OPEN QUESTIONS TO THE "PELLIZZI PRIZE 2020" FINALISTS

by Marco Fiala

During the EIMA DIGITAL PREVIEW (11-15 November 2020), an online meeting entitled "**Presentation of the Pellizzi Prize finalists**" was organized. In this webinar, the four finalists of the "*Giuseppe Pellizzi Prize 2020*" presented a video illustrating their PhD Theses (materials and methods, results, future perspectives).

During the event some of the 41 participants chatted some questions (Q) about video presentations.

Below I report the interesting answers (A) that the finalists have provided me, not having had the opportunity - for lack of time - to respond directly during the live streaming.

QUESTIONS TO CHRISTIAN BIRKMANN (*"Power shift operations in multi-group transmissions for standard tractors"*)

Schulze Lammers Peter (Club of Bologna Member)

Q: How is the rear gear realized in this configuration?

A: I am not completely sure what you mean by "rear gear", but nevertheless I will try to give you an answer. If you have in mind the rear axle (differential and final drive) and the tires, their characteristic values are included in the reduced vehicle inertia and torsional shaft stiffness that is applied at the output shaft of the transmission during simulation and on the test bench (see variable inertia and elastic shaft elements in the presentation). Tire slippage is not taken into account. If you have in mind the gears for reverse driving direction, it is assumed that the power shift operation is basically comparable. The operation of power reversing itself, which means to switch the driving direction under full load, was not investigated during the PhD thesis.

Paolo Marucco (University of Turin)

Q: From the practical point of view of the farmer, what is then the preferable PST layout? The one more performant in upscaling gears?

A: I think for a farmer it is important to have easy controllable, quick and comfortable gearshifts with less torque interruption as well as a compact tractor design. The transmission design itself is not of real interest to the farmer, if the engineers fulfill the aforementioned requirements. If the engineers are able to design a tractor with adequate size in comparison to benchmark tractors without using a grouped transmission design, this should be the preferred solution, because a transmission with only one group will offer the best possibilities to reach the best gear shift quality. Moreover, the customer will recognize a bad gear shift behavior every day, but gets probably used to a slightly longer tractor design. But, if you want to offer tractors including transmissions with a very high amount of gears, it is necessary to use a grouped transmission design, because otherwise the tractor size will be too big.

Stefan Böttinger (Club of Bologna Member)

Q: The shift jumps cause a reduction in traction, mechanical loads and discomfort. How can these effects be assessed?

A: By only considering shifting comfort, first of all the transmission design should offer one-swap gear shifts. If this is not possible the focus should be on designs that offer two-swaps with little main step size (e.g. 3x8 with bigger step size in the second group). But, of course, there are more requirements to be considered during the development process, than only the shifting performance. If the design of a transmission is defined, it is important to have a good gearshift actuation system. This means fast response times and less overshoot for conventional hydraulic actuation systems. Automatic gear shift parameter application is also helpful to optimize the gear shift quality for a high variety of load

conditions. For the future, if we consider additional electrical machines within the drivetrain, for example for 48V systems, one could imagine to use this e-machines to compensate the reduced torque transfer of the mechanical drive train whenever it is possible.

Marco Pezzini (Club of Bologna Member and Federunacoma Delegate)

Q: The study suggests some design principles for FPS transmissions. Was it possible to test a prototype of a transmission fully optimized according these principles, or will it be in the future?

A: During the PhD thesis, general applicable recommendations were derived within a theoretical pre-study with the help of simplified transmission models. We were also able to build up a prototype transmission that was based on a serial partial power shift transmission to validate the recommendations on a test bench, at least for one configuration of a multi-group transmission (4 groups with main step in the last group). Unfortunately, it was not possible to build up a fully optimized prototype transmission to test the recommendations for all kind of transmission designs that were covered by the theoretical pre-study. This would require very high effort, because nearly each different arrangement of the gear ratios will require a new transmission design and a well-adjusted gearshift actuation system to analyze the full optimization potential of each design.

Paolo Balsari (Club of Bologna Member and President)

Q: Will it be possible to determine the "sweet spot" between the need to have low size main steps and the need to possibly reduce to one the number of involved steps in the gearshift?

