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Centre for Virtual Reality and Visualisation 2020

Leibniz Supercomputing Centre
of the Bavarian Academy of Sciences and Humanities

V2C

V2C CENTRE FOR VIRTUAL REALITY AND VISUALISATION AT THE LRZ

Leibniz Supercomputing Centre
of the Bavarian Academy of Sciences and Humanities

V2C

CENTRE FOR VIRTUAL REALITY AND VISUALISATION AT THE LRZ

FOREWORD

Prof. Dr. Dieter Kranzlmüller
Director Leibniz Supercomputing Centre

The Centre for Virtual Reality and Visualisation (V2C) of the Leibniz Supercomputing Centre (LRZ) offers state-of-the-art technology and services for the visualisation of scientific data, which makes it possible to support, enrich and accelerate the gaining of new insights. The understanding of data and correlations is improved and made possible by the three-dimensional and high-definition representations on various installations. Users are provided both, an LED as well as a projector-based Powerwall, and a 5-sided projection installation for interactive and immersive studies by means of different input devices that enable user-centred navigation and interaction.

The service of the LRZ is tailored to the individual needs of the users and ranges from

providing the facilities and the supervision of demonstrations to the development of custom applications and the exploration of future technologies. Users originate from almost all scientific fields, from archaeology to zoology, and have a wide variety of specific requirements and demands.

Besides providing support for the basic and applied research, the LRZ especially supports international projects, involvement in teaching, public relation works and the concerned chairs as well as participation at workshops, congresses and conferences. The V2C has established itself at the LRZ as an essential tool for scientific research, with which to support users in their sustained efforts to gain new insights. Financing for the building as well as the necessary IT infrastructure was provided by the Free State of Bavaria and the Federal Government of Germany. The V2C is the highlight of every visit to the LRZ and a sought-after attraction during public events.

Virtual Worlds

Virtual Reality (VR) and visualisation are two distinct research areas that, when combined in a scientific context, can improve or sometimes even enable the analysis of datasets. Virtual reality describes a technology to create a virtual, immersive environment for the user whereas visualisation is a collection of techniques to create a visual representation of a dataset.

Virtual Reality

The term "virtual reality" was first used by Jaron Lanier in the 1980s and describes the simulation of an artificial world by providing a set of sensory stimulus. This is usually comprised of a mixture of computer graphics, stereoscopic displays, psychology of reception and some sort of interface between man and machine. Several aspects are important for immersive virtual environments: a wide field of

VIRTUAL REALITY AND VISUALISATION

view, a stereoscopic real-time display, positional tracking and an intuitive way to interact with the virtual world. By way of these immersive techniques the viewer can enter the virtual world and interact with it naturally. Virtual reality is not restricted to visual perception, but can provide other sensory inputs as well.

Visualisation

Visualisation is the creation of a visual representation of complex datasets to make the information contained in these datasets easily accessible. Visualisation can be divided into scientific visualisation, where measured or simulated spatial phenomena or objects are displayed, and information visualisation, which deals with the display of abstract data. Combining visualisation with virtual reality often allows for three-dimensional, natural representations of complex datasets that can be understood by users much more easily than two-dimensional visualisations.

Areas of application

Virtual reality and visualisation can be used in many different disciplines as illustrated by the various projects presented later on in this booklet.

Some examples for areas of application not mentioned later on include psychology (e. g. in therapies to fight phobias), safety training (e.g. to simulate incidents with industrial machinery), medicine (e.g. visualisation of MRI or CT data), industrial design (e.g. to evaluate prototypes), fluid mechanics, art, product presentations, entertainment and various other applications.

Technology

To provide an immersive experience, allow the user to dive into virtual worlds and work with highly detailed visualisations, a number of different technologies are used: Visual perception (visualisation of datasets), stereoscopic rendering (3-dimensional images) and positional tracking (interaction).

Visual Perception

Applications dealing with visualisation need to take a number of aspects concerning the psychology of perception into account in order to provide easy to understand and intuitive representations of the data. Colour, perspective, shading, shadows, depth of field and contrast are just a few examples that need to be considered and cleverly used by the software developers.

Stereoscopic Rendering

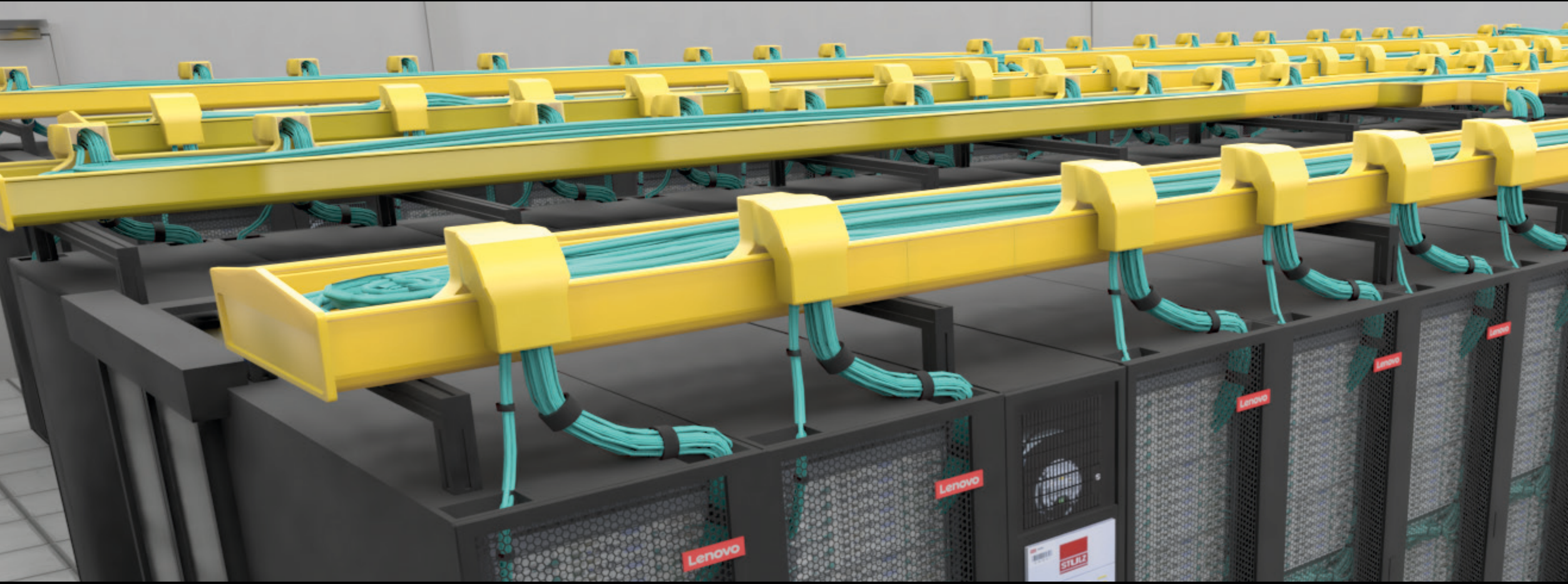
To create a realistic, three-dimensional effect a separate image with the corresponding perspective has to be presented for the left and right eye. There are a number of ways to separate these images: by colour (analygraph), spatial separation (head mounted displays), temporal (active stereo) or using the polarisation of light (passive stereo).

Active stereo is a technology that uses 3D glasses. Each "lens" is actually an LCD that can become opaque in order to block the vision for one eye while the image for the other eye is displayed.

One variation of passive stereo relies on circular polarisation of light. Differing polarisation filters are attached to the projectors for the left and right eye. The lenses of the 3D glasses are fitted with the corresponding filters. This technique is commonly used in 3D cinemas.

Positional Tracking

Intuitive interaction and perspective view in virtual worlds can only be provided when using positional tracking. In the Centre for Virtual Reality and Visualisation optical systems are in use that even allow for tracking of individual fingers. The technology is based on emitting infrared light into the room. The user wears special markers that reflect the infrared light which is then in turn recorded by cameras. Based on these images the position and orientation of the user can be computed.



Remote Visualisation

Visualising complex datasets often requires powerful hardware: high-end compute capabilities, large amounts of memory, specialised graphics hardware and sometimes even specialised software systems are requirements not always readily available in everyday work environments. For this purpose, the LRZ provides the service of remote visualisation.

Remote visualisation refers to a number of Linux-based virtual machines based in the LRZ cloud services that are driven by high-end server hardware and are tightly integrated with the infrastructure and services of the LRZ. Users can log into these machines remotely and the graphical user interface is streamed to their workplace. This enables scientists to use these machines just like they would do with local workstations.

The virtual machines are preconfigured with a selection of software tools commonly used in scientific visualisation. Additionally, other services, like the LRZ data science storage, are easily accessible as they are preconfigured to be accessed from within the remote visualisation services. This enables a seamless transition from running jobs on any of the LRZ-provided infrastructure to visualising the results using the remote visualisation services and eliminates the need to move large amounts of data between systems.

