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Virtual Planning, Control, and Machining for a Modular-Based Automated Factory Operation in an Augmented Reality Environment

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This study presents a modular-based implementation of augmented reality to provide an immersive experience in learning or teaching the planning phase, control system, and machining parameters of a fully automated work cell. The architecture of the system consists of three code modules that can operate independently or combined to create a complete system that is able to guide engineers from the layout planning phase to the prototyping of the final product. The layout planning module determines the best possible arrangement in a layout for the placement of various machines, in this case a conveyor belt for transportation, a robot arm for pick-and-place operations, and a computer numerical control milling machine to generate the final prototype. The robotic arm module simulates the pick-and-place operation offline from the conveyor belt to a computer numerical control (CNC) machine utilising collision detection and inverse kinematics. Finally, the CNC module performs virtual machining based on the Uniform Space Decomposition method and axis aligned bounding box collision detection. The conducted case study revealed that given the situation, a semi-circle shaped arrangement is desirable, whereas the pick-and-place system and the final generated G-code produced the highest deviation of 3.83 mm and 5.8 mm respectively.

An effective simulation is one that is able to place a user in a situation which is close, if not completely identical to the scenario of which the system is attempting to simulate. The correct term for providing a user with a sense of presence, or "being there", is immersive, where in the world of virtual interaction, is defined as a complex technology that replaces real-world sensory information with synthetic stimuli such as 3D visual imagery, spatialised sound, and force or tactile feedback[1]. In manufacturing, the advent of computer numerical control (CNC) machining creates a form of ubiquitous computing, and provides an effective simulation as it becomes a necessity. CNC simulations have been developed in virtual environments for numerically controlled (NC) tool path verification and machining process optimisation[2]. However, limitations still exist even though virtual reality (VR)-based systems have already been applied broadly in the manufacturing industry. Firstly, the system is usually costly, requires powerful hardware, and separates the simulation aspect from the machining aspect, meaning the user has to adjust the experience gathered from the 3D graphic environment to the real machining environment[3]. Secondly, the system is so tightly integrated that it is difficult to support continuous improvement and lessens flexibility, considering that a fully autonomous CNC manufacturing environment from start to finish involves many steps, not just the machining aspect[4]. For example, how does one determine the placement of machines to accommodate the CNC machining aspect, and how does one place the stock material onto the worktable in an autonomous system?

This brings forward the demand for a new technology, dubbed augmented reality (AR). AR is a rapidly growing field of research that aims to fully integrate virtual with real environment. AR has been developed since the early 90s, but has only recently been emerging as one of the forefront of technology, mainly due to the rise of popularity in smartphones and tablets[5]. Some of the systems that have been developed for production process are related to layout planning[6–10], product design[11–15], assembly[16–20], robot programming[21–26], and autonomous

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