An Analysis of Automation Scenarios in an Aerospace Environmental Testing Facility

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Abstract. This paper presents a real-life example of using industrial robots to automate the testing procedures of aerospace products. Three different scenarios are proposed as potential solutions to allow a Mobile Manipulator to help automate the environmental testing process. An overview of different simulation and Off Line Programming (OLP) software packages are presented and discussed as methods to test and validate the scenarios. A framework is presented consisting of a product data model to be used for the identification of the different products and a unified modelling system is introduced to allow information exchange at the operational level. The focus of this paper and future work is towards integrating all the elements of the proposed framework into a human machine interface to create a collaborative process involving human, robots, machines and products.

Keywords. Design for Automation, Industrial Robots, Testing, Aerospace, Simulation.

1. Introduction

Organisations have begun valuing the impact of automating manufacturing processes towards reducing costs and eliminating exhaustive repetitive tasks for human workers. Recent developments in the field of automation looked at the most optimal stages in a typical product's manufacturing lifecycle to adapt automation technologies. Such technologies can be seen manifested hugely in mass produced consumer products such as the automotive industry. For example, Dotoli et al [1] stated that factory automation had evolved to include modelling and simulation techniques that utilise information about the product and manufacturing processes, however, did not discuss the potential applications beyond manufacturing processes, or focusing on service, maintenance or testing related processes. There were misalignments between the use of robotic technologies to perform service-related tasks and automation. Automation in its broadest sense aims to systematically structure all aspects to do with the process execution, whereas the use of robotic technologies only serves to be a physical means of performing physical tasks. For example, Perez-Vidal et al [2], Abujelala et al [3], and Nayak and Padhye [4] proposed the use of robotic based operations, using physical interactions between machines and products in order to improve certain aspects

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towards full automation. Based on their work, automation can be defined as to encompass robots, information management, data modelling, simulation, and scenario developments to meet the overall industry requirements which is to be analysed in this research paper.

The reported research in this paper focuses on the development of the main automation scenarios through a preliminary observational study carried out in collaboration with BAE Systems a global defence, aerospace and security company. The key benefit that automation adaptation could bring to the environmental testing facilities and the collaborators at BAE Systems' facility in Rochester, UK, is potentially the planning of the operational aspects of automation in a light out section related to product testing. The study considers the environmental testing which includes cycles of vibration, heating and cooling on newly manufactured aerospace products. The product goes through a simulated environment incorporating hot and cold temperature cycles typically 125ºC and -50 ºC along with vibrations that would represent its aircraft environment. This approach to automation explored involves the use of a mobile manipulator, consisting of an articulated 6 axis robotic arm, along with an appropriate end of arm tool. The aim of using industrial robots as part of the automation solution later detailed in the framework components, is to allow the operation of test procedures using predefined protocols that would eventually free more time for the human operators to work on other more dexterity dependant tasks.

2. Problems to be Addressed

Some of the foreseen problems and challenges of this research lies in the vast range of products having different geometries, weights and specific performance patterns, that would require an industrial robot to recognise them, in a complete light out situation where no human intervention was normally required. Hence a conventional automation system is not applicable. This paper aims to provide an analysis of how the current testing procedures are conducted and to identify three automation scenarios for the case study. A framework is presented to show a new way of modelling the entire automation process.

3. Overview of Tools Available

Most Simulation and Off Line Programming (OLP) tools involve simulating the robotic task, using 3D models of the complete robot work-cell. This allows the physical robot to stay operational in the manufacturing floor, while alternative approaches of re-designing the work-cell are generated elsewhere. These simulation and OLP tools are embedded with different systems that improve the simulation of the robot and the surrounding environment. Some of these systems include path planning and collision monitoring functions [5][6]. Once the appropriate scenario is found, the program can be transferred to the robot via Ethernet.