The LRZ takes care of maintaining the hard- and software environment to provide the users with an easy to use and up-to-date visualisation system. For requirements not met by the machines of the remote visualisations, scientists may also access the LRZ Compute Cloud to create custom user-maintained virtual machines, install any required software and deploy them on the cloud nodes equipped with high-end GPUs.

Installations

The V2C is home to both large virtual reality installations of the LRZ: the Powerwall and the 5-sided projection installation.

Powerwall

The Powerwall features a screen with a size of 6m x 3.15m that is projected from the back in order to prevent shadows being cast by users or speakers.

Two 4K projectors provide high picture quality in order to project 3D images stereoscopically with four times the resolution of regular HD screens (4096 x 2160 pixels) in real time. The stereoscopic projection is based on circular polarisation filters and passive stereo projection. Behind the scenes, a cluster consisting of 6 nodes renders the images for the display. Additionally, the Powerwall is equipped with an optical positional tracking system that

CENTRE FOR VIRTUAL REALITY AND VISUALISATION

uses 6 cameras to provide accurate tracking information.

5-sided Projection Installation

This installation is based on the concept of the CAVE (CAVE automatic virtual environment) by Carolina Cruz-Neira. The idea is that a user steps into a cube where the sides, floor and ceiling are displays that completely cover the user's field of view. In contrast to the Powerwall this system not only provides a feeling of interaction with the virtual world but creates a sense of being inside it.

The installation in the V2C has the shape of a 5-sided cube with a size of 2.7m x 2.7m x 2.7m. Two HD stereo projectors are used for each wall whereas one is projecting onto the upper half of the wall and the second one onto the lower half. In order to generate a homogenous image, the pictures of both projectors overlap in the middle whilst gradually darkening towards the border. For this installation an active stereo projection is used.

The 5-sided projection installation is controlled by a cluster consisting of 12 nodes: 10 nodes for rendering images (one for each projector) and two master nodes for controlling the render nodes and updating the scene. Additionally the installation is equipped with a tracking system using 4 cameras in the corners of the ceiling of the cube. Optionally, 4 more cameras can be positioned on the floor to increase position as well as the tracked area. This is necessary for the optional finger tracking which can be used to interact with the virtual environment using gestures.

Technical Details

Installations

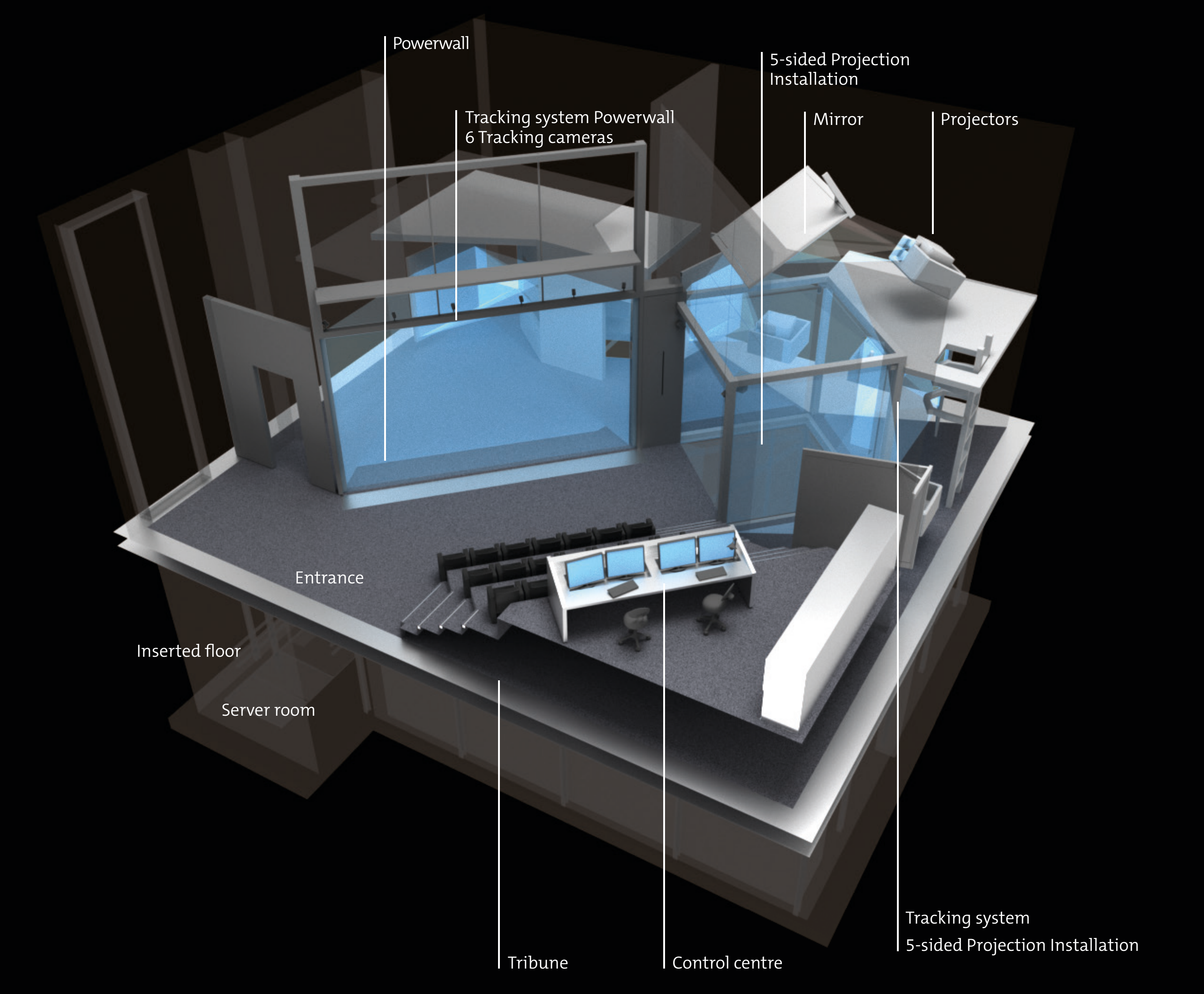
The following two projection installations are found in the Centre for Virtual Reality and Visualisation:

Powerwall
Cluster with 6 nodes:
2 Intel 8core Xeon CPUs
256 GB RAM
Nvidia Quadro P6000

6 x 3,15 m screen area
2 x Sony 4k projectors
ART ARTtrack2

5-sided Projection Installation
Cluster with 12 nodes:
2 Intel 8core Xeon CPUs
256 GB RAM
Nividia Quadro P6000

10 x Christie Simulation Mirage WU-3
ART TrackPack4 + optional 4 cameras


Powerwall
Tracking system Powerwall
6 Tracking cameras
5-sided Projection
Installation
Mirror
Projectors
Entrance
Inserted floor
Server room
Tribune
Control centre
Tracking system
5-sided Projection Installation

Additional Equipment

Besides the Powerwall and 5-sided projection installation, the Centre for Virtual Reality and Visualisation also provides several additional installations and devices.

High Resolution LED Display

In 2018 the range of installations was expanded by building a high resolution display - similar in principle to the Powerwall - in a conference room above the V2C. This setup does not feature any projectors but is based on the latest LED technology, offering several key advantages like very high brightness and contrast, excellent colour reproduction and active stereo capabilities.

The LED display features a size of 3.6m x 2m and a resolution of 2880 x 1620 pixels. It is connected to a state of the art graphics server to supply the

display with virtual reality content. The high brightness values of the LED technology make it possible to use the display even in bright daylight. Additionally the installation features a state of the art media system that allows to simultaneously display stereoscopic and non-stereoscopic content from multiple sources as well as the integration of a videoconference system for distributed visualisation and data analysis.

Head Mounted Displays

Within the last few years, virtual reality has become a more topical subject with the release of several affordable head mounted display solutions. With these devices being in high demand the V2C also features two labs equipped with several different head mounted displays like the HTC Vive (Pro), the Oculus Rift and Windows Mixed Reality Headsets. The main HMD lab is built around the tracking system of the HTC Vive and features a tracked area of about 8m x 5m. The large tracking space combined with the cables being routed through the ceiling allow for a more unrestricted movement and facilitates the analysis of larger models or datasets. Additionally a high end graphics workstation provides the processing power required for VR visualisations.

A second lab is equipped with several graphics workstations and various HMD devices ranging from the Oculus Rift and HTC Vive Pro to ultra-portable solutions like the Samsung GearVR.

BAVARIKON

Visualisation of Photorealistic 3D Models of Art and Cultural Assets in the Bavarikon Portal

bavarikon is the Internet portal of the Free State of Bavaria for the presentation of art, culture and other sources of knowledge from Bavarian institutions. It hosts a variety of materials contributed by archives, libraries and museums, as well as other state institutions involved in the preservation of historical monuments and the promotion of scholarship.

Launched in 2013 as a platform for the multidisciplinary digital presentation of art and cultural treasures from Bavaria, it was the first regional portal in Germany to show three-dimensionally scanned works of art and artifacts of cultural heritage on the Internet.

