Flexible and reconfigurable robotic inspection in manufacturing

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***Abstract*—Having a generic and flexible software infrastructure for inspection robots is the main goal of the SPIRIT project. SPIRIT is a EU funded project whose main tangible result is a software framework that includes an offline and an inline framework. The offline part is used for simulating the robotic workcell and configure the whole inspection task, e.g. select the robot and the inspection sensor and finally compute robot trajectory. The inline part instead is responsible for reproducing the simulated task on the real robot, it also includes innovative features like local and global re-planning, real-time data mapping for backprojecting sensor information on the 3D CAD model of the inspected part. In the project four different demonstrators have been developed, they all belongs to different industrial settings, i.e. automotive, aerospace and manufacture industry. Such high level of diversity demonstrates how the SPIRIT framework is general and flexible enough to be used in heterogeneous environments without prototyping and developing the entire workcell from scratch each time.**

***Index Terms*—inspection robots, machine vision, quality inspection**

I. Introduction

The usage of industrial robots for quality control and inspection tasks in general is increasing over the past years. Industrial manipulators in particular can be used for inspecting large and complex parts involving many inspection technologies and sensors that are used for detecting defects on the parts. Common way of deploying inspection solution is to have specific and dedicated robot and sensor configuration capable of solving the specific inspection task. The goal of the SPIRIT project [1] is to provide a set of highly general software solutions so that to simplify the deployment of inspection robots: this framework enables the transition from programming of a specific robotic inspection task to configuring the task itself.

The SPIRIT project developed a generic framework for the autonomous programming of the inspection task, that can manage very different industrial manipulators and very different sensors. The software autonomously generates a coverage plan that depends on the sensors properties and an adaptive motion planner generate a reactive motion trajectory. These make the inspection process generic and easily adaptable to very different inspection tasks, in different industrial settings too. In the project the partners come from automotive, manufacture and aerospace industries, for each industrial scenario a real robotic workcell has been developed to test and demonstrate the high level of flexibility and generality of the framework. Each demonstrator not only involves the inspection of different parts, but it also uses different robotics setup, namely different robot structure and kinematics, and different inspection technology, e.g. 3D inspection for the automotive industry, X-Ray inspection for the aerospace industry and thermography and laser inspection for the manufacture industry.

In the reminder of the paper the authors provide a brief description of each demonstrator, more in particular, four different test cases will be shown, they all have being used as test bed settings for the SPIRIT software framework, and in each of them specific software features have been highlighted.

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II. Real Inspection Test Cases

A. Test Case #1 - Automotive Industry

In this test case, the SPIRIT framework has been applied in the context of the automotive industry, more in particular, during the inspection task the system is performing 3D inspection of car engines during their assembly on the production line for detecting the presence/absence of a component, the alignment (spatial orientation with respect to a notch or relative to another component), or compliance (the component mounted is the correct one). This setup involves a UR10 robot manipulator with a 3D sensor mounted at its end-effector. In Figure 1 (left) the real and simulated environments are depicted. This test case has been also used for developing and testing the general hand-eye calibration method developed in [2].

B. Test Case #2 - Aerospace Industry

In Test Case #2 a real X-Ray inspection workcell has been used. The robotic setup can be seen in Figure 1 (middle left) in which two Stäubli 200XL robots are used for carrying on the X-Ray sensor composed by a ray emitter tube and a sensor on the mirrored robot that is able to detect the X-Rays. This setup has been thought for demonstrating the capability of the framework in achieving a continuous scanning operation with two

