A Real-Time Simulator for 3D Mental Image Reconstruction On Board the International Space Station

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Abstract

The operations of manned and unmanned space vehicles and their associated supporting docking and robotics systems require significant crew training both on ground and on orbit. A number of psychological and physiological factors are known to affect the crew on-board performance. Therefore, skills degrade over time and the frequency, depth of proficiency and refresher training need to be studied.

Currently a new experiment is designed in order to study the 3D mental image reconstruction for tasks involving the operation of all robotic components of the Mobile Servicing System (MSS) of the International Space Station (ISS). The MSS is composed of three main components, i.e., MBS (Mobile Remote Servicer Base System), Canadarm2 (SSRMS), and Dextre (SPDM), including its two arms, its body roll and its two grippers at their end.

The long-term goal of this research project is to gather data to study skill degradation and recovery of psychomotor and cognitive skills. This data will be analyzed to help define metrics that could be used to assess the level of readiness of an operator to perform complex tasks. To study performance degradation and skill recovery, a highly efficient simulator is required in order to ensure on orbit real time simulation and fast feedback to the operator.

In general, on the ground, the astronaut training is carried out at CSA using the high-fidelity MSS Operation and Training Simulator (MOTS), which consists of class I and II crew stations, graphics supercomputers, instructor stations and operations stations. It provides training to prepare mission specialists to operate the MSS, which includes familiarity with visual displays and computer equipment used on board the ISS.

In this project, the challenge is the real-time simulation of Canadarm2 and Dextre while performing graphics rendering of the worksite environment using just a single computer, in particular a P4 1.8Ghz IBM ThinkPad. Although the overall system contains three seven-degrees-of-freedom robots with joint and link elasticity, this R&D on-orbit simulator can feature a lower fidelity and a significantly reduced number of features compared to official ISS simulator but it is mandatory that everything runs in real-time on a single Laptop. Hence, it is necessary to make some judicious choices of the physical and system functionalities, which should be included in the multibody dynamics simulator. Therefore, some trade-offs are inevitably required between the model complexity and the time to execute.

The dynamics simulator is based on CSA's in-house modeling tool Symofros (www.symofros.org). Here it is important to note that the control architecture on the ISS only permits to operate one robotic system at a time, generally by means of hand controllers. All other systems are braked at that time. This means, either the MBS, Canadarm2, Dextre arm 1 or arm 2 or the body roll of Dextre can be manipulated. This fact allows from the modeling point of view for crucial simplifications.

To accurately evaluate and improve the operator's ability to extract and use efficiently three-dimensional information from each viewpoint, the simulator relies on the modeling technology from SGDL (www.sgdl.com) to generate highly realistic images. SGDL is a high level technology for modeling, graphics and volume operators. It is based on projective geometry and represents objects using simple projective primitives. For the graphics rendering of the models, the projective primitive are transformed into an approximate polygonal representation. This minimizes the computational load on the CPU and optimizes the rendering rate by using graphics card hardware acceleration. At the same time, a collision detection algorithm is applied to the exact projective primitives to monitor any collision event. The simulation is stopped and a visual feedback is provided to the operator when a collision occurs.

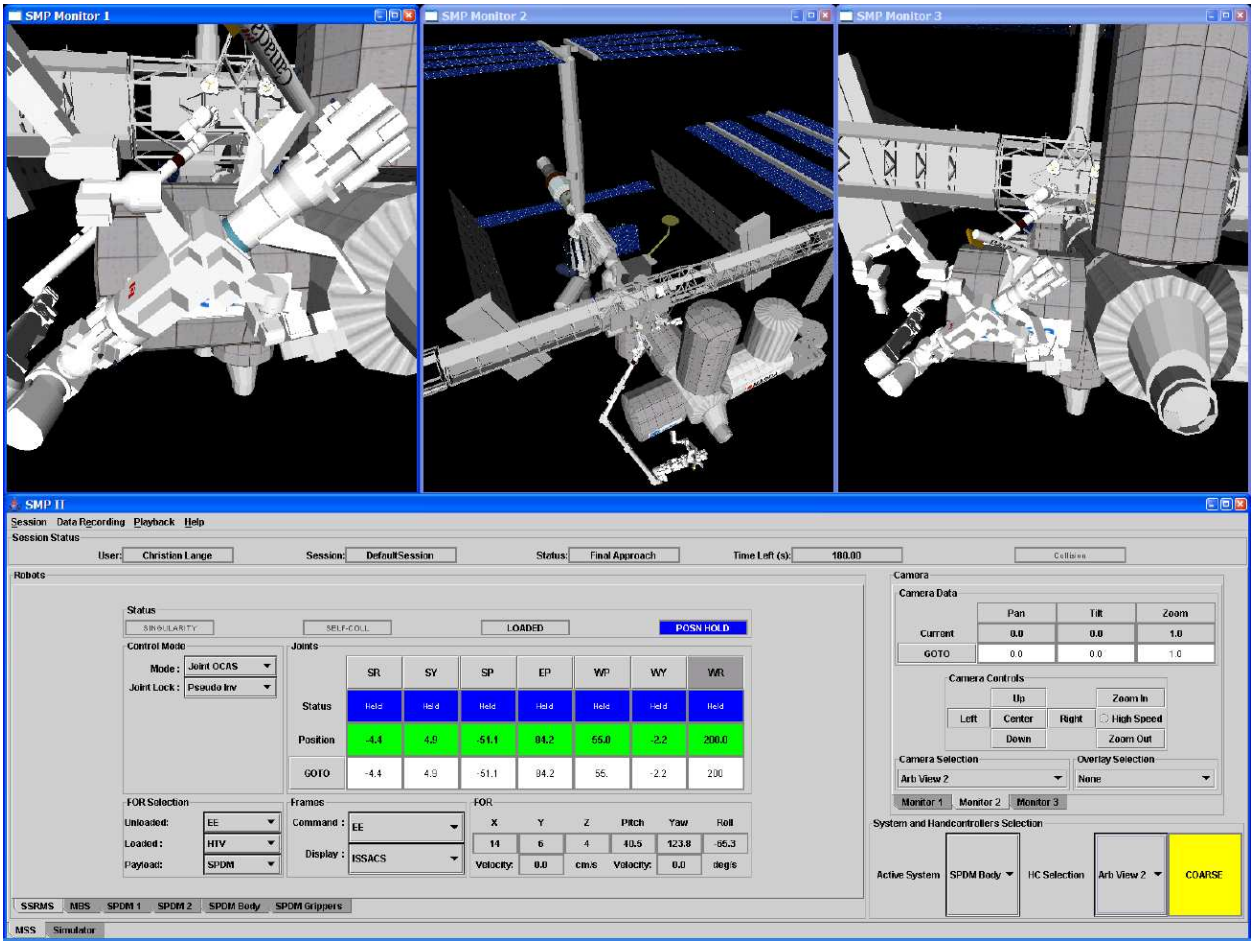

Figure 1: SMP 2 simulator screenshot