As part of bavarikon, a 3D digitisation service-hub was set up at the Munich DigitiZation Center of the Bavarian State Library, which is responsible for the ongoing technical, editorial

BSB bavarikon Kultur und Wissensschätze Bayerns

Felix Horn
Munich DigitiZation Center / Digital Library
Bayerische Staatsbibliothek

HISTORY OF ART

and organisational operation of the bavarikon platform. Its objective is to create content with a cross-disciplinary 3D digitisation service for all cultural bavarian institutions. The prerequisites to use the service are an assessment of the content by bavarikon's advisory board, the technical feasibility and the willingness to present the objects – free of charge – to the general public on bavarikon.

bavarikon mainly uses 3D scanners (laser and stripe light) or image-based photogrammetric processes to digitize three-dimensional art and cultural heritage assets. During the 3D-scanning, the artworks are captured photorealistically, i.e. in detail both in their geometry and their colour. The aim of the scanning process is to digitize the objects accurate in every detail and in a photorealistic manner to ensure that this data can be reused in the future, e.g. for documentation during restoration or for 3d printing. At the end the photorealistic 3D models can be displayed directly in the browser using a specially programmed 3D viewer based on the cross-platform standard WebGL (Web Graphics Library), which is now supported by all common browsers and allows the viewing of 3D models directly in the browser software.

The high-resolution 3D models can be reused for example in virtual museums. There, the virtual artworks can easily be curated in thematic and content-related groups. Such a museum can, for example, be visualized using VR/AR applications with appropriate viewing aids, e.g. VR glasses or, as is possible at the LRZ, using a CAVE.

www.bavarikon.de

Elisabeth Mayer
Markus Wiedemann
Michael Käsdorf
Leibniz Supercomputing Centre

IMPERIAL HALL

3D reconstruction of the Imperial Hall

The 3D reconstruction of the Imperial Hall of the New Residence in Bamberg, painted from 1707 by Melchior Steidl, was carried out as a pilot project of the Corpus of Baroque ceiling painting in Germany (CbDD). The illusionistic wall and ceiling painting of the Baroque is particularly suitable for three-dimensional modeling. With the aid of the 3D model, questions about the viewpoint and the mobile observer as well as the ceremonial use and the function of the room can be tested and answered. The increase of the illusionistic effect in the not particulary tall Imperial Hall was just as much a topic as the installation of the fresco with regard to the historical uses of the space, the installation of the doors and the circulation ways in the residence.

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN
Corpus of Baroque Ceiling Painting in Germany
Prof. Dr. Stephan Hoppe
Institute of Art History
LMU Munich
Bernhard Strackenbrock illustrated architecture
Bayerische Schlösserverwaltung

The ceiling and wall painting is a crucial element in the design of baroque interiors. Colourful and with complex artistic programs, it defines the early modern architecture, so to speak, from above, both in the ecclesiastical and the secular area: in castles and banqueting halls, in churches and monasteries, in staircases or libraries. Throughout Europe this image medium, bound to architecture, unfolds astonishing diversity and innovative power in a variety of techniques from the middle of the 16th to the end of the 18th century. The Corpus of baroque ceiling painting in Germany researches and publishes the ceiling and wall painting of the period between about 1550 and 1800 in the territory of the Federal Republic of Germany.

To display the Imperial Hall in the highest quality and as realistic as possible, photogrammetry was used: for this Bernhard Strackenbrock from illustrated architecture was commissioned. The 3D model was calculated by means of photography data. Afterwards the V2C prepared the model for virtual reality, by reworking the textures and light to achieve a lifelike representation of the hall as well as making it accessible in VR.

THE CHAMBER CHAPEL

Cooperation between Students from Art History and "Art and Multimedia"

In the north wing of the Schleißheim New Palace, Max Emanuel II, Elector of Bavaria, built a chapel (1722-1726) for his second wife the Electress Therese Kunigunde. Within the chamber chapel there is not only an elaborately created and elegant stucco ornamentation on the ceiling but also original 17th-century scagliola panels (imitation inlaid marble made of stucco). Visitors are prohibited from entering the chamber chapel due to safety issues.

In the 2015/2016 winter semester, "Art History" and "Art and Multimedia" students from the Ludwig-Maximilians-Universität München collaborated through their courses "Baroque Castles in Munich. Their Visualisation Possibilities with New Media" (Ute Engel from the Institute for Art History, LMU Munich) and "3D-Software in Creative Processes" (Karin

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Institute for Art History
LMU Munich

Dr. Karin Guminski
Institute of Art Education
LMU Munich

Students from
Art and Multimedia

Guminski, Art and Multimedia, Institute for Art Education, LMU Munich). Through this cooperation, the students had the chance to discuss what the advantages of modern three-dimensional visualisation technology has to offer for art historic content. They presented the results in the 5-sided installation of the LRZ. Parallel to the dialog, the course "3D Software in Creative Processes" worked on the 3D model of the chapel. Initially a course for beginners in 3D modelling – the results spoke for themselves.

The project of the students was updated, to draw more attention to the fine details of the real chamber chapel. Components received a remodelling and were added into the scene; additionally the textures were given an overhaul. Through a new visit to the chamber chapel, it was possible to make high quality photos, which could not compare to the resolution, quality and colours of those of the students. Using reflex cameras and paying attention to the light situation (without hard shadows) made it possible to capture high-quality images and avoided the need to a high amount of post processing. The ceiling was remodeled and the ornamental stucco reliefs were added to the 3D model to better represent the baroque construction in the digital model.

Elisabeth Mayer
Kristian Weinand
Lea Weil
Michael Käsdorf
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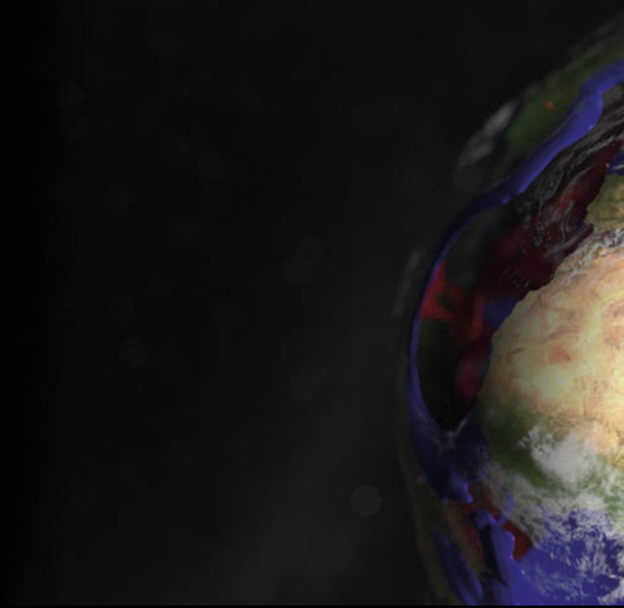

GEOSCIENCES

GLOBAL HIGH-RESOLUTION EARTH MODELS

A First Deep Look Into the Inaccessible Mantle

Understanding the convective flow in Earth‘s mantle is of fundamental importance, as it ultimately is responsible for all surface tectonic motions.

The slow, viscous creep-like flow in this roughly 3000 km deep region of solid rock underneath the tectonic plates with time scales of hundreds of millions of years, controls the heat transported from the interior of our planet to the surface. The amount of heat extracted from the underlying core strongly influences the character and strength of Earth‘s magnetic field. Moreover, the buoyancy forces driving mantle flow move the tectonic plates around and thus continuously reshape Earth‘s surface. The relative motion of plates leads to stress build-up at their boundaries that is released through recurring earthquake activity. Precise knowledge of the enormous forces acting

LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN
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within the mantle is thus a key ingredient in modeling these natural hazards. However, models of mantle dynamics are still often qualitative in nature to date. One particular problem is that we cannot access the deep interior of our planet and can therefore not make direct in situ measurements of the relevant physical parameters.

Fortunately, modern software and powerful high-performance computing infrastructures allow us to generate complex 3D models of the time evolution of mantle flow through large-scale numerical simulations. Models with several hundred million grid cells are nowadays possible using the facilities of the LRZ. These models provide quantitative estimates on the inaccessible paramaters, such as buoyancy and temperature, as well as predictions of the associated gravity field and seismic wavefield that can be tested against Earth observations. 3D visualizations of the computed physical parameters, produced by the V2C group of the LRZ, allow us to inspect the models such as if one were actually travelling down into the Earth.

This way, convective processes that occur thousands of kilometers below our feet are "accessible" – for the first time – by combining the simulations with high-end virtual reality techniques.

A next generation of mantle convection models that will be even more earth-like due to even higher resolution will be made possible by future supercomputing facilities, which will bring us one step closer to the ambitious goal. of quantifying the enormous forces that the mantle exerts on the tectonic plates.