OLP involves seven crucial steps. The first step involves the use of a 3D CAD model of a part. The next step involves extracting features such as corners and edges from the CAD model. These features are used to create the robot position tags, which define certain locations for the end effector of the robot. OLP software packages have functions which can create those tags from the CAD data. The third step involves the trajectory planning, using secondary application programming interface (API) that can specify the most efficient pathway with no collision. The fourth step involves process planning, which is the determination of the necessary steps required to manufacture the product. However, most commercial OLP software packages are not equipped with process planning functions. The fifth step involves the post-processing stage, mostly used to test input/output (I/O) connections and calibrating the trajectory. Simulation is then conducted to find any errors or collisions. Afterwards, the program is transferred to the physical robot, along with the calibration process [6]. These different APIs used to generate the motion planning, generates pathways which are not always designed for high accuracy process, especially when dealing with 6 axes robots. These OLP software packages can provide collision prone pathways as these 6 axes robot can have many different configurations for a single target position [7]. It was found in the aerospace sector that there is a rise in using industrial robots especially to conduct drilling process, handling and turnkey machining centres, but they are always seeking new applications for collaborative robotics.

Most robot manufacturers develop their own software and programming languages. Hence there is little interoperability between the different simulation and OLP software packages. However, there exist some universal software packages that contain different libraries for different types of robots. Some of these software packages include [8,9]: V-Rep, Webots, Robotic Toolbox from Matlab, Gazebo, RoboDK, Artiminds and Visual components. Many of these universal software packages, especially the RoboDK, have in-built pre-processors to convert simulation data into proprietary robot codes. Lin [10] used the RoboDK software to develop an autonomous path planning method to avoid collisions. The dynamic path planning involved the use of Rapidly Exploring Random Tree (RRT) algorithm. The RRT algorithm was programmed on Matlab, whilst the simulation was conducted on the RoboDK software. Which also allowed connection to the universal robot controller via TCP/IP [10].

In summary, the main technical tools available to perform robot simulation tasks show a lack of geometric interpretation in the robots' OEM software. Universal simulations and OLP software packages, such as RoboDK and Visual Components, can still be used in the framework proposed in this research as a method to generate and identify optimum scenarios for the navigation and manipulation of the products using the Mobile Manipulator. These simulation tools will then form the basic tools needed to create robot related data models to allow manipulation tasks. However, the framework will use a lot of other elements in order to formalize a systematic approach for generic products within aerospace complexity. The next Section reports the industrial investigation in order to describe the actual tasks required.

4. Industry Investigation

During the industrial investigation, the complete lifecycle of the currently utilised testing process was observed with the support of operating workers. The observation took 3 months to complete with interviews conducted with the product testing engineering management, as well as some operators with testing knowledge. This Section introduces three scenarios and describes how automation framework of this research will essentially allow a Mobile Manipulator to conduct the testing procedures.

Scenario One: The first scenario considered was labelled as transportation tasks, involving the Mobile Manipulator to navigate autonomously to a shelf containing products to be tested. Once the Manipulator reaches the shelf, the robotic arm, along with a specific End of Arm Tool (EOAT) will be used to grasp the product. The Mobile Manipulator is then made aware of which chambers are currently available and it autonomously navigates to one of the available chambers. If none are available, the robot looks for other instructions.

Scenario Two: The second scenario considered was labelled as the connection task which is broken down into three sub-tasks. The first sub-task refers to automatically opening the door of the chamber. Note that the existing method involves the human operator manually pulling a handle to unlock the locking mechanism and pulling the door which will need a trigger signal sent via a robot manipulator wirelessly. The door rests on two rotatable hinges and opens outwards. The second sub-task refers to the robotic arm and gripper accurately placing the product onto the fixture already clamped inside the chamber. This will require very accurate movements of both the robotic arm and the gripper to position the product to enable the electrical connectivity which could be obtained with product data and process model. The robotic arm and gripper should then clamp the product onto the fixture and revert to a safe position to allow the door to close. The system will then commence the environmental test procedure. The third sub-task refers to when the thermocycling test is complete or when the product has failed during the process. The Mobile Manipulator is then made aware of the outcome of the product (Pass or failed). The Mobile Manipulator will then retrieve the product from the chamber which will need communication signal sent, and place them on either a shelf specific for passed or failed products. Finally, if the shelf containing products to be tested are empty, the Mobile Manipulator could then be involved in other tasks such as navigate to a storage room and collect further products for testing.

