Study Results on Employing Virtual and Augmented Reality for Spacecraft Operations and Astronaut Training at ESOC and EAC

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In this presentation, we present results of two studies on leveraging Virtual Reality (VR) (2017 - 2018) and Augmented Reality (AR) (2018-2019) for operations and astronaut training, which were performed for ESOC and EAC. The studies covered a broad range of topics ranging from conceptual aspects to concrete practical results made with proof-of-concept implementations and deployments. The aim of the presentation is to give an overview of what we consider the most relevant results. The following results will be covered:

- **Practical**
  Practical results cover software/system design, proof-of-concept implementations, and experiences made using them and include:
  - **High-precision Model-based AR Tracking**
    Using model-based AR tracking, it was possible to achieve high-precision tracking, which is critical for high-quality manuals/procedures. Furthermore, high-precision tracking can also be employed for verifying the correct assembly of physical components.
  - **Integration of AR/VR Devices and COTS with ESA Software Systems**
    Over the course of both studies, a mix of different VR/AR devices/COTS and ESA software systems covering a Mission Control Systems (MCS) and a Simulator had to be integrated. For this, the use of a flexible multi-protocol Message-oriented Middleware (MoM) Open Source Software (OSS) proved to be very helpful.
  - **Multi-modal AR HoloLens Application for Rover Operation**
    A versatile HoloLens AR application for rover operation was developed supporting multiple use cases covering on-site and remote operator scenarios.
  - **VR for Astronaut Training: A VR Training Chain, from Modelling to Execution with Corresponding Tooling**
    VR provides the possibility to simulate dangerous or expensive scenarios, such as an emergency in a virtual lunar base. Furthermore, besides the “core” VR application, tooling support along the full chain of training development/modelling, training execution/monitoring, and training experience was developed considering needs of trainers, trainees, and training developers. The tools were integrated into VR and ESA software.
- **Conceptual**
  Conceptual results cover, e.g., collection of ideas and methodologies for performing studies and include:
  - **Use Case Identification and Development of Details**
    We achieve very good results by interactive involvement of multiple stakeholders using a two-step idea gathering and interview process.
  - **Agile-like Workflows/Development Processes**
    Following mixed aims of exploration and concrete prototyping, agile-like processes showed to be very helpful in achieving the study aims.
  - **Collected Use Case Ideas and Associated Taxonomies**
    Use cases were identified and classified based on commonalities/differences resulting in a simple taxonomy.