The Collaboration Surfaces project
is a project for purchase and development of equipment and the Hems Lab.

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Scientific justification and goals

Distributed Multimedia Plays (DMP)
Collaboration surfaces are essential parts of the DMP three-layer systems architecture. DMP provides near-natural virtual networked auto-stereoscopic continuous (multi-) view video and multichannel sound collaboration between users (and users and servers) [RON07a]. The end-to-end maximum time delay is guaranteed (< 10-30 ms) by allowing the quality of audio-visual content and the scene composition vary with time and traffic. The adaptation scheme is called Quality Shaping. The scheme uses traffic classes, controlled dropping of packets, traffic measurements, forecasting of traffic and feedback control. Adaptive parameters are the maximum end-to-end delay, the number of 3D scene sub-objects, object temporal and spatial resolution, sub-object adaptive and scalable compression, and the number of spatial views. The scheme also includes scene object behavior analysis. The architecture supports pertinent security and graceful degradation of quality. The architecture introduces independent parallelism by definition. The most basic critical part of DMP, the regeneration of objects from sub-objects by interpolation when sub-objects are dropped in the network, has been extensively tested. Very good interpolation and segmentation methods has been developed and presented in a number of Master’s theses and PhD papers at the Dept. of telematics, e.g., [JEN10], [PAN10], [TAM10].

The AppTraNet protocol
A new protocol called the AppTraNet protocol [LAR07b] combines the application layer, transport layer and network layer protocols into one protocol, with only one common header. The protocol handles the setup and management of collaborative distributed scenes and content transfer. A priority queuing hardware mechanism is used in network nodes to handle controlled dropping and delay of content packets and guaranteed transport (but not delay) of control packets. This mechanism has been verified by simulation [RON08a].

The Hems Lab
The Hems Lab v 1.0 and v 2.0 are downscaled DMP realizations [RON07a]. While the quality of the scenes intends to approach ‘near-natural quality’ in the long term, the present stereoscopic implementation (version 1.0) and the present 5-view implementation (version 2.0) have good quality. The environment combines virtual (from digital library and remote collaborators) and live musical theater drama elements and sequences, including actors/singers playing/singing roles, and scenography, selected from musical theaters/operas [RON08b]. Other applications of Hems Lab are TV productions, games, education, and virtual meetings.
**Telepresence, 3D TV and Video-Based Rendering**

Tandberg [TAN10], Sisco and others produce state-of-the-art videoconferencing systems denoted telepresence systems, using protocols such as TiP (RTP, RTCP), SIP and H.323 over UDP/IP. The EU research project, 3DPresence, [3DP10], estimates the end-to-end time delay is about 400 ms. The research of DMP builds upon experience from telepresence, state-of-the-art research of networking, digital video and computer vision, such as 3D-TV and Video (Image)-Based Rendering. [KAU07] gives an excellent overview of the history of 3D TV. [MAT04] demonstrates a 3D TV system architecture, using a multiview camera array and autostereo multiview lenticular-based projection. [KAU07] further shows a generalised 3D TV system based on N x Video + Depth streams after images are captured. The following rendering steps are performed: image rectification, disparity matching, depth map creation, and de-rectification. While most works assume standard cameras and processing on standard images, other researchers have proposed introducing infrared light to support segmentation of scene objects [DAV98], and chroma keying using invisible light [BEN02].

**Research methodology**

The main characteristics of the action research methodology as applied in this project are the iterations between Design/Creation and Research, and iterations within Design/Creation and within Research. To evaluate scene quality, both subjective (perceptional) and objective measurements are used. The subjective tests are based on comparing the virtual quality of the technical systems with the real world scene quality.