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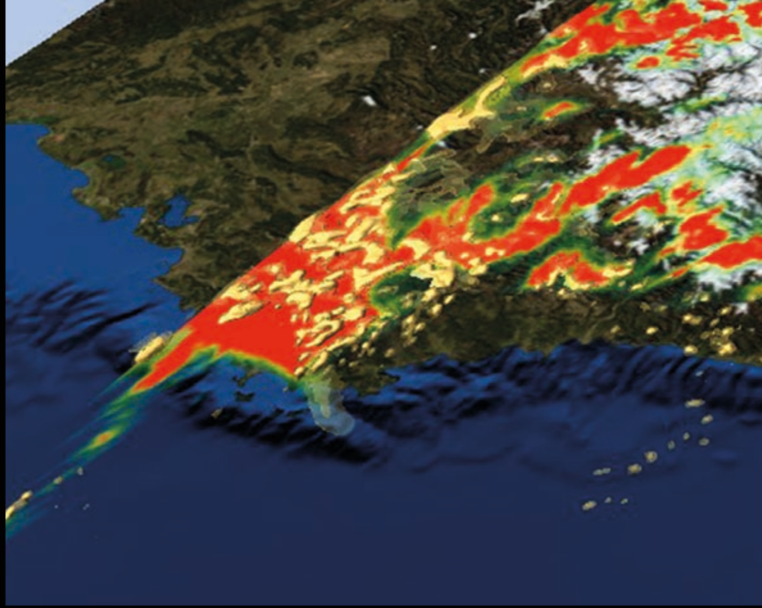


METEOROLOGY

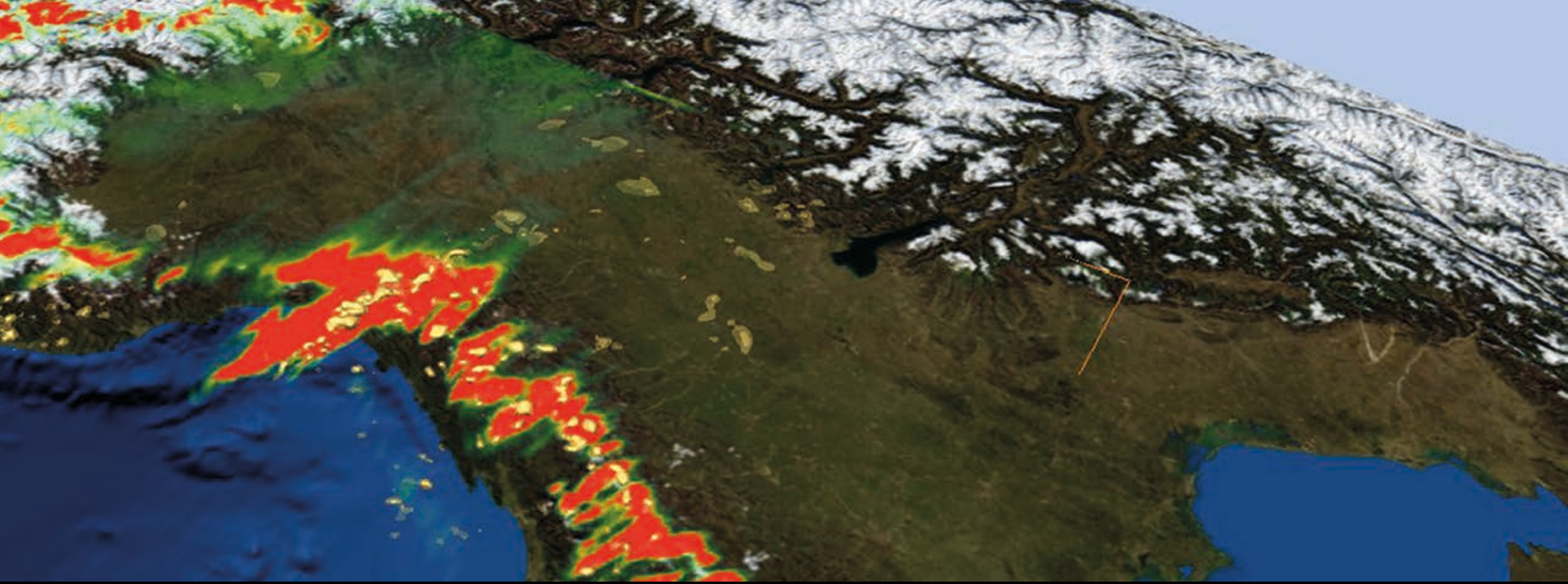
Climate Research within the EU Project DRIHM

Predicting weather and climate and its impacts on the environment, including hazards such as floods and landslides, is still one of the main challenges of the 21st century, with significant societal and economic implications. At the heart of this challenge, as also suggested by the DRIHM (Distributed Research Infrastructure for Hydro-Meteorology Study) project, lies the ability to have easy access to hydro-meteorological data and models, and to facilitate the collaboration between meteorologists, hydrologists, and Earth science experts for accelerated scientific advances in hydrometeorological research (HMR).

The proposed DRIHM project intends to develop a prototype e-Science environment to facilitate this collaboration, and provide end-to-end HMR services (models, datasets and post-processing

DRIHM
DISTRIBUTED RESEARCH INFRASTRUCTURE FOR HYDRO-METEOROLOGY

Dr. Antonio Parodi
Project Leader of DRIHM
CIMA Research Foundation



tools) at the European level, with the ability to expand to the global scale. The objectives of DRIHM are to lead the definition of a common long-term strategy, to foster the development of new HMR models and observational archives for the study of severe hydrometeorological events, to promote the execution and analysis of high-end simulations, and to support the dissemination of predictive models as decision analysis tools.

DRIHM combines the European expertise in HMR, and in grid and high performance computing (HPC). Joint research activities will improve the efficient use of European e-Infrastructures, notably Grid and HPC, for HMR modeling and observational databases, model evaluation tool sets and access to HMR model results. Networking activities will disseminate DRIHM results at the European and global levels in order to increase the cohesion of European and possibly worldwide HMR communities, and to increase the awareness of the potential of ICT for HMR. Service activities will deploy the end-to-end DRIHM services and tools in support of HMR networks and virtual organizations on top of the existing European e-Infrastructures.

www.drihm.eu/

Jutta Dreer
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CLIMATE SIMULATION

Visualisation of Extreme Rainfall Events

The ClimEx project is an international cooperation between research facilities, universities and public water agencies in Bavaria and Québec. It investigates the effects of climate change on meteorological and hydrological extreme events and implications for water management in both states. As part of this collaboration, possible scenarios regarding the climate trend between the years 1950 and 2099 were simulated. The SuperMUC of the LRZ completed the calculations of the simulation data.

The project partners selected three time intervals within the outcome of the simulation. Each interval contains 60 hours of data, which represent distinct rainfall events in Bavaria. The first of the three excerpts portrays the precipitation preceding the 1999 Pentecost

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Bayerisches Landesamt für Umwelt
gefördert durch
Bayerisches Staatsministerium für Umwelt und Verbraucherschutz

flood. This event, which draws upon historical meteorological data from 1999, serves as a point of reference for the remaining two events, which take place in 2060 and 2081. The V2C preprocessed and prepared the raw numerical information for a clear and vivid presentation in a computer-generated three-dimensional space.

Apart from the rainfall data, the VR-application also contains a 3D-model of Bavaria, which was the result of combining a digital elevation model, provided by the Bavarian Agency for Surveying and Geoinformation, with satellite pictures of Bavaria, taken by Sentinel-2. Additionally, the V2C added nameplates of the major Bavarian cities to the map, in order to facilitate threatened areas of high population density. To further put the data into context, a slide show of historical pictures of the aftermath of the 1999 Pentecost flood are on display once the visualisation of its rainfall event concludes. These photographs are placed within the application at the location where they were originally taken.

This visualisation enables a comprehensible presentation of the consequences of climate change for laypersons and specialists alike.

www.climex-project.org/

Martin Leduc, PhD
Ouranos

Daniel Kolb
Jens Weismüller
Wolfgang Kurtz
Leibniz Supercomputing Centre

SENSEPARATION

Encounters between People in Virtual and Real Space

The interdisciplinary and experimental project considers the cross-borders connection of humans between virtual and real space. For that matter, an encounter amongst two people at two separate locations takes place. In the process of staging this encounter, tactile, visual and auditory sensory perception are separated and therefore enhanced. With the help of an avatar, the user can interact in a virtual space with a person in a real space. This allows for a new perspective on experiencing emotionless and distant meetings.

Senseparation is an interdisciplinary project by the University of Art and Design Linz, the Ludwigs-Maximilians-Universität München and the Leibniz Supercomputing Centre with participants from the Johannes Kepler University Linz and the Technical University of Munich.

