**Slide 1**

Good morning, my name is Federico Rollo and I’m going to talk about the study and simulation of an autonomous and mobile robot for hydroponic greenhouse tasks.

**Slide 2**

Due to the advent of new technologies and the necessity of a bigger food quantity in less time, Agriculture 4.0 field is growing exponentially in the last years . Different solution have been already presented to overcome the population growth and one of the most popular is the use of robots and machineries to perform the human beings hard labour allowing a bigger productivity in a less time.

The following work aims to present a robot which can autonomously pick zucchini flowers from a plant and it is divided in two main parts. The first part regards the feasibility study and the design of both the algorithm and the robot while the second one simulates the whole project in a greenhouse environment to prove its feasibility

**Slide 3**

In this flowchart can be seen the process that the robot follows during the work. Starting from the initialization point in the left high corner the robot moves on the next plant, point the plant take a picture and if there is a flower it approaches the plant otherwise it searches for other plants. Once a plant Is approached the flower are analyzed and if they should be picked a rough 3D localization process begin. With the space position of the flower the robot plans a trajectory for the manipulator which approach the flower. Here thanks to a depthcam and the image processing a more precise localization is performed and the endeffector will move on the cutting point, gather the flower and cut the stem. The flower is then released in the collecting box and the arm return on its home position. Now, if there are other flowers on the plant the robot continues with the picking process otherwise it searches for other plants either on its row or if no other plants are present on the next plant station. When all the plants have been controlled then the robot return to its docking station and the whole process finish.

**Slide 4**

In this picture can be seen a simplification of the hydroponic greenhouse where there are two main places: the packaging station and the real greenhouse. Can be seen how in the greenhouse there are eight zucchini plats and the robot. The robot moves on catwalk due to the rough terrain in the greenhouse and the blue lines represent the path that the robot will move on.

**Slide 5**

Let’s start now by looking at the mobile platform choice. Three different platform has ben considered: the car-like robot, the differential-drive robot and the mecanum wheel robot.

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The car-like robot is characterized by a good stability an a good tracion due to the four wheels and it is able to steer the front wheels to steer the whole structure. Anyway, this structure is difficult to control in narrow passages especially when there is the necessity of performing some manouvers.

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Instead, the differential drive robot has a bad stability due to the presence of only two actuated wheels and an omnidirectional wheels but the model and its controllability are simpler, indeed it’s model is the same of a unicicle robot after an imput transformation

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There exists another configuration of the differential wheel drive where the wheels are replaced with some tank crawler. This configuration maintains the pros of the previous one and improve also the stability and the traction of the robot indeed they are wiidly used for rough terrain works. Any’way this configuration is expensive and not always this costs are affordable.

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The last robot is the mecanum wheel robot. This is an omnidirectional robot with a good controllability and a good stability it can be moved extremely easily in a closed environment. But the traction of the mecanum wheels is not good on rough terrain.

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As can be seen in the picture the mecanum wheels are characterized by some rollers positioned at 45 degrees with respect to the sagittal plane of the wheel. These wheels produce a force perpendicular to the rollers and then by rotating the wheel in different directions the sum of the four wheel forces produce movements in different diections. Indeed this kind of robot need of four motors, one for each wheel.

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The motion planning of the mobile platform has been divided in three phases: path planning, trajectory generation and timing law. The first one can be performed in two ways: using a manual design where the user write the path on the environment map or using the generalized Voronoi diagram which autonomously built a safety path equidistant from the obstacles in the environment. For the trajectory generation a trapezoidal speed profile has been used to find the timing law and finally once the trajectory has been defined the robot follows it thanks to the tracking controller designed using the backstepping control technique

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Looking now at the robotic arm, a 6 Degree of freedom robotic arm has been chosen characterized by the union of an anthropomorphic arm and a spherical wrist. The dexterity of this robot is enough to perform the position and orientation on the end effector on the plant and indeed it is widley used for these task. Its kinematics and differential kinematics have been studied and used for simulation purposes to prove the utilizability of this robot.