![Figure 1. Action Research](image-url)
Collaboration Surface Design and Research
In this follow-up project the plan is to develop and test the quality of a modular, quality-enhanced (beyond state-of-the-art) Collaboration Space, Hems Lab 3.0. This includes carrying out experiments to evaluate the quality of experience and establish user requirements and system quality specifications when applying the Collaboration Surface in virtual music and musical theatre. Moreover, the Collaboration Surface will be applied for new gaming concepts, to obtain real feel by using stereoscopy in serious games, and to enhance the satisfaction of First Person Shooter (FPS) games. The following task shall be carried out:

- Build and evaluate a wall-size auto-stereoscopic continuous-view display (own proposal) based on:
  - Continuous-view convex lens array screen (in front)
  - Pixel-integrating concave lens array screen (behind)
  - Pico projectors (back projection)
  - FPGA-based distributed processing and play-out system

- To be able to build large Collaboration Spaces with continuous displays of any size using smaller displays and camera arrays, the joints between the displays can be covered by combined stripes of auto-stereoscopic continuous-view displays, camera arrays and audio equipment.
- Test, calibrate, configure and improve a newly designed Camera Cluster Array, which is capable of shooting 3-9 (more than RGB) spectral bands, in order to support the design of enhanced concepts for object segmentation and object (eye) motion tracking, and ‘ultra definition’ in time and space.
- Apply a newly designed processing array of FPGAs with 3-dimensional systolic arrays to implement processing of the output of Camera Cluster Array. Develop software and hardware by co-design, real-time embedded programming, and methods for allocation of functional processes to processing units.

The joints between displays shall be used for camera arrays and audio equipment. The intention is to make the joints nearly invisible and the whole image continuous by introducing a combined camera array and auto-stereoscopic continuous-view stripe. Such stripes also integrate microphones and loudspeakers. To start with, headsets will be applied to obtain the ‘position-realistic’ surround. Later, arrays of microphones, sound processing, and arrays of loudspeakers will be introduced.

In addition to object segmentation and motion tracking, various methods shall be applied to correct for small lens aberration and imaging chip artefacts, and for stitching of images. Calibration schemes for the collaboration surfaces shall be proposed and evaluated.

The software and hardware architectures for Camera Cluster Array and display processing involve research on embedded hw/sw co-design, real-time, heterogeneous multi-programming, systolic
arrays, FPGA realisation, and methods for allocation of functional processes to processing units. As can be seen, this development involves several research areas and extensive evaluation.

The concept of SceneProfile [RON07a], which defines the possibilities and limitations of DMP collaboration spaces, shall be further elaborated. Eye tracking and object focus (receiver) shall be implemented to decide the number of views and the resolution of the focused objects (sender).

The results from quality evaluation and design of new concepts and research can be published at Electronic Imaging, ACM Multimedia, IEEE, and other well-known conferences.

**Virtual Music Theatre research**
Experiments shall be carried out to evaluate the system quality performance and establish user requirements and system quality specifications when applying The Hems Lab in virtual music and musical theatre education, design, rehearsal and performing arts. For virtual song rehearsal, it is desirable to have the score/notes presented on the screen in front of the singer.

**Hems Lab game applications**
The Hems Lab will be highly valuable for gaming research. The research area encompasses development of new gaming concepts, how to use stereoscopy to enhance the satisfaction of First Person Shooter (FPS) games, and to use stereoscopy in serious games. The Hems Lab can also be used to recreate the reality as true as possible. This can be modeled by stereoscopy to obtain a synthesized world where the gamer can move freely. Alternatively, one can realize this by shooting a number of 360-degree images at different points and letting the user jump between the points. This technique will not provide the same degree of freedom as synthesized 3D, but will give a much more realistic picture of the surroundings since the pictures are shot by a high-quality camera. In this way, one can experience Rome (or the moon) in the Hems Lab!

**The infrastructure**
The equipment shall extend the existing Hems Lab versions 1.0 and 2.0 as described above. The rooms A264/268 in the 'Elektrobygget' give sufficient space also for a small Hems Lab version 3.0. The new Collaboration Surface shall be built around a new concept of using two lens arrays and pico projectors. The lens arrays will be developed in cooperation with Inst. for produktutvikling og materialer, NTNU. The display hardware shall be PC-cards with FPGA onboard. The newly designed Camera Cluster Array shall be extended to handle 5 to 9 sub-colors, and camera arrays that shall be integrated with display lenses as stripes on the joints between display modules. The image processing shall be performed by FPGA modules, configured in a 3-dimensional processing architecture. To store audiovisual content, SATA 3.0 hard disks configured as RAID shall be applied. The audio arrays shall be integrated with the joint stripes. Mechanics for the displays/Collaboration Surfaces and general purpose PCs will be needed.