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Vest Electronics:
Bernhard Slawik, Franziska Tachtler, Rico Sperl, Nathan Guo

Sound System and Design:
César Escudero Andaluz, Jure Fingušt, Rico Sperl, Ulrich Brandstätter

VR Implementation:
Felix Manke, Tibor Goldschwendt, Oleg Maltsev, Christoph Anthes

Camera Tracking:
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Communication Server:
Ivan Petkov und Marlene Brandstätter

Visual Design:
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Virtual Environments:
Michael Käsdorf und Natascha Singer

Video Production:
Tomi Stevenson, Natascha Singer, César Escudero Andaluz

www.senseparation.net

Dr. Christoph Anthes
Leibniz Supercomputing Centre

AVATAR AS PROSTHESIS

Creating and Interacting with Digital Avatars

The project “Avatar as Prosthesis” is an artistic research project by media artist Gretta Louw, which studies the digital representation of people as avatars in the virtual world. The digital avatar could be a figure on a computer screen or be standing directly in front of the user in a Virtual Reality (VR) environment. Gretta Louw’s research not only encompasses the technical side but studies intensely the effects of an interaction between the two worlds on social contact and interpersonal relationships.

In the 2016/2017 winter semester, the students of the LMU Munich had the chance to experiment with the 3D modeling of avatars in new programs. During the course, students were encouraged to address the questions “what is an avatar?” and “can an avatar be a kind of prosthesis?” with Gretta Louw and

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Gretta Louw

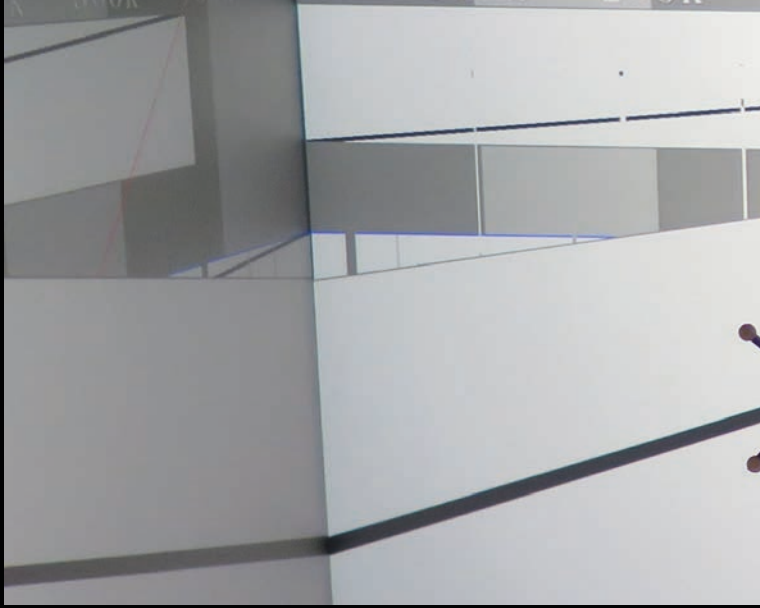
artists from the Stiftung Pfennigparade. Each student created an avatar in 3D space, either modelled on their own image, an ideal image of themselves, or based on a concept from another artist. In the end, there was a large variety of avatars, ranging from a bodybuilder, an angel, and a dragon to a self-portrait and a totem.

Gretta Louw has been researching this socially relevant topic since 2013. She has conducted interviews and collaborated with a wide variety of artists in order to gain a better understanding of the underlying psychology behind the interactions between people and avatars. Throughout the project, Gretta has expanded the meaning of the word "avatar" from the usual definition of characters in videos, computer games, and VR applications to every online presence or social media account. As VR has developed, the technology has become more accessible and affordable. The hardware has become more distributed and it is easier than ever to create one's own avatar.

During the project, there was a collaboration between "Art and Multimedia" students of the Ludwig-Maximilians-Universität München (LMU), Dr. Karin Guminski from the Institute of Art Education at the LMU, the Stiftung Pfennigparade – an organisation supporting disabled artists, and the Cultural Department of the City of Munich.

http://avatarasprosthesis.com/

Elisabeth Mayer
Leibniz Supercomputing Centre



GENETICS AND BIOINFORMATICS

MrSymBioMath

The project 'High Performance, Cloud and Symbolic Computing in Big-Data Problems applied to Mathematical Modeling of Comparative Genomics' (Mr.SymBioMath) concerns itself with the processing of large amounts of data within the field of bioinformatics and biomedicine and is an interdisciplinary project. Funded by the European Union's Seventh Framework Programme for research, technological development, and demonstration it is an Industry-Academia Partnerships and Pathways (IAPP) project under grant agreement number 324554. The partners – the University of Malaga, RISC Software GmbH, Johannes Kepler University Linz, Integromics S.L., Servicio Andaluz de Salud and the LRZ – cover a large range of expertise like bioinformatics, biomedicine, cloud computing as well as efficient processing of large amounts of data.

LIFE SCIENCES

Additionally the LRZ supplied their proficiency in the field of interactive data visualization.

The project focused on bioinformatics and biomedicine. On the one hand, the project deals with genome comparison, on the other the connection between genome variations and allergic reactions are studied within biomedical applications.

These two fields require the processing of large genome datasets, so Mr.SymBioMath works on efficient execution of such processing-intensive scientific tasks on cloud computing infrastructure. In doing so, solutions are developed for the storage and processing of large datasets, since genome data typically can reach terabyte scale. The applications developed by Mr.SymBioMath are used for the visualization of genome comparisons, as well as the creation of workflows in the fields of biomedicine and bioinformatics. These applications are able to run on various devices, like mobile phones, desktop computers and virtual reality equipment.

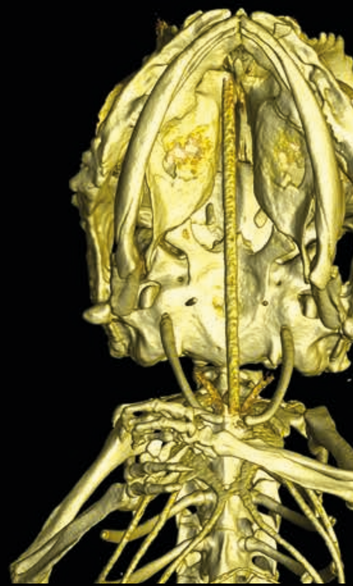
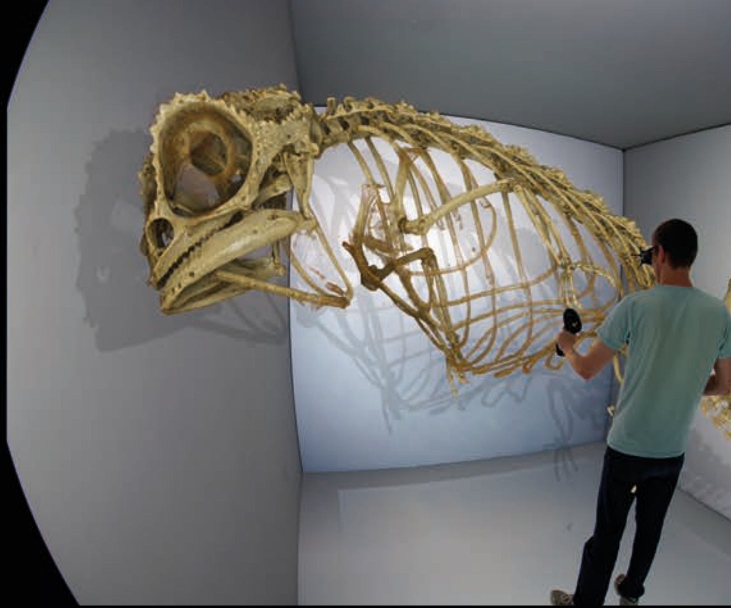
The LRZ developed an application for flexible representations of genome comparisons that is used to visualize the results. The comparison between two genomes is typically represented by dot plots, with one genome being shown on the x-axis and another on the y-axis. A section that appears in both genomes is marked by a dot. The innovative aspects of this application are the simultaneous comparison of multiple genomes as well as the three dimensional representation.

www.mrsymbiomath.eu

Dr. Balàzs Tukora, Dr. Christoph Anthes, Paul Heinzlreiter
Leibniz Supercomputing Centre

V2C

lrz

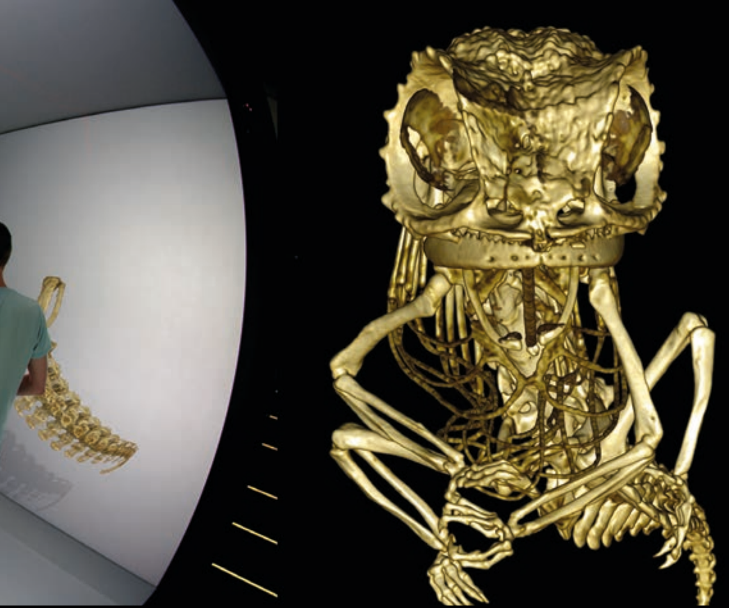
  

ZOOLOGY

Extreme Miniaturization of Dwarf Chameleons

Structural examination of biological structures is essential to understand their function. Like in many other scientific fields, computer supported 3D methods are increasingly used for such studies. This concerns both the acquisition and the analysis and visualisation of data. One option for data generation is x-ray computed tomography with a "Micro-CT" device, like the one which has been in operation at the Bavarian Natural History Collections in Munich for some years. Similar to medical diagnostics, x-ray images are taken at periodic angles with subsequent computation of a 3-dimensional dataset. This method allows for an accurate visualisation of tissue and structures with high x-ray absorption. A typical application for this technique is investigation of vertebrate skeletons.

