Hum.-Comput. Interact. 6, ETRA, Article 145 (May 2022), 18 pages.
- Blog: https://kenpfeuffer.com/2022/05/29/gaze-hand-alignment-gaze-and-hand-pointers-for-interacting-with-menus-in-augmented-reality/
- PDF: https://pure.au.dk/portal/files/270196599/145_nocopyright_Final_Gaze_Hand_Alignment_ETRA2022.pdf
- Video: https://www.youtube.com/watch?v=U0T_wd_VD9w

## [UBI-C] User Studies of Fundamental Interaction Techniques in Extended Reality

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

Future augmented, virtual, and extended reality (XR) headsets and smart glasses may replace or complement our phones, raising many new design challenges such as how users interact without traditional mouse, keyboard, and touchscreen. Those environments integrate 3D user interfaces with interaction techniques such as a handheld controller, freehand gestures, eye-tracking, and other ways. To better provide a foundation for future 3D content control, this project focuses on an empirical user study to evaluate interaction techniques.

In our prior work (reference below), we evaluated several existing techniques where users can employ their hand gestures and eye-gaze to interact with targets out of reach. A controlled user study environment was devised, based on a several target sizes and distance from the user (see below). In the user study, participants went through a series of tasks. This allows to gather a dataset for analysis of user performance and experience.



Study conditions we tested


User in the study

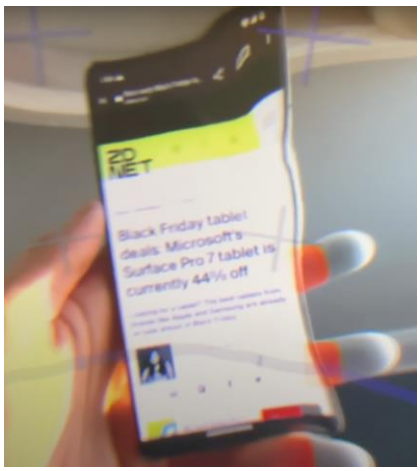
The potential group of students will focus on the planning, implementation, and conduct of user studies in this space. Potentially, a Fitts Law based evaluation can be involved in this project. Students will learn and develop skills in 3D programming by using the Unity platform. They will also gain experience with design, implementation, and evaluation using head mounted devices (e.g., Vive Pro, Hololens 2, Oculus Quest 2).

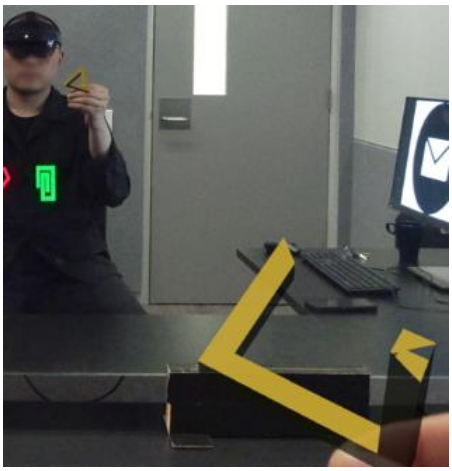
Related Literature:

- Uta Wagner, Mathias N. Lystbæk, Pavel Manakhov, Jens Emil Sloth Grønbæk, Ken Pfeuffer, and Hans Gellersen. 2023. A Fitts' Law Study of Gaze-Hand Alignment for Selection in 3D User Interfaces. In Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23).
- Blog: https://kenpfeuffer.com/2023/05/01/fitts-law-study-on-3d-gaze-and-gesture-selection-techniques/
- Video: https://www.youtube.com/watch?v=XiCkV3eaHOY
- PDF: https://pure.au.dk/portal/files/312128746/Fitts_Law_Uta.pdf

## [UBI-D] 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.

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.

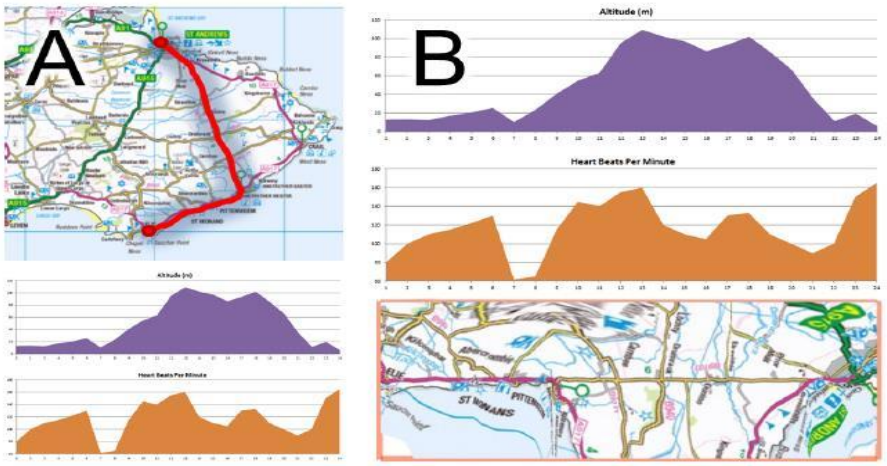
Related literature:

- 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-E] TimeRibbons – Spatiotemporal Visualization (Niklas Elmqvist – elm@cs.au.dk)

What if you could line up your daily runs for an entire month side-by-side to see your improvement, even if you ran during different times and along different routes? Or what if you could compare your daily commute as it varies depending on times and traffic to figure out the best and worst routes to work? This project deals with designing, developing, and evaluating spatiotemporal visualizations of multiple routes over time and space using online geographic maps organized into so-called TimeRibbons that can be lined up and compared side by side.