The lab includes only standard ICT equipment. No problems regarding ‘HMS’ are expected.
The participants

Performing arts, Department of Music (NTNU).
At the Department of Music, performing arts, (IM) there is a solid and well established tradition for training voice students for opera and music theatre. In the bachelor program the students usually participate in 3-4 opera productions, mostly in the IM’s collaboration with external professional institutions, like Musikkteatret in Trondheim and Operafestukene i Kristiansund. Likewise the IM’s own students in composition have produced specially designed small scale chamber operas for vocal and instrumentals students at IM; lately in cooperation with the festival “Sommersang på Ringve”, June 2007. Most of the classical singers in the bachelor program aim for a master education at opera schools in Scandinavia, but we now experience a fast growing interest for IM’s own master education in music dramatics. IM’s special location in Olavskvartalet and our facilities make it natural and exciting to extend the opera/music theatre activities in our student programs. In Norway there is little tradition for research and reflections around music dramatics as a phenomenon. Exploring new methods in preparing the artists for the stage is not systematically run elsewhere in Norway, to our best knowledge. In this field exchange of experience and knowledge in an interdisciplinary program at NTNU might be a very valuable contribution to research and development in music dramatics.

Acoustics Research Centre (ARC), Department of Electronics and Telecommunications (NTNU)/SINTEF

IKT & Network Media Handling research group, Q2S (NTNU)
Research on virtual acoustics techniques, or auralization, has been carried out in the acoustics group (ARC) at NTNU for a long time, as well as by Prof. Peter Svensson during his time at Chalmers University in Gothenburg (-1999). The virtual acoustics research is presently focusing on real-time rendering techniques that include diffraction, which leads to substantially increased realism. In addition, more recent research on 3D audio techniques is carried out in both ARC and Q2S at NTNU. The focus is on multi-channel loudspeaker techniques for realistic sound reproduction over extended areas in space, which is exactly what is needed in setups like the Hems lab. Furthermore, a recently initiated project, “Quality of Experience in Virtual Collaboration” together with industry partners SINTEF IKT, TANDBERG and StatOilHydro aims at raising the quality in video conference applications. This activity is also eminently suited for linking to the Hems lab project.

Networked Multimedia Systems, Department of Telematics (NTNU)
This research area is part of the Networked Systems research area at the Dept. of Telematics, which has six professors and 10-12 PhD students. Four PhDs, one postdoc and 10-12 master students have performed DMP related research. The futuristic DMP architecture solves by design all real-time and capacity problems associated with Internet today. With DMP, the quality of scenes will in the future approach ‘near-natural’. In 2008, 2009 and 2010 the Item EiT villages have developed music dramas and shown that Hems Lab 1.0 is a very convenient virtual rehearsal environment for learning and performing arts roles. An Item EiT village 2010 designed a virtual Tivoli, where a live singer were acting together with a virtual Tivoli shown on a 3D screen (Hems Lab 1.0). The virtual Tivoli was presented at the HF and SVT faculties 100 year celebration on the 14th of August 2010. The plan is to engage master students, EiT, a postdoc for 2011 and a multidisciplinary PhD from 2011 for Collaboration Surface research.
Relevance to strategic commitments at NTNU