Dr. Bernhard Ruthensteiner
Benedikt Geier
Dr. Frank Glaw
Bavarian State Collection of Zoology



Reptiles, birds and mammals form the largest group (amniota) of vertebrates and share a common basic structure. The difference in size within this group is enormous, extending from large, almost 30-metre long whales and dinosaurs to us humans and then to minute organisms like the Madagascan dwarf chameleon Brookesia micra; with a maximum length of 29 mm from its snout to the tale it is among the smallest amniotes. Comparative analysis of the chameleon's anatomy should help to understand the limits of the miniaturisation of higher vertebrates and discover special adaptions. Regarding this dwarf chameleon, the most striking example are the proportions of the excessively big eyes compared to the head– indicating that this highly developed organ cannot be shrunk without loss of functionality.

To evaluate such results and to understand the structures, the way of visualising the data plays a very important role. Interactive real-time rendering in combination with Virtual Reality, as in use at the LRZ, allows scientists to quickly analyse the structure of the skeleton and the understanding of some spatial connections are improved when compared to other types of visualisation.

Dr. Peter Weinert
Leibniz Supercomputing Centre

MOOSAIK

Environmental Communication with Augmented Reality

The fen Thalhamer Moos is located in the Isental west of Mühldorf am Inn. Due to its significance for rare and even some endangered flora and fauna the area has become part of Natura 2000, a european network of nature protection areas. The marsh is conserved and managed to preserve the fragile ecosystem and create a habitat for rare plants, insects, amphibians, birds and mammals. Besides the current efforts to maintain and renaturalise this ecosystem, the number of visitors to the fen has to be managed, in order to create undisturbed areas for the endangered fauna. Since the Thalhamer Moos is a popular recreation area for the local population, a nature trail is planned to educate people about the unique local flaura and fauna, inform them about the significance of the fen for the protection of the environment and help the

Wildland Stiftung Bayern

Eric Imm, Patrizia Weindl
Wildland-Stiftung Bayern

visitors to realise the necessity of the limitations imposed by the conservation efforts.

For the first time the efforts will be supported by an Augmented Reality (AR) App. It enabled the integration of additional content and provides interested visitors with in-depth information during and after their visit to the fen. Supplementary multimedia content like animal sounds or short video sequences enhance the environmental education and can be used to encourage users to pay closer attention to nature. In this context, ongoing research is focussing on the topic of how to use an AR app to create a more compelling experience rather than distract from nature.

Humans tend to perceive species we already know as more worthy of protection than others. The app can help people to become more familiar with shy or very small species that tend to be overlooked. Augmented Reality allows to display animated 3D models of animals or plants in the real environment and give visitors the chance to observe them in their natural environment.

The focus of the project is the development of workflows to create the virtual models and optimise the process of creating a digital animal or plant by comparing various software tools and methods to digitise existing objects. Since Augmented Reality is not a well researched platform in the context of environmental education and communication, this project also provides the opportunity to develop approaches and strategies that can be used in future projects in this area.

Constantin Geier
Kristian Weinand
Lea Weil
Leibniz Supercomputing Centre

ARCHITECTURE

100 YEARS BAUHAUS

The Barcelona-Pavilion by Mies van der Rohe belongs to the most significant buildings of the modern architecture. It was built as part of the 1929 Barcelona International Exposition and was torn down 8 months after its completion. Even decades after its demolition the importance of the building was undisputed, therefore it was reconstructed by Spanish architects from 1983 to 1986. Since its development, the building has been interpreted, recreated and visualized for many, many times. In cooperation with Prof. Dr.-Ing Rudolf Bertig from the University RWTH Aachen the CAD-Stelle Bayern got involved with the subject Barcelona Pavilion in 2012. At that time a 3D model was constructed with the common 3D CAD modeling methods. In the course of Prof. Dr.-Ing Rudolf Bertig's supervised exhibition "100 Years Bauhaus" the adjustment and realization of the 3D-model for the 5-sided

cad stelle bayern

Pavla Ryzlerova
Robert Schmid
CAD Stelle Bayern

Prof. Dr.-Ing. Rudolf Bertig

projection installation at the LRZ in Garching has begun in September 2018.

Prof. Bertig who is known as a “Mies van der Rohe expert” verified the accuracy and the accordance of the 3D-model in comparison with the original copies of the floorplans acquired from MOMA. In a common decision it was decided not to display the current state of the pavilion but the state of 1929 including the surroundings as faithful as possible and add the presentation as an external special unit to the “100 Years Bauhaus” exhibition. Besides that, an optimized and standardized workflow for collaborations between the CAD-Stelle Bayern and the LRZ should be created as a by-product. The main goal is the improved exchange of 3D data from CAD models in virtual environments. This offers the opportunity to shorten and simplify decision-making processes directly in the virtual reality and especially in the 5-sided projection installation without high time losses.

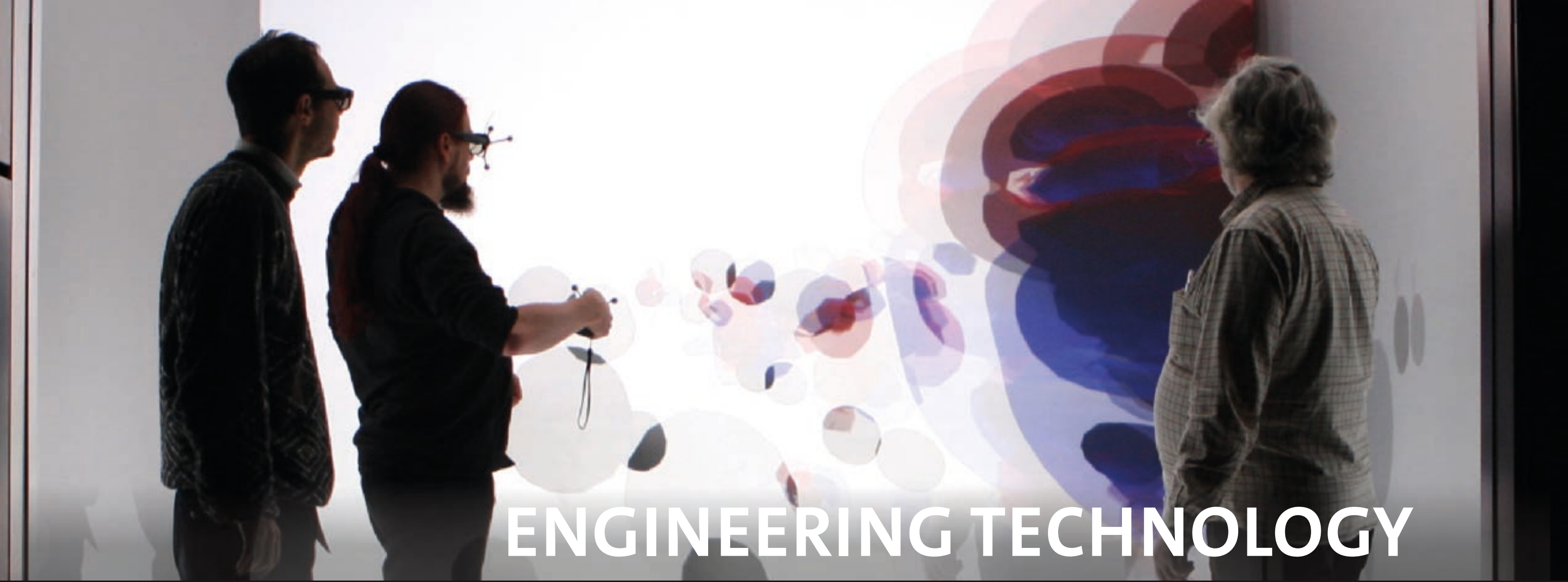
CHEMISTRY AND MATERIALS SCIENCE

NOMAD

The Novel Materials Discovery Laboratory, is a European Centre of Excellence (CoE) dedicated to Big-Data in materials science. NOMAD creates, collects, stores, and cleanses data, computed by the most important materials-science codes. NOMAD develops data-mining tools in order to find structure, correlations, and novel information that could not be discovered from studying smaller data sets. The large volume of data and innovative tools will enable researchers in basic science and engineering to advance materials science, identify new physical phenomena, and help industry to improve existing and develop novel products and technologies.

