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VIRTUAL PROTOTYPING ROBOTIC CELL FOR MUSHROOM CROPS AUTOMATED HARVESTING

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Abstract: *Continuing previously developed works, the modular robotic manufacturing cell presented in this paper refers to a third fully automated subsystem dedicated for automated mushroom's harvesting and transport as well as compost bags' automated collecting and transporting outdoors of the production system. The modular robotic manufacturing cell is designed by authors as part of a completely new robotic subsystem allowing septic cultivation condition and respecting food safety standards by completely excluding human operators involvement in the production cycles and allowing controllable and repeatable production cycles by continuously monitoring and adapting of the environment parameters to different production phases (as incubation and fructification are).*
Key words: *mushrooms harvesting, robotic system, virtual prototyping*

1. INTRODUCTION

Previously presented papers have illustrated author's contributions in the field of design and virtual prototyping of a fully automated facility for mushroom's cultivation and harvesting developed as a completely new (already patented) system (Petre et al., 2008a and Petre et al., 2008b). The conceptual model of the overall above mentioned fully automated facility as well as the virtual prototype of the first robotic manufacturing cell included in the system (for compost sterilization and inoculation) have been already presented in previously 20th DAAAM Symposium (Nicolescu et al., 2009a and Nicolescu et al., 2009b).

The present paper is focused on illustrating author's achievements in the field of automatic mushroom's cultivation fully automated facility, by focusing on detailing specific design of the fructification's robotic harvesting cell (Fig.1), this modular unit representing the last production link / robotic cell in the mushroom's cultivation and fructification harvesting full automated facility virtual prototyping.

As previously presented (Nicolescu, A.; et al. 2009a and Nicolescu, A.; et al. 2009b), the fully automatic production facility is benefiting from new (already patented) biotechnology for mushroom's cultivation, assuming liquid mycelium inoculation of compost bags vertically disposed on specially designed pallets and supports type (patent pending), allowing three compost bags at time sustaining and fixing. Pallets and supports for compost bags are transported along entire production facility using roller conveyors that interconnect the modular robotic cell units dedicated for different phases performing (compost's sterilization, thermal regulation, inoculation etc.). The incubation and fructification phases are performed in dedicated areas (atmosphere controlled rooms) specially designed as automatic storage-retrieval systems (AS-RS). Finally the pallets and supports containing bags with fructifications are directed to the automatic / robotic harvesting area (Nicolescu, 2010).

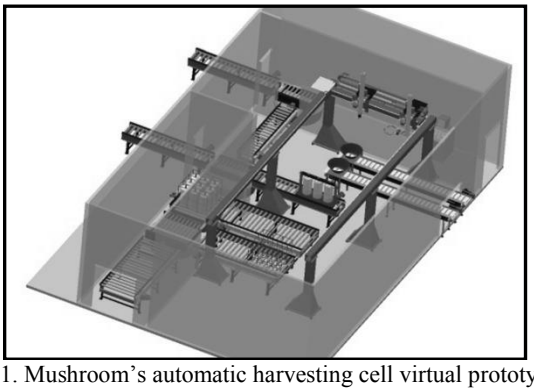


Fig. 1. Mushroom's automatic harvesting cell virtual prototype

2. THE ROBOTIC HARVESTING CELL

Once the pallets with bags having fructifications reach the robotic harvesting area, a specially designed gantry robot with two end-effectors (patent pending) allows pick-up of each bag with fructifications from the pallet / support (using a first end-effector), bag's transport to the collecting tables and evacuation conveyors, fructification's harvesting (using a second specially designed end-effector) and finally bag's transport and storage in a specially designed support / pallet system for bags' collecting and automatic transport in facility's outdoors areas.

The central element of the robotic harvesting cell (Fig. 1) is the specially designed gantry robot (Fig. 2) equipped with two end-effectors. The robot (***, 2009) has totally 5 NC axes. Two of them are set as independent Z-axes, two as independent Y-axes and one as a common X-axis. Each Z-axis is equipped with a specific end-effector, one being designed for bag's manipulation and transporting and the second for mushroom's harvesting. Figure 3 presents the virtual prototype for the harvesting robot equipped with both end-effectors.

For bag's manipulation (pick-up from the pallet / bag's support) and their transport to the harvesting area, the authors designed a three finger gripper (Nicolescu, 2005) powered by an electric actuator (Fig. 3) while for the fructification harvesting task a special designed end-effector (patent pending) has been designed accordingly specific harvesting actions involving straight movement along bag's longitudinal axis and mushrooms collected through a funnel disposed on the top of a belt conveyor. Figure 4 a, b highlights two sequences captured from the harvesting process simulation and reveals the functional role of each robot's end-effector at appropriate time.