The active participants perform state-of-the-art research within their areas, but do not have test facilities like the Hems Lab. This interdisciplinary project using Hems Lab enables new and important research, and is a contribution to de-fragmenting the research at NTNU, in Norway and in Europe. The intention is to bring the NTNU research on collaboration spaces, future multimedia networks, virtual music theatre, and games up on international level. The Hems Lab and interdisciplinary action research are the prerequisites for success. The relevance for music drama education and research is described in the previous section. When the Hems Lab version 3.0 is up and running, the plan is to run one EiT ‘village’ per year, educate three MSc's per year, two MA's per year, and two PhDs. Three professors from four departments and three faculties, and several postdocs will also be engaged in the research. The relevance for music drama education and research is described in the previous section. When the Hems Lab version 3.0 is up and running, the plan is to run one EiT ‘village’ per year, educate three MSc's per year, two MA's per year, and two PhDs. Three professors from four departments and three faculties, and several postdocs will also be engaged in the research. The relevant for music drama education and research is described in the previous section. When the Hems Lab version 3.0 is up and running, the plan is to run one EiT ‘village’ per year, educate three MSc's per year, two MA's per year, and two PhDs. Three professors from four departments and three faculties, and several postdocs will also be engaged in the research. The relevant for music drama education and research is described in the previous section. When the Hems Lab version 3.0 is up and running, the plan is to run one EiT ‘village’ per year, educate three MSc's per year, two MA's per year, and two PhDs. Three professors from four departments and three faculties, and several postdocs will also be engaged in the research. The relevant for music drama education and research is described in the previous section. When the Hems Lab version 3.0 is up and running, the plan is to run one EiT ‘village’ per year, educate three MSc's per year, two MA's per year, and two PhDs. Three professors from four departments and three faculties, and several postdocs will also be engaged in the research. The relevant for music drama education and research is described in the previous section. When the Hems Lab version 3.0 is up and running, the plan is to run one EiT ‘village’ per year, educate three MSc's per year, two MA's per year, and two PhDs. Three professors from four departments and three faculties, and several postdocs will also be engaged in the research.

The importance for scientific cooperation

Prof. Rønningen has participated in several arts projects, using video in the stage design (e.g., Olavshallen, Arbeiderforeningen and Vår Frue Kirke). Contact is also established with Trondheim Symfoniorkester, and a project with Avantgarden has been staged. Rønningen also has been a consultant for the rehabilitation of Arbeiderforeningen, where a flexible stage and use of new visual expressions are focused. There is also contact with Den Norske Opera & Ballett for similar applications. The video processing modules developed in this project can be used together with projection equipment in such arts applications. When Hems Lab version 3.0 is up and running, the plan is to interface the system to ‘Verdione systems’, provided by the NFR Verdione project.

Tandberg, Cisco and Cyviz are companies that should be able to utilize the results from this project for their visualizing and video conferencing equipment. The spring 2010 Tandberg participated in a master’s thesis work on 5-view shooting and presentation in Hems Lab v 2.0 at Item. The plan is that the ‘media technology and arts’ SFI centre shall be up and running within two years. Then the intention is to transfer the Collaboration Surface and DMP technology to Norwegian and international SFI participants. Cypress (San Jose) is the main technology partner regarding camera/imaging chips, Noca (Trondheim) produce our PCBs, and Pico (Seattle) designs FPGA boards for our projects.

Vulnerability

The two first generations of Hems Lab has been built up over 5-6 years, and has been applied by EiT (2008, 2009 and 2010), project students, master students, research assistants, PhD students, in addition to employees’ research and arts design. A considerable number of papers and reports have been published. This means that we have already shown the ability to build and apply such equipment, do research, and present state-of-the-art results internationally. Now the plan is to build
up the third generation Hems Lab by adding the new Collaboration Surface. This will be built on own display technology, camera chip technology from Cypress and own Camera Cluster Array technology, and own video processing equipment with Pico/Xilinx FPGA boards. Existing audio technology from Q2S will be applied. Establishing the processing systems has shown to be quite straightforward. The challenges (the research) are the new continuous-view display and the integrated 'joint strip' which are beyond the state-of-the-art research in optics, electronic imaging, and video technology. Another main concern is the recruitment of manpower for DMP research at Item. When Hems Lab v2.0 was established, the main problem was delivery of system components. Philips closed down their production of multi-view displays, and Thomson do not sell camera modules in volumes we are talking about. The project is about severe scene quality enhancements, and is a step on a long path to approach a 'near-natural' quality level. The Hems Lab v 1.0 and 2.0 were built in rooms (A264 and A268, Elektro), which with improvements of projection equipment during 2010, are suitable also for the third generation Hems lab. The third generation Hems Lab will be built and run by PhD students, master students, student assistants and lab engineers at Item.

**Other**

The equipment will be modular and portable, which means that it can be installed for a period in venues as referenced in Section 5. For example, AV technology-based performances are planned to take place in Arbeiderforeningen from 2011, and the Hems Lab equipment can be installed there for, say, 3-5 weeks.