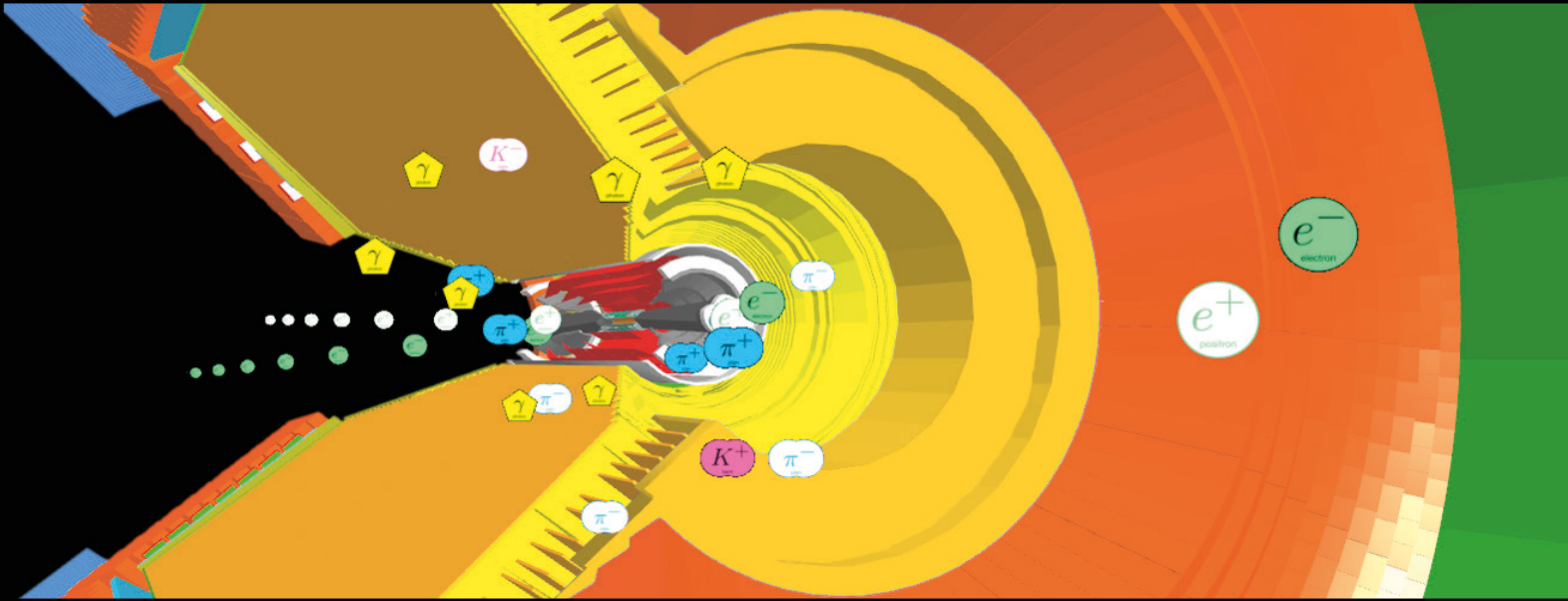
An important part of NOMAD is the use of advanced graphics to enable understanding of the large volume of data produced by chemical

NOMAD PI
Prof. Dr. Matthias Scheffler,
Theory Department,
Fritz Haber Institute of the
Max Planck Society (Berlin)



simulations. In particular, virtual reality approaches bring the user to the nanoscale, allowing them to “become an electron” and explore the system visually in an intuitive way. We have developed a software suite using the most common virtual reality platforms, specifically Google Cardboard, Samsung GearVR, HTC Vive and our CAVE-like environment at the Leibniz Supercomputing Centre. The software adjusts the rendering quality and interaction possibilities according to the equipment’s capabilities. Our goal is to offer the system that suits the users‘ budget and needs best. With the system, we can visualize crystal structures (ordered arrangement of atoms, ions or molecules in a material), Fermi surfaces (abstract boundary useful for predicting the thermal, electrical, magnetic, and optical properties of metals, semimetals, and doped semiconductors), molecular-dynamics simulations with or without electron density (for studying chemical reactions and other material properties), and excitons (bound states of an electron and an electron hole which are attracted to each other by the electrostatic Coulomb force). The latter are 6-dimensional objects where virtual reality can show its potential to visualize effects that otherwise are hard to capture.

Dr. Rubén Jesús García-Hernández
Leibniz Supercomputing Centre



PHYSICS

Visualisation of Measurements of the Belle II Detector

The Belle II detector is a particle physics experiment at the KEK research center in Tsukuba, Japan. Belle II is specifically designed, to identify particles created in collisions and to measure their properties with high precision. The measured data will enable the Belle II collaboration, consisting of about 750 scientists from over 100 research institutes across the world, to deepen their understanding of elementary particle physics. The main goals of the collaboration are the precise determination of fundamental physical constants and the search for so-called New Physics. The first improves the knowledge of important parameters of the Standard Model, the theory developed to describe the behavior of elementary particles, while the latter aims at the discovery of unknown physics phenomena beyond this theory.

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Prof. Dr. Thomas Kuhr, Dr. Michael Bender
Excellence Cluster Universe
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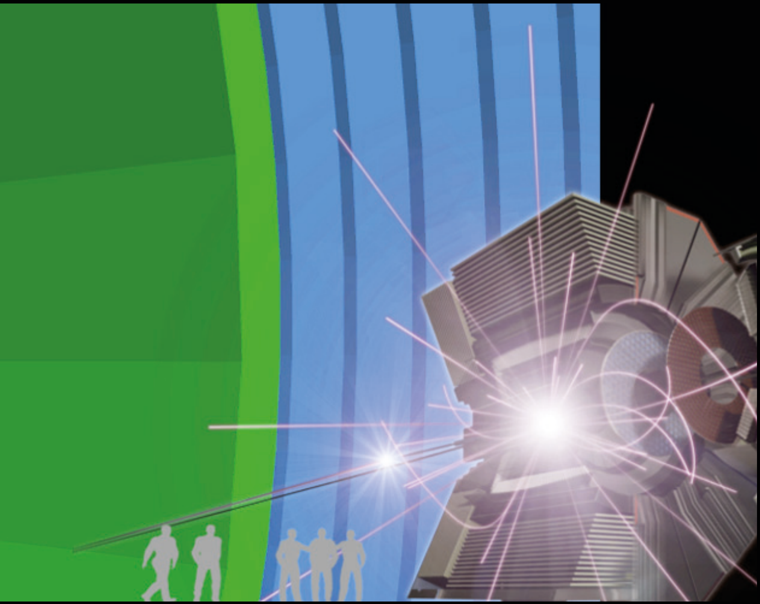
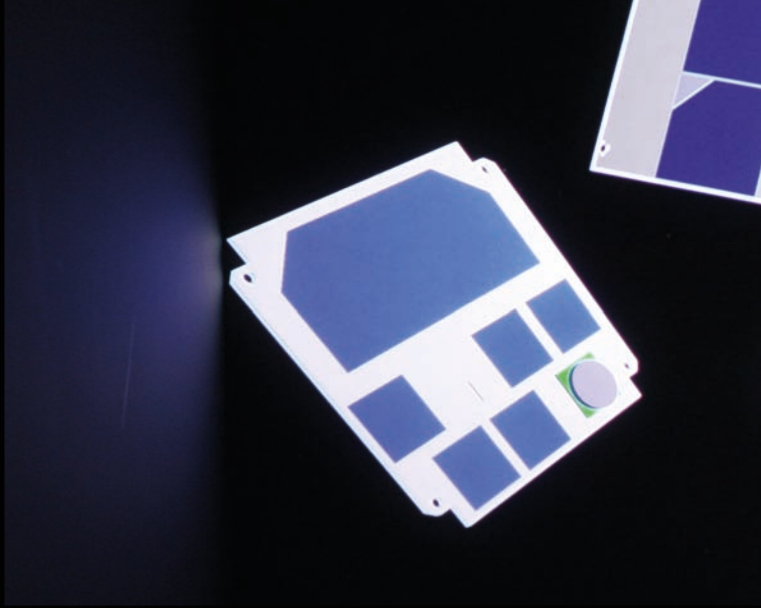


The Belle II detector is located at the interaction point of the SuperKEKB accelerator, the most powerful lepton collider in the world. It accelerates electrons and their anti-matter partners, the positrons, almost to the speed of light and brings them to collision in the center of the Belle II detector. With a design luminosity of 8 x 1035cm-2s-1, SuperKEKB is planned to break the world record in particle collision rate and will produce an unprecedented amount of electron positron collision data.