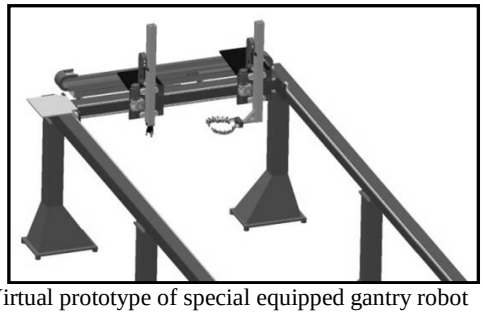


Fig. 2. Virtual prototype of special equipped gantry robot

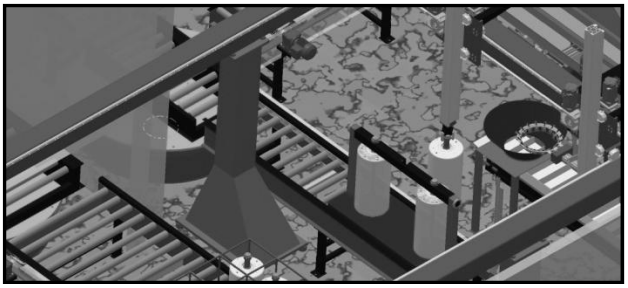
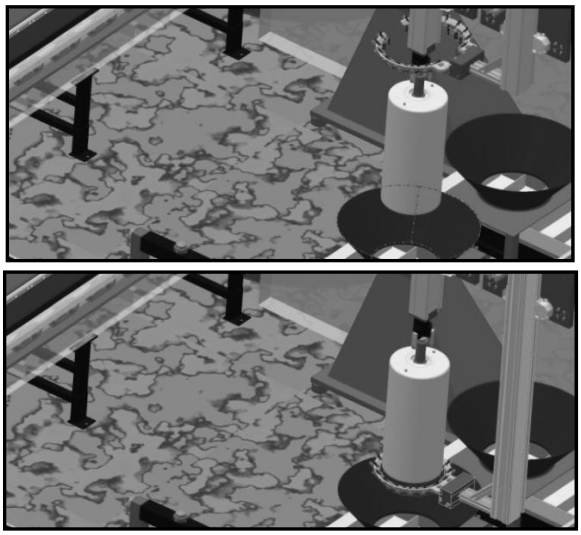


Fig. 3. Bag's manipulation and transport end-effector in action



a b

Fig. 4. Fructification harvesting using special designed end-effector: a) starting – up phase b) end phase

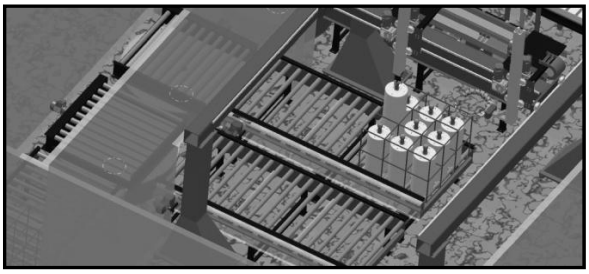


Fig. 5. Depleted bags removal from harvesting area

However, fructification harvesting represents a difficult task due to non-uniform fructification bodies' size and bag's non-uniform cylindrical shape. To overcome above mentioned aspects the authors designed a completely new technical solution (patent pending) for a "self adaptive sliding blades harvesting end-effector", closing end opening of end-effector being made by a bilateral electric actuator. The self adaptive sliding blades harvesting end-effector has been designed by using standardized mechanical components (Mitsumi, 2010).

After the harvesting operation had been completed the gantry robot transport depleted bags to a storage pallet (Fig. 5) that once being filled is lead outdoors of the facility and replaced with an empty one using a pallet's transfer system and roller conveyors (Nicolescu, 2010).

3. CONCLUSIONS

The modular robotic system presented in this paper is component of an already patent protected fully automated facility for mushrooms cultivation and conditioning system..

The modular robotic cell presented in this paper is dedicated for mushroom harvesting and bag's automated collecting and evacuation outdoors of automatic facility. In order for performing mushroom's harvesting a special gantry robot has been designed, including five NC axes and equipped with two completely new special designed end-effectors (patent pending), while for bag's collecting and evacuation a dedicated palletizing and transport system has been designed.

The overall modular robotic facility has following advantages (as a sum of the involved advantages induced by each modular robotic section specific design): the facility guarantees the alimentary and therapeutic safety of the products by respecting all standard conditions; it uses an efficient method of sterilizing the compost by total decontamination, accomplished in a shorter time (70% time less) and reducing by 40% the energy consumption costs compared to classic procedures; it fully ensures the total sterile conditions imposed by appropriate biological material cultivation, eliminating any hazards regarding human contamination of the production areas; it prevents human access in the sterile zones, allowing 100% automatic pallet's / bag's sterilization, handling, transport, transfer, compost thermo-regulation and inoculation, pallet's / bag's manipulation and storage, mushroom's incubation and fructification by controlled process performing, as well as automated mushrooms harvesting, all operations being performed by modular robotic equipments; the installations are controlled by a central command system which also controls the system parameters for the sterilizing system, the thermo regulation areas, the robotic inoculation system, the pallets identification, bags visual inspection, pallet's / bag's handling, transfer, transport and storage systems, the environment parameters control of the incubation / fructification areas, the robotic harvesting system and the final product packing equipment (Petre, 2008b and Nicolescu A., 2009a). Real scale production system will be fully operational starting by June 2011. By the time, virtual prototyping for individual units and overall system, functioning simulation, detailed design phases, have been already performed.

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