AUTORECON (AUTOnomous co-operative machine for higly RECONfigurable assembly operations of the future)

C. Canali, F. Chen, M.D'Imperio, F. Cannella, D.G.Caldwell

Department of Advanced Robotics, Istituto Italiano di Tecnologia
via Morego, 30, 16163 Genova

***Abstract*—A wide range of industrial sectors today is still organized in a fixed combination of fixed linear sequences of operations where manual and automated tasks are repeated in the same way each cycle time in the most suitable and optimized way. This paradigm is very efficient when the production is set to the maximum capacity (usually for most products this is limited to a relatively short period following the Start Of Operation) and considering no halt situation due to technical problems, but it is very inefficient in case of desaturated lines. Even the most flexible among production lines is still based on the same sequential hierarchical paradigm since flexibility is declined as the possibility to mix in the same plant different but still sequential processes for different variants of the products. AUTORECON (AUTOnomous co-operative machine for highly RECONfigurable assembly operations of the future) studied the possibility introducion of a new approach to the idea of assembly line: the use of autonomous production and handling units able to perform different tasks can radically change the approach to the production sequence. Thanks to the integration of an autonomous set of technologies and agents, the operation during an assembly task can be performed in a dynamic way instead of in a fixed sequence. Robot agents can change task (for example from welding to handling) and position inside the working cell. Another characteristic introduced into the project is the possibility for robots and tools to cooperate among themselves. The advantage of this approach is that every agent has the possibility to recover eventual failures to any Robot or Tool. In case of a failure a robot can move to a different position and temporary perform a different job after reconfiguring itself. This approach answers quickly to the stop of production and reduce losses as much as possible. At the same time the high reconfigurable level is an advantage in the case a change into the production line is needed (for example if a new product need to be assembled). The work presented here briefly describes the agents of the project. Particular emphasis is dedicated to the robotic gripper that, due to its dexterity and versatility, represent one of the most innovative component introduced by AUTORECON into an industrial assembly enviroment.**

I. Introduction

Assembly lines of today are still organized in a fixed combination of fixed linear sequences of operations where manual and automated tasks are repeated in the same way each cycle time in the most suitable and optimized way. This paradigm is efficient in case that the production is set to the maximum capacity and considering no halt situation due to technical problems. The increasing need for High Mix and Low Volume (HMLV) production pushes the industry to investigate new solutions for increasing flexibility [6]. Technologies that need to be developed and integrated to do this involves reconfigurable tools, intelligent control and Monitoring systems and open integration and communication architectures AUTORECON [1] is an European project designed to investigate the possibility of integrate autonomous and highly flexible robot agents in industrial production and assembly lines. This set of robots and tools open the possibility, in the same plant, to change the sequence of operations. This is possible introducing autonomous production and handling units which can change task and position with the use of mobile platforms, they can cooperate among themselves based on current process sequences, and in particular they have the possibility to recover eventual failures to any Robot or Tool by switching position, perform a different task or auto-reconfigure themselves to answer quickly to the stop of production. This scenario can have a big impact in reducing hence losses as much as possible, but also in realizing a flexible production line easy to reconfigure in case of a different or new product needs to be assembled.

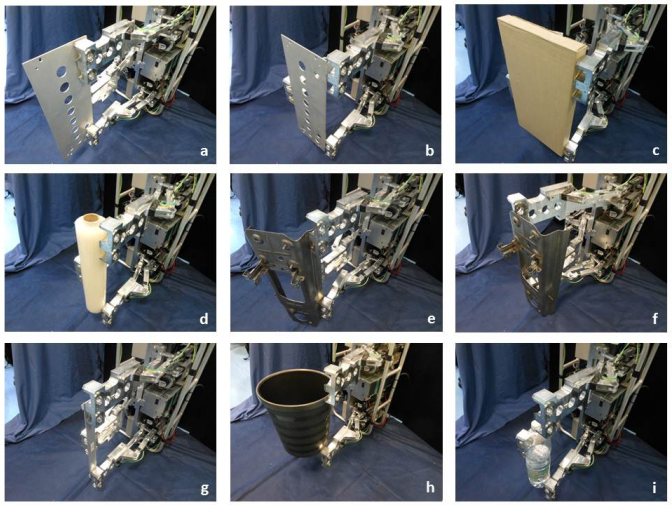

Fig. 1. Several configuration of the gripper can be used to grasp objects with very various shape, weight and size. Designed to work into automotive enviroment its use can be extended to many other kind of objects, has it has been demonstrated during several test. Here an heterogeneous set of items has been selected to be grasped

II. Scenario definition

The demonstration of the feasibility of an autonomous and reconfigurable production line, that is the goal of the AUTORECON project, has been done setting up a realistic scenario inspired by the automotive case. The main actor of the scenario is a mobile robot (composed by and industrial antropomorphic robot [4] and a mobile platform designed by TECNALIA [3]. A novel dexterous gripper is used to collect all the components of the assembly and prepare them for the welding procedure. The flexible gripper has the ability of reconfigure itself to match the different geometric shape of the workpieces [8]: a system with highly reconfigurable ability has been designed.The final working prototype of the gripper has been developed by IIT can be seen in Figure 1. The dexterous gripper has the ability to grasp, lift and manipulate several metal automotive parts to match its primary goal, but it can be used with different kind of materials and items, as showed in picture 1, not only metal sheet. In the specific case of AUTORECON, the smallest part is 20 cm long and

