Abstract

Digital Human Models (DHM), belong to a class of human-in-the-loop simulations having primary applications in the area of virtual ergonomics, virtual prototyping, and task evaluations. These models replicate physical and mental human behaviour in a prototypical complex system. As an advantage, the potential strengths and weakness of the complete system configuration can be analysed without requiring any traditional design prototypes or system mock-ups. Recent DHMs can effectively analyse posture, seating, reach, and visibility. However, a DHM specific step-wise configuration is needed, where manual intervention is a bottleneck. It also constrains natural and human like behaviour simulation. With the advent of smart manufacturing, knowledge management, computer control, big data and artificial intelligence, DHMs can be modelled for autonomous and natural simulations. New and advanced DHM frameworks that can facilitate varied human population, work system data and perform simulations in an automated manner. To start with, DHMs must be equipped with an ability to be aware of the surrounding workspace, utilise knowledge and take human-like decisions. This work is precisely oriented towards the endowment of DHMs with such mechanisms.

Following the first three phases of design research methodology, the work is divided into seven chapters. First, the problem understanding phase, which consists of ethnographic and human factor based field studies. The studies were performed ISRO

and IISc premises. They utilise interviews, surveys and eye-trackers for understanding the role of vision on manual assembly. Second, the ideation phase, which involves developing a complex DHM framework connecting visual perception with cognition and decision-making. A functional visual perception model is first developed on the basis of human acuity and accommodation characteristics. It is capable of qualitative and quantitative analysis of workspace objects on the basis of their saliency, size and distance. Next, for representing, filtering and storing the human and visual information, a symbolic knowledge schema is developed that effectively acts as a bank of spatial information, human experience and short term memory. Further, a set of physical and mental behaviour algorithms are modelled that utilise the perception and knowledge models for the simulation of an exploratory visual search task. Third, the prototype phase, which consists of software development for the implementation of the framework. Using a prototypical system implementation, the applicability and usefulness of the framework and the underlying modules are exhibited.

The reported work, therefore, has three primary contributions. First, a set of qualitative and quantitative experimental human studies that manifest the importance of vision and its behavioural influence on the manual assembly tasks. Second, an early stage functional vision model of DHM-Object perception. A method of quantifying object clarity as legibility is developed that relies on human acuity and accommodation as well as object's saliency, size and distance, Third, a novel paradigm of perception, cognition and decision-making developed as a modular framework for DHM task simulations. In light of simulating an exploratory visual search task, natural and human like try-out manoeuvres are demonstrated in a virtual workspace.