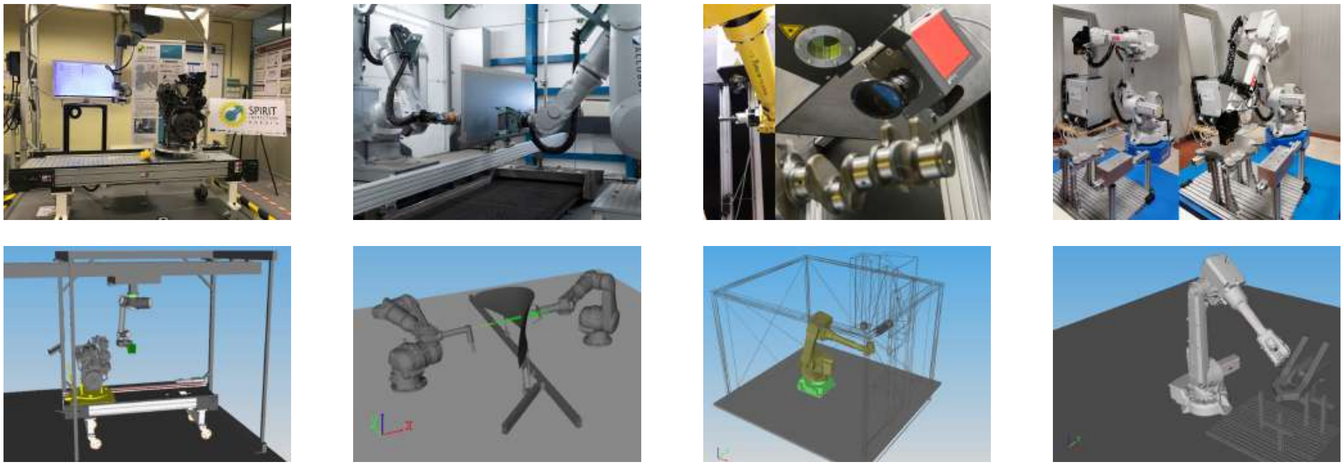

Fig. 1: SPIRIT Test Cases, real (*first row*) and simulated (*second row*) environments. From left to right respectively: Test Case #1, #2, #3a and #3b.

robots moving synchronously while performing the inspection task. Moreover, this test case has been specifically used for testing the real-time data mapping algorithm developed in [3].

C. Test Case #3a - Manufacture Industry and Thermography Inspection

In Test Case 3 the SPIRIT framework is used for the detection of surface defects on forged parts for aircrafts. Such parts can have vary varying shapes, with a length of up to 3 meters and they mostly consist of structural parts made of titanium respectively steel. Initially, for these parts thermography inspection has been selected as the right technology for detecting cracks and defects. After a preliminary test and study phase we discovered that it was not possible to successfully detect defects from thermal images of these titanium parts, so the test case has been split in two more cases in which a further inspection technology could be exploited, namely the laser one, this revealed to be the right choice in this setup. Thermography has been kept as testing setup in the context of the project but it has been used for detecting cracks and defects on manufactured parts like camshafts. In this new test case the whole inspection setup has been completely disrupted by considering the sensor (an InfraTec ImageIR 8300 hp thermal camera) fixed and the part mounted on the Fanuc robot end-effector. This new setup demonstrates how the SPIRIT concept is flexsible and general enough to handle also this other scenario. In Figure 1 (middle right) the real and simulated environments are depicted.

D. Test Case #3b - Manufacture Industry and Laser Inspection

The same industrial scenario as the previous test case has been used for testing the SPIRIT framework with another inspection technology, the laser one. In particular, in this demonstrator a Keyence LJ-V7080b laser profilometer has been mounted on a ABB robot manipulator. In Figure 1 (right) the real and simulated environments are depicted. More in detail, the SPIRIT framework has been tested in performing crack and defect detection on forged parts made by titanium or aluminium, also in this case the most relevant features of the whole framework have been the coverage planning and local-global replanning, the former used for performing the inspection of the whole object, the latter instead used for adapting at run-time the trajectory and so recovering possible errors introduced by wrong calibration or unexpected deformation of the object surface.

III. Conclusion

In this paper the authors are presenting the demonstrators developed in the SPIRIT project. The high diversity of the demonstrators helps to show how this framework proposes a novel approach and useful tools to automatize inspection tasks that may take several time in the real cases (e.g. inspection of composite parts in the aerospace industry can take hours because require high human intervention). Moreover this framework demonstrates to be very flexible and easy to adapt to many different scenarios, this makes possible to achieve an high level of generality (e.g. different inspection technologies).

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