Change impact analysis with sensitivity filtered AR/VR for design reviews

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Increasingly more complex and diverse solution elements (mechanical, hydraulic, pneumatic, electronic, software control) make product synthesis and integration more dependent on holistic systems engineering thinking, which calls for multi-domain product and system compatibility and validation reviews. Model-based Systems Engineering (MBSE) seeks to cope with complexity by enabling the use of simplified system representation that support the engineering workflow. However, simplifications and modeling concepts vary greatly between domains, which poses great challenges when it comes to systems integration in general and system design reviews in particular. Inhomogeneous verbiage and differing design concepts between the various stakeholders collaborating in the development of the system impede the efficiency of traditional design reviews. Design reviews usually comprise different development partner interests and boundary conditions (OEM, supplier, engineering service provider, final customer service provider etc.) The cross-domain nature of design review teams poses challenges, but also opportunities to explore design and architecture changes as well. Alternatives can be evaluated collaboratively, therefore leveraging domain expert-knowledge from participants with diverse backgrounds.

Virtual and Augmented reality (VR/AR) methods as a tool for systems development and evaluation have so far been largely neglected in systems development outside of geometrical representations of parts and assemblies. A VR/AR "heat map" representation of system dependencies, which overlays with the 3D representation of the system under review provides a new approach to a unified visualization of a system and its interconnections between components beyond just geometry data for all stakeholders. Design review teams require tools and methods to perform cross-functional impact analyses using a generic representation of interdependencies across various domains. The visualization in virtual space will highlight component meshes with strong dependencies and additional visual clues that are easily grasped by the design review collaborators.

Enabling collaborators to explore all system dependencies that are of interest during the review a VR/AR visualization requires means to avoid overwhelming users with an indiscriminate presentation of every possible dependency existing in a system. This means some form of filtering or processing dependencies is required. In this way, collaborative reviews can be conducted and the system interrelationships are presented in a way that is easy to understand and serves as a common base for reviews and actions among all development stakeholders.

In order to leverage VR/AR technology for a better cross-domain understanding of systems dependencies a “sensitivity adjustment” is required to avoid overly crowded and impractical user interfaces. This means a filter is required to select whether connections should be visible to the nth degree or cut off after a defined level of depth and potentially an option to filter on different

types of interconnections and granularity. The visual clues represented in the virtual space are adjusted according to the filters, in order to highlight the component independencies that the engineer wants to emphasize on. In order to provide a generic tool that works across a large area of development and design methodologies there needs to be a means to measure the significance of dependencies between to areas of a system, beyond the mere counting of tracing connections. However, for this work, the specific type of change to a system are not taken into account, and a generic change to a system component or area will be assumed. A preliminary impact analysis of a component change to a jet engine serves as an example to lay out, evaluate the filtering methods needed to process, and present a change impact through various dependencies within the engine system while maintaining an adequate user experience and leverage VR/AR technologies. In order to have a first impression of the visualization, we imported the jet engine alongside with predefined dependencies into a mobile Augmented Reality application and highlighted meshes according to their dependencies. In a next step, we created a simple User Interface Mockup for possible Interactions.

With systems interaction model being one of the main development capabilities MBSE provides the heat maps available via AR technology must account for the multitude linkages in complex systems (link in <> link out, domain-specific, interdisciplinary, number, type of criticality, age ...). This poses further challenges for a generic approach to evaluate the significance of dependencies, but is crucial for subsequent filtered VR/AR processing and representations and to not overwhelm

Providing a heat-map representation with filtering capabilities in order to select the level of depth and order for different types of interdependencies within a system enables users to explore various system perspectives and analyze dependencies without in-depth knowledge of domain-modeling techniques. Using VR/AR representations to visualize systemic impacts of changes improves cross-domain collaboration, allows for a swift exploration of alternatives, and supports collaborative expert decision-making on the spot. Here, filtering avoids overwhelming users with potentially irrelevant while at the same time providing a tool for users to decide which granularity and type of information is relevant to their specific review situation. Enabling participants of design reviews to perform ad-hoc preliminary impact analyses can not only improve communications between domains as well as communication with regular development teams by enabling the design review team to attach preliminary findings regarding the impact a decided change action. Enabling ad-hoc impact analyses with AR provides opportunities to also define the scope of a desired change to the system more clearly and reduce the number of iterations needed for the desired design outcome.