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Anyway, one of the most important things of the robot is not the robot itself but it is its vision system. An RGB-D camera o the Time of flight typology has been used to regognize identify and localizate the flowers in the environment.

The two tasks where the vision system is used are in the flower recognition and the flower localization.

For the first task a k-mean algorithm has been developed based on the color clastering while for the second one a moore-neighbour tracing algorithm with modified Jacob’s stopping has been used for the flowers separation and the consecutive localization.

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In these pictures can be seen how the results of the k-mean algorithm with the colour clustering. In practice starting from the original image the algorithm creates 3 color centroids which labels the image with 3 different color. Thank to this labeling then the clusters are extracted form the picture using their image masks.

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Regarding the flower localization instead the algorithm works directly with the clustered image. It performs a binarization noise attenuation and hole filling on the image and thank to the moore-neighbour algorithm it extract its borders and consequently its centroids. In this way the flower are separated and a rough estimation of its centroids is computed. We will see in the simulations how this algorithm has been applied to the flowers stem to estimate thei position in the space and finally puick the flower

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The control of the arm has been performed using a simple kinematic control. A trajectory Is created from the end effector to the estimated flower stem position and using the inverse of the robot jacobian and a feedforward and feedback contribution a simple algorithm is has been designed.

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Also in this case the trajectory has been divided in path planning and timing law. The path planning simply starts from the initial position and orientation of the robot and create a linear path until the final position and orientation are reached while the timing law, similarly to the one for the mobile platdform, has a trapezoidal speed profile which is based on the maximal velocity and acceleration of the robot end effector.

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Once that the robot planning has been finished different real existing robot has been reported to give an idea on the agriculture robot market indeed we can see here four famous robot used in picking tasks like the root ai robot for tomato picking, the rubion robot for strawberries, the iron ox greenhouse which is a fully automated hydroponic greenhouse and the sweeper robot used for sweet peppers harvesting.

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Also some original solution has been presented depending on the user needs. In this first slide three mobile platform have been presented from he cheaper to the expensive one. They have all the wualities to be used in the greenhouses but the platform on the right is the betterone because it has bigger dimention, performance and sensors and can also be equipped with other sensors and tools like the autocharging station.

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For the robotic arm the Kinova solution have been chosen for their lightweight, performance and costs. The two configuration can be chosen depending on the final structure of the greenhouse because the first one ha a bigger payload and reach but it is most cumbersome. Moreover the kinova provides an RGB-D camera module which can be applied directly to the robots and used directly from the robot Input output module.

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Using the studies done until now a simulation has been developed using two tools: Matlab and Simulink where all the controllers and machine learning algorithm have been developed and Vrep where the real simulation and the robot have been built. The mobile platform and the robotic arm have been created using joints and primitive shapes while the cameras and the end effector has been provided from the Vrep tools.

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We can see now on this sped up video how the robot algorithm work. We can see ow the robot point the plants decide If approach and then pick the flower present on the plant

When there are no flowers on the plant the robot does’t approach the plant. And finally it return on it docking station

**Slide 23**

In this other video instead we can see how the machine learning algorithm work. After the plant pointing of the robot the machine learning algorithm serches for flowers and if they are present the robot approach the plant and take another picture. With that picture the flower stems are extracted and then segmented and finally their centroid position is computed with which the final flower 3d localization in the environment is computed.

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In conclusion although the project has been simplified under some aspect the simulation has proven to work and this means that if some future improvements will be applied then a real application could be performed in a real agriculture 4.0 hydroponic greenhouse. Some of the future improvements are the localization system implementation, the uses of better machin learning algorithm to extract the flower stem, the uses of multiple robots to implement a distributed systems of collaborative robots, the use of more sophisticated robot controller and trajectory generation and other smaller improvements.

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Thank you for your attention.