During the analysis, scientists reconstruct the particles created in the collisions, by carefully scrutinizing the signals measured in various detector components. In order to get a better understanding of this data, it is often helpful to visualize it. This is were so-called event displays are used. An event display is a visual representation of the reconstructed data, which gives an impression of how the collision actually looked like in the detector. An even more realistic impression can be obtained with Virtual Reality (VR) applications. The Cave implementation of the Belle II event display at LRZ, is such an VR application, which offers an unique way to explore and understand Belle II data.



ASTRONAUTICS

MOVE-II Satellite

MOVE-II is a CubeSat, a tiny satellite with dimensions of 10 x 10 x 13 cm and a mass of 1.2 kg. It is the second satellite of the Technical University of Munich (TUM) and the follow-up project of First-MOVE. The name MOVE is an acronym and stands for Munich Orbital Verification Experiment. The number “II” implies that it is the second of its series.

The CubeSat is developed in cooperation between the Chair of Astronautics (LRT) and the Scientific Workgroup for Rocketry and Space Flight (WARR). About 60 Bachelor and Master Students from various faculties, backed by two PhD students, are currently working on the satellite, mostly in their free time.

In the space industry, new technologies are usually verified in precursor missions, before used within expensive projects. Our satellite is

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FKZ 50RM 1509

built for a similar purpose. We are developing, implementing and verifying a so-called satellite bus, meaning all parts of the satellite required to run the payload. This includes the communication system, the on-board data handling system, the attitude control system, the power supply, the structure and the thermal control system. Besides that, the performance and degradation of a new generation of solar cells, which have never been in outer space before, is investigated by our satellite as its scientific mission.

MOVE-II is funded by the Federal Ministry of Economics and Energy (BMWi), following a decision of the German Bundestag, via the German Aerospace Center (DLR) with funding grant number 50 RM 1509. The idea of this educational project is to give students the opportunity to complement their theoretical education within lectures by the experience of working on a real satellite. We hope that with MOVE-II a next generation of experienced space engineers is risen. Our CubeSat was launched by a Falcon-9 rocket in November 2018 into a 575 km, sun-synchronous low earth orbit.

Elisabeth Mayer
Markus Wiedemann
Leibniz Supercomputing Centre

FLUID DYNAMICS

Iteractive Immersive Visual Data Exploration

Interactive high-performance computing is doubtlessly beneficial for many computational science and engineering applications whenever simulation results should be visually processed in real time, i. e. during the computation process. According to the former US President Obama‘s Council of Advisors on Science and Technology “high-performance computing must now assume a broader meaning, encompassing not only flops, but also the ability, for example, to efficiently manipulate vast and rapidly increasing quantities of both numerical and non-numerical data” [1].

Nevertheless, those interactive or in situ approaches usually entail lots of challenges that have to be tackled – one of them addressing the fast and efficient data transfer between simulation back- and visualisation front-end

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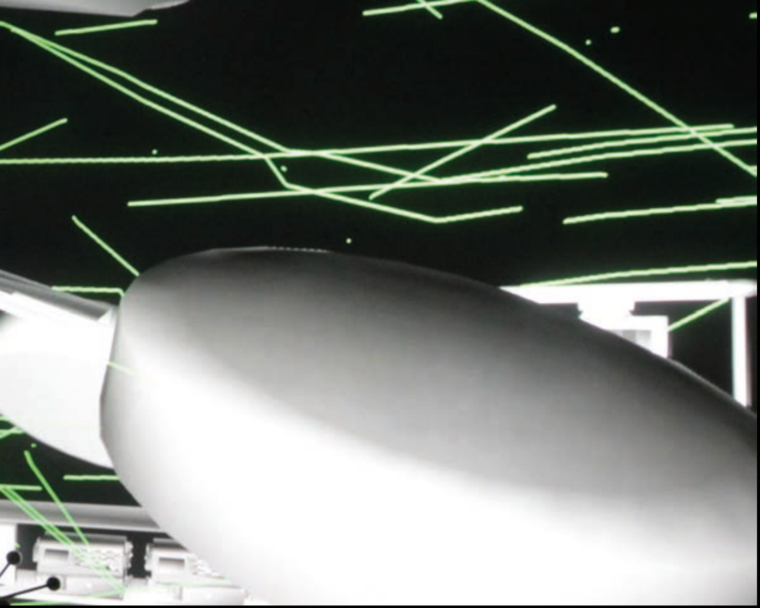

where several gigabytes of data per second are nothing unusual. Here, a data exploration technique called sliding window [2] allows for online/offline visualisation of huge data sets (up to hundreds of billions of unknowns), coping with any bandwidth limitations, and enabling users to study both large and small scale effects of the simulation results in an interactive fashion.

Within this project, pollution distribution in an operation theatre should be predicted with the objective to keep particles and bacteria floating in the air away from a patient during surgeries. Therefore, an airflow introduced from the back wall of the room creates a steady stream over the patient's body, thus 'blowing' away any contamination. For better visual comprehension of the computed results an immersive virtual reality facility (CAVE – Cave Automatic Virtual Environment) is coupled to the running application. While standing in the CAVE, users have the possibility of moving around, zooming into the data, moving forward/backward in time, or manipulating simulation parameters (e. g. boundary conditions) in order to evaluate various scenarios and experience phenomena in a virtual world that would not be possible or accessible in reality.

[1] T. Kalil, J. Miller: Advancing U.S. leadership in high-performance computing. The White House, https://www.whitehouse.gov/blog/2015/07/29/advancing-us-leadership-high-performance-computing
[2] R.-P. Mundani, J. Frisch, V. Varduhn, E. Rank: A sliding window technique for interactive high-performance computing scenarios. Advances in Engineering Software, Vol. 84, pp. 21–30, 2015.

LECTURE VIRTUAL REALITY

The course Virtual Reality consists of a theoretical part, in form of a lecture, which is held at the Ludwigs-Maximilians-Universität München (LMU) and a practical component in form of a project practical, which takes place in the LRZ.

The contents of the lecture reach from giving a historical overview on technical developments and application areas, over linear algebra to a broad selection of interaction metaphors, navigation and locomotion concepts. Adjoining areas from cognitive psychology, like perception models from Gestalt theory to depth perception, are taught in the context of an in depth review of data visualisation. The lecture focuses on teaching technological and mathematical concepts of the technology virtual reality, like stereoscopy, tracking and perspective view.

Prof. Dr. Dieter Kranzlmüller
Institute of Informatics
LMU Munich

TEACHING

Those concepts are deepened in form of exercises in the practical part as well as in subsequent project practical. In the latter, students create their own projects using the facilities of the LRZ. The theme of the project is chosen freely, only subject to quality criteria like stability and interactivity. Often, new games or reinterpretations of existing games, like Angry Birds, Pong or Bubbles, are designed and developed. However, also scenes from the real environment, for example archery in virtual space, or from the cineastic world, like Star Wars inspired applications, are also implemented.

The final results of the course are presented yearly to a large audience at the Virtual Reality Open Lab Day at the LRZ.

Markus Wiedemann
Leibniz Supercomputing Centre

LECTURE ART & MULTIMEDIA

The Centre for Virtual Reality and Visualisation (V2C) and the Art and Multimedia B.A. program of the Institute for Art Education at the Ludwig-Maximilians-Universität München (LMU) have been collaborating for many years. Under the supervision of Dr. Karin Guminski (LMU) and the team of the V2C, students are able to gain knowledge on three-dimensional concepts and design as well as virtual reality (VR).

The title of these courses are among others "3D-Software in creative processes". The goal is to introduce students to working with 3D programs and to teach a creative approach to software. After the introduction, the students both work on individual or a group project and are in constant contact with tutors, teachers and staff of the V2C. Additionally, with the extensive support of the V2C, students are

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Dr. Karin Guminski
Institute of Art Education
LMU Munich

Artwork:
Maria Rezvanova
Art and Multimedia
LMU Munich

able to further deepen their knowledge of VR. The finished models are then prepared for the 5-sided projection installation and shown in a final presentation. Depending on the topic, experts from the field are also invited to teach in the lecture.

Subjects of past semesters included associations with artworks, development of avatars, interactive encounters in virtual space, and many more (see Chapter 4 Art). Additionally, there were architectural projects, where students had to learn how to work with strict specifications, as well as artistic projects, for example the implementation of a painting into a 3D scene, were also offered in the course. In one of the projects, called "Associations with the Merzbau from Kurt Schwitters", the students had the chance not only to work theoretically with the cubistic looking work from 1923-1936 but also practically. The room was well suited for a creative reconstruction, mainly due to its geometric structure. The students were then able to – through the facilities of the V2C - walk through their interpretations of the artwork and gain new perspectives of the object.