TimeRibbons is a spatiotemporal visualization technique based on distortion of a 2D visual space so that the movements of multiple entities through time and space are straightened out and aligned side-by-side on the same temporal axis. The technique implementation will most likely be a web-based JavaScript application that uses Google Maps or OpenStreetMap to extract geographic map data and WebGL to distort the textures onto straight ribbons. These ribbons are then lined up using a common relative time axis. Furthermore, visual representations will be used to correlate routes across multiple ribbons.




Transmogrification from Brosz et al. (UIST 2013).

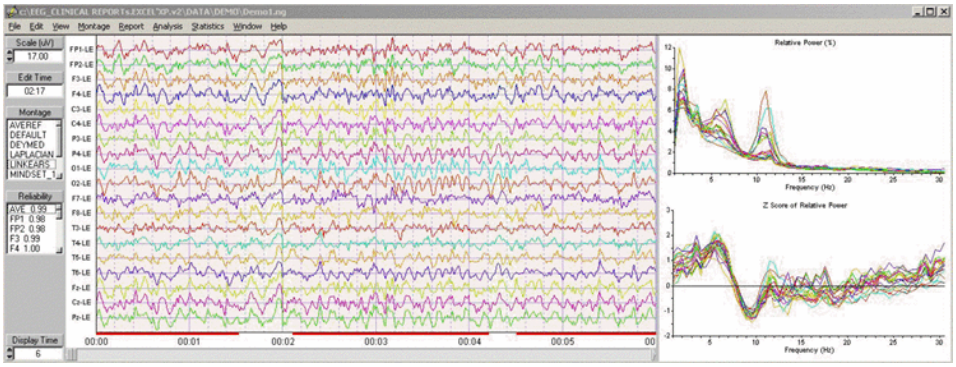
Related Literature

- John Brosz, Miguel A. Nacenta, Richard Pusch, Sheelagh Carpendale, Christophe Hurter. Transmogrification: Casual Manipulation of Visualizations. In Proceedings of the ACM Symposium on User Interface Software and Technology, 2013. (PDF)

## [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

## [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).

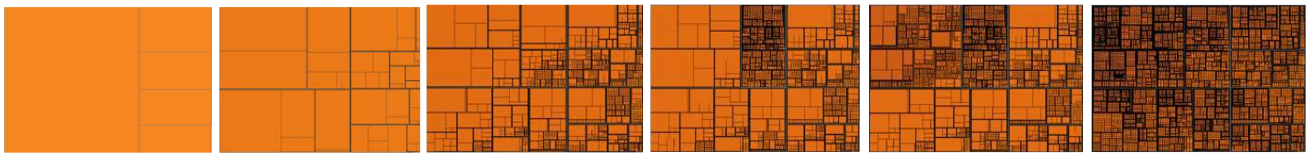
Your task in this project is to invent and implement an organic rendering style for selected charts (preferably implicit tree diagrams) that gives a chart an organic – i.e., “amoebic” or “cellular” – look & feel that can be parametrized in its distortion of the underlying chart in a smooth manner from 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
- Nadieh Bremer 2016 “More fun data visualizations with the gooey effect” url: https://www.visualcinnamon.com/2016/06/fun-data-visualizations-svg-gooey-effect/

### [UBI-H] 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.



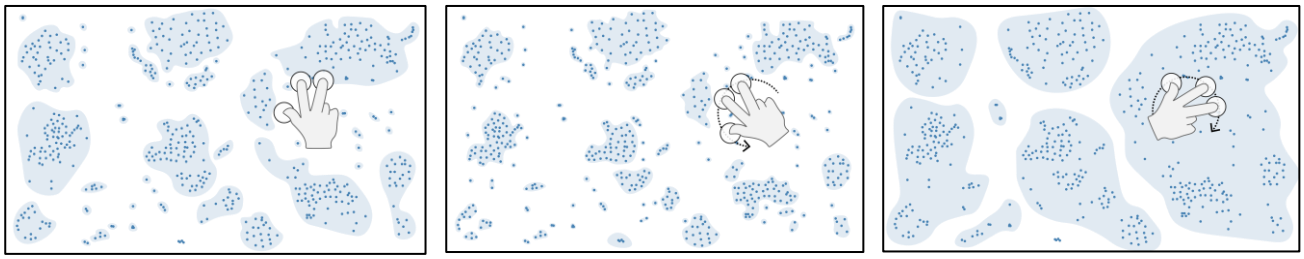
Yet for a variety of other charts, it is still open how to integrate such a progressive visualization paradigm with them and their usual layout algorithms. In this project, it is your task to fill some of these gaps and to propose – e.g., Progressive Line Charts, Progressive Area Charts, Progressive 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-I] 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.