Fig. 2. from left to right: the mobile robot pickup the gripper all the parts are grasped and placed on a fixture into the loading area

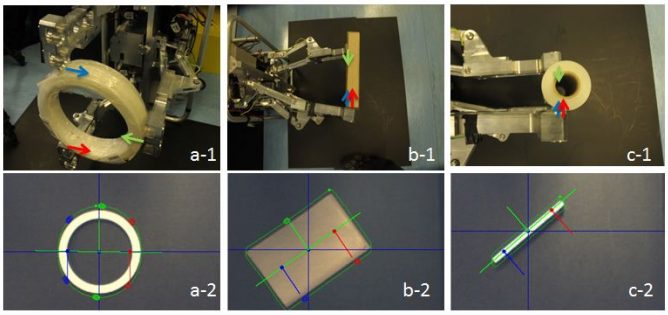

Fig. 3. A vision can drive the gripper to autonomously detect grasping points

less than 1kg, while the biggest metal part is 1.5 m long and it weights 10 kg. The designed flexible gripper has the following is characterized by a large range of accessible configuration, reconfiguration operation can be performed automatically, after receiving the request of a particular configuration from a master device, or following a vision system able to detect grasping points. The design is based on a multi-fingers setting with clamping functionality. Each finger is completely independent from each other and has two degrees of freedom (DOF). A setup with three fingers has been used [5]. The gripper has an embedded PC on board so it can be considered as an autonomous agent. An advanced customized integrated vision system is integrated into the gripper. An an autonomous vision system can detect the optimal grasping point of an object (usually 3 points) and ask to the gripper to reconfigure itself for the grasping procedure [2], as shown in Fig.3.

To complete the overview is worthwhile to mention that in the AUTORECON demo scenario the gripper is used by a Mobile Platform [3] with a COMAU Robot mounted on it. The Mobile Unit is able to move in a completely autonomous way inside the factory according to the needs of the production, allowing, in case of an emergency breakdown of another Robot, to navigate to a docking station close to it, take over the on-going stopped operation by picking up the used tool (gripper, welding gun, etc.) and continue the operation.

III. AUTORECON DEMO AND RESULTS

AUTORECON project has been completed with the setup of the described demo scenario. In picture 2 some of the tasks performed into the work-cell are shown. At first the platform is docked. The robot pickup the dexterous gripper from its tool-stand. Several metal parts are collected from various rack placed into the loading area and moved on a fixture used for the welding operation. In a second stage the fault of a robot into the welding area is simulated and the mobile unit release the dexterous gripper on the tool stand. Than it moves to the welding area to continue the welding procedure originally scheduled for the *broken* robot.

ACKNOWLEDGMENT

This work has been funded under the EU FP7 project AUTORECON (www.autorecon.eu) (Grant no. 285189).

REFERENCES

[1] www.autorecon.eu

[2] An Automatic Assembly Parts Detection and Grasping System for Industrial Manufacturing, Canali C., Cannella F., Chen F., Sofia G., Eytan A. and Caldwell D. G. 2014 IEEE International Conference on Automation Science and Engineering, pp. 215-220, Taipei, Taiwan, August 18-22, 2014

[3] http://www.tecnalia.com/en/

[4] http://www.comau.com/

[5] High reconfigurable robotic gripper for flexible assembly *Canali C., *Cannella F., *Chen F., *Hauptman T., *Sofia G. and *Caldwell D. G. ASME 2014 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, pp. 1-7, August 17-20, 2014, Buffalo, New York, USA

[6] Chen, Fei, et al. "Optimal Subtask Allocation for Human and Robot Collaboration Within Hybrid Assembly System." IEEE Transactions on Automation Science and Engineering (2013): 1-11.

[7] Mouri, Tetsuya, Haruhisa Kawasaki, and Satoshi Ito. "Unknown object grasping strategy imitating human grasping reflex for anthropomorphic robot hand." Journal of Advanced Mechanical Design, Systems, and Manufacturing 1 (2007): 1-11.

[8] A. Wolf et. al, "Grippers in Motion" ISBN3-540-25657-1

[9] Grebenstein, M. et al. "The DLR hand arm system," Robotics and Automation (ICRA), 2011 IEEE International Conference on , vol., no., pp.3175,3182, 9-13 May 2011 doi: 10.1109/ICRA.2011.5980371

[10] http://www.ros.org/

[11] F. Chen, F. Cannella, C. Canali, T. Hauptman, G. Sofia, D. G. Caldwell, "In-Hand Precise Twisting and Positioning by a Novel Dexterous Robotic Gripper for Industrial High-Speed Assembly", IEEE International Conference on Robotics and Automation (ICRA 2014), Hong Kong, China, May 2014.

[12] F. Chen, F. Cannella, C. Canali, A. Eytan, A. Bottero, D. G. Caldwell, "Theoretical and Kinematic Solution of High Reconfigurable Grasping for Industrial Manufacturing", in IEEE International Conference on Robotics and Biomimetics (Robio2013), Shenzhen, China, Dec. 2013, pp. 734-739.