A: From a shifting quality point of view, one-group transmissions (only offering one-swaps) are the preferred solution to reach the best power shift quality. For these transmissions the steps between the different ratios (which equal the main step size in a one-group transmission) equal the required gear step size and therefore this transmission design offers the lowest possible main step size. But, these transmissions will be too long/big/expensive if the number of gears is high.

For e.g. two- and three-group transmissions, the main step size reduces, if the group that offers the bigger step size between the gears, will also offer the higher number of gears. For example, considering a transmission design that offers 24 gears by using two groups and by offering the bigger gear step sizes in the second group. For this kind of transmission the main step size will be reduced, if it is a 3x8 configuration instead of a 8x3 configuration. But, besides the main step size, it is also important to take the individual internal transmission inertias into account, especially if you want to rate different transmission designs e.g. in comparison to a 4x6 configuration.

QUESTIONS TO HAO GAN (*"An autonomous immature green citrus fruit yield mapping system"*

Josse De Baerdemaeker (Club of Bologna Member)

Q1: Can you also provide information on the location of the fruit on the trees?

A1: Technically, the fruit detection algorithm would also tell the location of the fruit in the video frames. However, the location information of fruit is only relative. It cannot output the absolute location information of each fruit. Also, the algorithm cannot tell the 3D location of the detected fruit. The multi-modal system has two color cameras, which can be used for localizaing fruit using stereo-vision. However, it is very challenging to do so in real-time. It is possible to calculate locations off-line.

Hermann Auernhammer (Club of Bologna Member)

Q2: What happens in the detection of a fruit behind another one and how often is this the case?

A2: If an orange is completely behind another one in the video for the whole time, it will not be detected. However, this situation is very rare. In most cases, an orange will appear in the video for some time as the robot is moving along the tree. Based on one previous experiment (only on one variety), approximately 70% of all fruit are at the surface of the canopies.

Margarita Ruiz-Altisent (Club of Bologna Member)

Q3: I suppose you need to establish models for real number of fruits, with direct counting data?

A3: Yes. To count the real number of fruit, manual counting in the field should be done, eventually. Due to time limit, the accuracy of this system is only based on the video. Future studies include a comparison between the counts by the robot and the manual counts should be done. Also, there should be further experiment to study the percentage of visible fruit (fruit at the surface or sub-surface of canopies) for different varieties.

Marco Fiala (Club of Bologna Member and Secretary General)

Q4: At the end of the orchard row, how the robot turns and enters into side-next row, continuing in scanning operations? Also: does this second navigation mode allow the mobility of the robot even in irregularly shaped orchards?

A4: At the end of the row, the robot will rely on the Lidar data to turn using the SLAM algorithm. The width of the rows should be set to allow the robot to estimate the location of the next row. This step was not tested in the field due to time limits. The second navigation mode will allow the robot to navigate in irregularly shaped orchards. The visual information (detecting upper tree edges) was not the only source for navigation. The visual information was added on top of the SLAM algorithm.

Paolo Balsari (Club of Bologna Member and President)

Q5: In the future, could the dataset obtained from the yield mapping be used also as a prescription map for sprayers and/or fertilizer in the same orchard?

A5: The output of the system will be geo-referenced yield maps. If weather information and other information related to irrigation needs and fertilizer needs can be added, the maps can be used as prescription maps for site-specific spraying and fertilizing.

Q6: What is a foreseeable time-to-market of such a solution?

A6: There are a lot of challenges and factors. The working efficiency of such a robot must be improved and the price must be reduced dramatically. Currently, this robot can only scan part of the tree canopies and cost more than &40k. So, it is hard to estimate the time-to-market for such an autonomous robot now. A more feasible way to promote such a system to the market may be mounting the vision system on a tractor.

QUESTIONS TO MODI RAJESH U (*"Design, development and evaluation of tractor operated seeder for mat type paddy nursery"*)

Paolo Balsari (Club of Bologna Member and President)

Q1: Is in the future possible to increase the working speed of the machine?

R1: Yes, it is possible to increase the working speed of the machine. The results obtained from the field evaluation indicated that the working speed of the machine can be increased up to 2.2 km/h from 1.7 km/h.