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

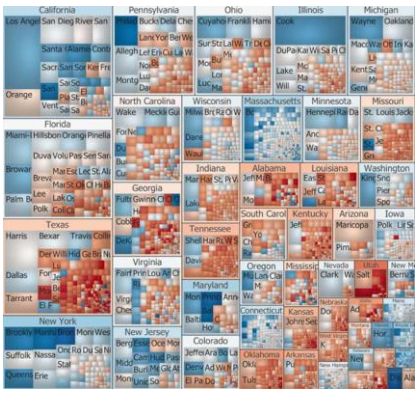
Related Literature:


- 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-J] Focus&Context Visualization through Eye Tracking

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

What if one could “zoom-in” a particular region of a data visualization just by keeping one’s eyes on it? The moment one would focus on a different region, the zoomed-in region would zoom-out again and instead the newly focused region would show more and more detail. Using a commercial eye-tracker and treemaps as underlying visualization, it will be your task to make this futuristic interaction technique reality. The framework that you’ll develop will manage levels of detail and screen real estate based on input from a Tobii nano tracker. To do this, you can build on a basic Python framework that realizes the data stream from the hardware to the software and that has been built in a previous project.

Related Literature:


- Elmqvist and Fekete 2010 “Hierarchical Aggregation for Information Visualization: Overview, Techniques, and Design Guidelines”, in IEEE TVCG. doi: https://doi.org/10.1109/TVCG.2009.84
- Tu and Shen 2008 “Balloon Focus: a Seamless Multi-Focus+Context Method for Treemaps”, in IEEE TVCG. doi: https://doi.org/10.1109/TVCG.2008.114

### [UBI-K] 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-K1] 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-K2] 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-L] Technologies for green / sustainable living (Peter Gall Krogh – pkrogh@cc.au.dk )

What might be the role of digital technologies for promoting/ helping green sustainable living? The digital infrastructures of our societies are by character far from CO2 neutral, and not in themselves "green". However, the infrastructure, configuration, and design of such technologies, may significantly help us lead more sustainable life. The ambition of this theme is to unpack, design, build, and prototype initial systems, artefact and concepts that help us develop everyday strategies for a more sustainable life on earth. Concepts may range from improved everyday tactics for sustainable consumption, to planning green personal transportation, infrastructure communities to digital support concept such as prosperity without growth.

*Note that this project will be carried out in cooperation with the Socio-technical Design Group at the Department of Communication and Culture.*

### [UBI-M] Collective interaction - performative music playing (Peter Gall Krogh – pkrogh@cc.au.dk )

The dream and vision of most interactive networked technologies was originally that they would bring us closer together, and by that improve interpersonal/ -cultural/ -ethnical, -political/ -spices understanding. However, we are not there yet… On the contrary we witness Sherry Turkle (2012) write a book on being *alone together* and Eric Pickersgill https://www.ericpickersgill.com/ making the photo series (2014-present): *removed* both pointing to how novel interactive technologies are breaking up the social and societal ties of feeling **togetherness**. Maybe changing the interaction paradigm at the root could render new directions. This is the motivation driving the notion of collective interaction. We believe that performative e-music playing can be a fruitful ground for exploration. The project frame includes two subthemes: The amateur music playing and professional performance.

*Collective music playing for everyone:*
The theme is directed towards question on how we might develop musical instrument playing apps that invites us and rewards us for playing with others. In Ireland the pub-tradition “session”, gathers amateur musician (and that is all people) to join and play whatever instrument they feel comfortable. From the advanced and difficult instruments like the violin and harmonica to tambourin and rattles. In other countries and cultures music and singing are ways of gathering people and collectively celebrating events. With the words of Richard Sennett we are becoming de-skilled in being and living together. How can amateur e-music playing help promote togetherness? And how may that extend the concept and grounds for the notion of collective interaction?

*Performative musical instruments for the professional artist*
e-music playing is often hidden in and behind laptops. The laptop absorbs the attention and movements of the artistic and reduces the range of supporting expressive acts on stage. The computer limits rather than enhance the performative options of the musical artist. How may we design electronic music instruments that emphasize performance and even audience involving experiences? How may we change many current concert experiences from individual participants photo or video capturing the event, to become active participants in creating the event? How may concerts become actual collective interactive experiences?

*Note that this project will be carried out in cooperation with the Socio-technical Design Group at the Department of Communication and Culture.*