Scenario Three: The third scenario refers to the management of the entire automation process. It is a model of the interaction, between the products, robots, machines (or processes, e.g., Test Set and Test Chamber). An information model containing the process information, referring to the thermocycling process and Test Set protocols specific for each product, along with product information such as its geometry, pick up points and configuration pathways, is required to allow the Mobile Manipulator to pick up the product and secure it in an available chamber. The chamber and the Test Set are then made aware about the product that needs to be tested and run its specific cycle. A communication protocol between the Test Chamber, Test Set and Mobile Manipulator is required. A suitable navigation system is required for the Mobile Manipulator to navigate seamlessly throughout the environment. A central supervisory system is required to oversee the entire processes, where suitable algorithms can be deployed to optimise the rate of the testing process.

5. The Proposed Framework

The proposed framework consists of 5 modules. An intuitive Human Machine Interface (HMI) will prompt a user to choose a product for testing. But if there is no human prompt, the robot will operate on the next available unit. Each product has its own geometry, test profile patterns, configurations, handling points and other associated information. A Product Data Model will be used to categorise all the information, which would allow the Mobile Manipulator and Test Set to identify the product. Elsouri et al introduces a method of structuring product related data from Manufacturing system (i.e defects, product structure, assemblies, etc) [11]. The foundations of the structuring method will be used as a template to develop the Product Data Model. The issue lies in identifying a method of simulating and programming the Mobile Manipulator to safely interact with the product and the environment. As mentioned previously, the use of simulation and OLP software packages will be used to generate different scenarios of how the Mobile Manipulator will navigate, manipulate and secure the products onto the chamber. Through the simulation, optimal pathways and robot motions will be identified. These actions of the Mobile Manipulator interacting with different products will be used as an addition to the Product Data Model, which will be used by the Mobile Manipulator to identify the product that needs to be tested and using pre-defined pathways, to interact with the product.

The coordination of the different processes of the automation system will be handled by a Unified Modelling System, which allows information exchange at the operational level. As described previously, the Mobile Manipulator needs to know which product needs to be tested, The Unified Modelling System will provide the Product Data Model for the specific product, which will allow the Mobile Manipulator to locate and manipulate the product. The status information of the Test Set and chamber will be relayed to the Unified Modelling System, allowing the Mobile Manipulator to identify which chamber to navigate to. The Intuitive HMI will provide an event-based simulation of the process in real time. The use of the simulation and OLP software packages will provide a visual display of how the tasks will be carried out. Figure 1 shows the overview of the framework to be developed.

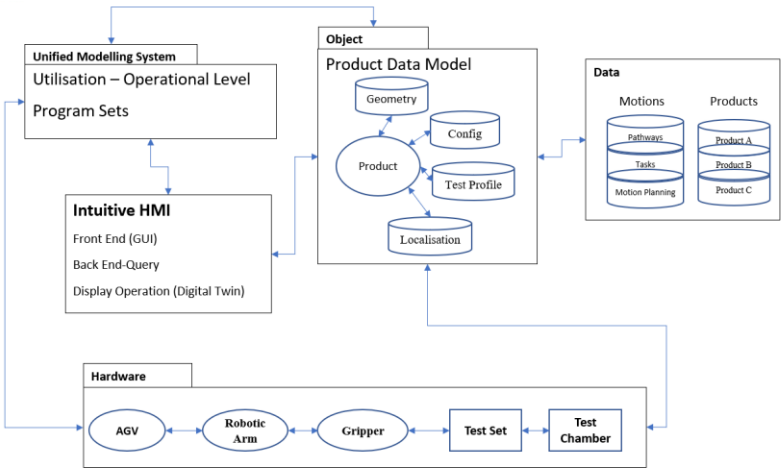

Figure 1 showing an overview of the framework to be developed

6. Conclusion and Future Work

This paper introduced an industrial case study. Three scenarios were introduced to automate the environmental testing process using a Mobile Manipulator. The findings from industrial investigation of the three scenarios led to a proposed framework to allow the modeling of the process and the components of the case study and a method of implementing a Unified Modelling System to allow information exchange at the operational level. An overview of different simulation and OLP software packages was described, for their role in developing a visual display of the automation system, which will be used in the HMI module of the framework to be developed. The future work will involve developing the product data model and identifying suitable simulation and OLP software packages to simulate the Mobile Manipulator and the three scenarios and prove its feasibility in real life applications.

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