**General comments and recommendations for the project ECHORD++ GAROTICS**

The experiment **GAROTICS** belonging to the EU project ECHORD++ can be considered **satisfactory** and **successful** at its final phase, in December 2016, due to the following facts:

1. A functional **prototype** has been assembled by partner STRAUSS, which is currently producing and selling machines for the asparagus sector nationally (Germany) and internationally. Their machines are well accepted in the sector, and given that the new prototype design has inherited their more than 20 years of experience with asparagus, it is reasonable to expect the same level of **acceptance** for future machines. There is an important network of customers that are already demanding higher levels of autonomy.
2. The problem of **asparagus detection** in real time with machine vision, while not fully solved at present due to some occlusions caused by the gripper closest to the camera, has made great progress in the last months. The key algorithms are basically defined and successfully validated, and therefore only experimental-based refinements will be necessary before the detection engine becomes ready for the market.
3. The strategy envisioned for the movement of the **gripper** (pneumatic end-effector) and its mechanical design seem to be efficient for the double-gripper machine demonstrated in the laboratory. Further tests will be necessary to increase the long-term efficiency in the field, but the general philosophy for retrieving asparagus has been determined with a satisfactory performance, and thus no major modifications are expected.
4. **Customer usability**. The current prototype is well adjusted to the conventional dam dimensions of use in Germany and UK. The machine can be pulled by a regular tractor, and its external dimensions allow for its transportation under a typical transit environment. The prototype working speed is currently a minor concern and the four pneumatic tires have shown an appropriate roving capacity.

The following **recommendations** and **thoughts** may be helpful for the future continuation of the project and the deployment of upgraded versions in the way to commercialization:

1. A **list of requirements** elaborated by end-users will be necessary to assess whether or not the machine complies with the needs of the asparagus growers. The definition of quantitative parameters will help to measure how close you are to the expected solution. Requirements are not supposed to be fixed and may be redefined if their accomplishment creates a technical, social, or economical conflict. Such parameters as number of asparagus per hectare or hour will give an idea of the harvesting capacity and will allow further estimations of efficiency, mainly when comparing with potential competing solutions (automatic or manual).
2. The bases for the detection and gripping strategy are already established. Even though many improvements will be added along the way, it is recommendable to start defining the **intellectual property** (IP) policy to protect key algorithms and gripper designs.
3. The automatic navigation abilities of the machines have not been defined yet, but forecasting a customer demand on this matter, a detailed description of the **safety measurements** will be necessary before commercialization. Even without automating guidance, the grippers have a cutting tool that might be accessible by field workers, and the grippers might be tangled with weeds, animals, or wires accidentally dropped in the field. Given that agricultural fields are opened, anything can end up in a cultivated dam, and safety is always the first concern for farm machines, especially when automated tasks are introduced.
4. **Massive testing**. The machine has been tested through developing experiments both in the lab and in the field, but long-term reliability and endurance tests need being scheduled for upcoming developments on the machines. Important questions such as the autonomy of the machine, how many cuts can be performed before sharpening the mechanical scissors, how many hours the rubber bands will last, potential crushes of the computers, effects of environmental conditions on electronics and sensors, misalignment due to wearing of the gripper joints, will have to be answered before industrializing the prototype. Also, statistics on the success rates, false positives, asparagus dropped outside the box, immature cuts, and so forth will be handy after massive testing.
5. **Other uses**. Although the business plan is not written yet, the price of the machine will likely be important for the end-users, especially if they do not share the machine or possess large extensions, as is the case in Europe. As the harvesting season is short, it would be economically more efficient if the machine could be used for other agricultural tasks with minor structural changes. Given that there will be a fast detection system for the asparagus, efficient fertilization can be achieved where the small asparagus are or precision spraying might be applied where there are no asparagus. The gripping end-effector, with minor modifications (changing the scissor), could transform the harvesting machine in a precision planter… which will make harvesting more efficient as the asparagus will have a known distribution!
6. **Precision Agriculture compliancy**. The automated tasks envisioned for the asparagus machine will result in high precision tasks. The farmers of today demand more information every day. A GPS receiver might be installed in the machine at a reasonable cost with a new set of added capabilities within precision farming: automated navigation in barren fields, remote tracking of the trajectory and speed of the machine, yield monitoring by weighing the boxes and coupling weight increments with global coordinates, and so on.

In summary, the GAROTICS experiment ends with its four key problems ―detection, cut, gripping, and deposition of green asparagus― almost solved. The prototype presented and demonstrated in December 2016 can be considered at a TRL 6-7. With a new research action, it is expected to move forward two TR levels and reach the commercial stage in less than three years.

Francisco Rovira-Más

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