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USING THE DIGITAL TWIN OF AN EDUCATIONAL ROBOTIC CELL DURING PANDEMIC

Thomas Martin Rudolf
Luis Antonio Moncayo Martinez

Departamento Académico de Ingeniería Industrial y Operaciones
Instituto Tecnológico Autónomo de México – ITAM
Río Hondo No.1
Col. Progreso Tizapán,
CDMX, 01080 MEXICO

ABSTRACT

During the 2020 pandemic caused by COVID-19, universities face the problem of how to teach laboratories without using the university installations. At the ITAM, there is one specific lab that teaches students how to plan and program a production line using machine tools, robots and conveyors equipped with sensors and actuators controlled by PLC. During the pandemic, we built up a digital twin of the same robotic cell using SIMIO and other simulation tools to provide the experience of planning and improving the production line virtually.

1 INTRODUCTION

During undergraduate studies in engineering, laboratories constitutes an important part of the educational process. During the course Robotic Cells at ITAM, students of mechatronic engineering and industrial engineering learn how to plan and implement a complete production line including the programming of PLC and the optimization of the production process. Besides the conveyor, the robotic cell includes a 6 DoF industrial robot and two CNC machine tools (milling and turning machine tools). The process flow is implemented in SIMIO, the G-Code to run the CNC machine is generated using PLM NX12.

During the 2020 worldwide pandemic, the university had to be closed and the lectures were taught virtually. This situation, however, led to the new challenge of how to provide an adequate lab where students could learn the majority of objectives of this lab. Since one part of the lab was already planned in SIMIO, it was obvious to integrate robot movements, trajectory planning and manufacturing via CNC machines into the simulation model. This case study discusses the digital twin of this specific educational robotic cell and explains the results and lessons learned.

2 CREATING THE DIGITAL TWIN OF AN ROBOTIC CELL

The robotic cell (RC) at ITAM's laboratory contains four conveyors in a rectangle arrangement. Each corner has an elevator to move the palates form one conveyor to the next. The elevator is equipped with a position sensor to detect the presence of a palate. At the end of each conveyor an end stop and a sensor are installed that allow a controlled passing to the next conveyor. In the center of the conveyors the 6 DoF robot is mounted. Two CNC machine tool and a material storage are installed outside around the conveyors each of them reachable by the robot. This scenario is implemented in SIMIO to analyze and optimize the production process of chess figures. Under normal circumstances, the students manufacture the parts using the CNC machine tools and program the robot to do the necessary trajectories and record the processes time. This time serve as an input to our SIMIO model to run the sequential simulation. During the pandemic, we were forced to work a major part using simulation tools. The G-code to run the CNC machines are generated by the CAM software PLM NX12. This software allows the configuration of different manufacturing operations for milling and turning processes and contains a simulation menu that estimates the machining times for each operation. Due to the situation it was impossible to run the G-code to manufacture the required pieces, but using the estimated operation times, the SIMIO model could be fed and analyzed. Furthermore, the robot movements were implemented using the robotic toolbox by Corke (2017). The movement times for different trajectories are calculated and the axis movements can be stored for a later direct programming of the robot. These trajectory times can be interpreted as "Setup Time" and "Teardown Time" when the workpieces are mounted into the CNC machines. The SIMIO model is used to analyze the time sequences. The times for the setup, the processing and the teardown were taken from the above mentioned simulation software tools and processed via python into a excel file. This file is then imported into the SIMIO model. The chess figures "TOWER" and "PAWN" are to be processed. The following combination are tested (processing *TOWER / PAWN*):

Table 1: Different combination of the manufacturing process depending on contours to be manufactured and the production machine that conducts the process.

Variant	(1) without pawn	(2)	(3)	(4)
Turning	All outer diameters contours	All outer diameters contours	Turning all outer diameters, drilling	All outer diameters contours, drilling, inner diameters
Milling	Inner diameter via hole milling and cavity milling	Inner diameter via hole milling and cavity milling, drilling	Inner diameter via hole milling and cavity milling	Cavity milling

3 RESULTS AND DISCUSSION

The first variant lead to a wait time since the milling process takes approximately 3 times longer than the corresponding turning process. Changing some manufacturing operation from the milling machine to the turning machine can reduce the process time and above all equilibrate the process time of both machines. Further, the variants (2) to (4) include the production of a second chess figure (PAWN) that only requires turning operations and can therefore be processed while the milling machine is running a TOWER operation.

Using several simulation tools the students are able to learn how to line up a production line, using times for setup, processing and teardown during the pandemic. Furthermore, this procedure might lead to a decrease in the ramp up time at the robotic cell. The robotic movements are already prepared and it needs only some simple adjustments for some movements (especially close to the CNC machines to avoid collisions).

Future steps to be planned are the improvement of the integration of the calculated times. Instead of an external python script, the implementation via the .net API provided by SIMIO and PLM NX could lead to better and easier to use of integration of simulations tools.

REFERENCES

Corke, P. 2017. *Robotics, Vision and Control: Fundamental Algorithms in Matlab*; 2nd ed., Springer International Publishing AG