Marco Pezzini (Club of Bologna Member and Federunacoma Delegate)

Q2: Is the machine market-ready? How many of them do you think could be placed on Indian market?

R2: I would like to inform you that a new machine has been made ready based on the prototype of paddy mat type nursery seeder developed during my PhD research work at prestigious Punjab Agricultural University, Ludhiana, India. I had evaluated it on three locations and also at limited farmer's field. Moreover, before placing it in the Indian market, it will be rigorously popularized in the state by Punjab Agricultural University, Ludhiana with REC recommendations. Hopefully, in thousand numbers machine will be delivered after signing of MOUs with various manufactures.

QUESTIONS TO XIN ZHANG (*"Study of canopy-machine interaction in mass mechanical harvest of fresh market apples")*

Stefan Böttinger (Club of Bologna Member)

Q1: How can your results be transferred to other apple varieties and other cultivation regions?

R1a: Apple varieties: in my study, I tried my best to cover as much leading apple varieties as possible (up to 6) to represent the entire group of apple crop in Pacific Northwest (PNW) region (particularly in WA), where annually produces more than 65% of fresh market apples out of the U.S. In fact, some apple varieties (e.g., Fuji) is also very popular around the world. So I'd say it won't be too hard to transfer the results from my work to others.

R1b: Apple cultivations: it is a dominant apple planting cultivation here in PNW using Simple, Narrow, Accessible, and Productive (SNAP) cultivation system (aka., formal tree architecture) in commercial orchards, where there is a vertical trunk and 7 to 8 pairs of horizontal branches permanently trained to trellis wires. Such tree cultivation provides enough and even sunlight penetration, air circulation, as well as easier access by either human or robotic machines. It is now one of the leading cultivation systems in the U.S. and is favored by many growers. Check out this publication where all 6 different apple varieties and cultivation systems that I used in my study were introduced in detail:

- Zhang, X., He, L., Karkee, M., Whiting, M. D., & Zhang, Q. (2020). Field evaluation of targeted shake-and-catch harvesting technologies for fresh market apple. Transactions of the ASABE. (in press). https://doi.org/10.13031/trans.13779

Paolo Balsari (Club of Bologna Member and President)

Q2: One of the results of the study has been the guidelines for canopy management. Can the system under study be implemented also for automatic pruning?

R2: Yes, you're completely correct. The first two studies in my dissertation can also serve as guidelines for automatic precision pruning, where it is also an urgent need for this type of cultivation system (see my 2nd part answer above for Dr. Böttinger). Usually, a group of semi-trained labors need to precisely pruning branch-by-branch in such orchards instead of mechanical hedging, where the labor cost is a big concern to growers, too. Of course, computer vision systems need to be designed to incorporate with the developed pruning guidelines for such purposes. One of my previous colleagues in Dr. Karkee's #AgRobotics lab is currently working on this project, which can be found here:

- https://labs.wsu.edu/karkee-ag-robotics/research/

Marco Fiala (Club of Bologna Member and Secretary General):?

Q3: How the proposed solution is compared with the manual harvesting, in terms of productivity?

R3: If the end-effector is properly positioned at the target branch, the productivity of the machine is much higher than human labors. Taking one of the apple varieties in this study as an example (i.e., Scifresh), generally it has about 10-20 fruits per branch, if the shaking is engaged between 2-5 sec, about 90% of the fruits could be safely detached and caught by the machine. This productivity is remarkably higher than human picking (about 2 sec per apple) in commercial orchards based on our experiments. We therefore proposed the study of automatic estimation of shaking points using computer vision and deep learning methods in order to save time for positioning the end-effector (~72% of time were spent on this task during a complete harvest cycle). Check out this publication where we have introduced a complete processing pipeline. The well-annotated image datasets are also publicly accessible:

- Zhang, X., Karkee, M., Zhang, Q., & Whiting, M. D. (2020). Computer vision based tree trunk and branch identification and shaking points detection in dense-foliage canopy for automated harvesting of apples. Journal of Field Robotics, 1–18. https://doi.org/10.1002/rob.21998
- Image data open repository: https://research.libraries.wsu.edu/xmlui/handle/2376/17719