# Mechanization and Automation in Fruit Harvesting: Challenges and Opportunities

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The process of use of artificial power operated devices to control movement and performance specific action is usually called as mechanization. When operations of these devices are controlled by computers and sensors, it termed as automation. The mechanization and automation of horticultural operations is perceived imperative today as not only yield could be increased by this but also losses can be prevented to a greater extent. The future prosperity of fruit growers thus heavily relies on the improvement of production and processing practices by integration of mechanization and automation in orchard management. The shift towards mechanization is also a need due to alarming rate of rural migration which is creating larger shortage of labour in the horticulture production systems. Additionally, the growth of urban employment and enhancements in quality of life is further underscoring the necessity for mechanization in the horticultural landscape.

**Challenges in mechanization of fruit orchards**

Mechanization and automation have brought significant advancements to fruit orchards, especially in the developed world by revolutionizing the way, the tasks are performed and efficiency in production is achieved. However, despite the numerous benefits, there are challenges that come with the implementation of mechanization in fruit orchards. One of the major challenges is the variability and delicacy of fruit. Different fruits require different handling processes. The diverse shapes and sizes of fruit trees make it challenging to develop machines and equipment that can effectively harvest fruits without damaging fruit trees. A critical consideration when developing harvesting machines is to ensure the detachment and collection of fruit from the tree with standards necessary for market acceptance. The sensitivity of tree fruits further complicates this task, as they are prone to damage, and any harvested fruit must adhere to strict market acceptance criteria regarding size and external defects, such as bruising and punctures. Thus, mechanized harvesting is more difficult to implement for fresh market fruit because of the lower tolerance for bruising and external defects. Mass mechanized harvesting has not therefore yet reached commercial viability for fresh market tree fruit, primarily because of excessive fruits damage.

**Figure 1:** Harvest-induced fruit damage in apples.

(**Source:** De Kleine and Karkee, 2015)

**Orchard Physiographic and environmental Challenges**

Challenges in mechanization and automation in fruit orchards are also often rooted in the complexity of orchard physiography and environments. The uneven orchard terrain and changing weather creates problems for the consistent operation of machines. Under the natural growing conditions, many of the robotic machines do not perform. Further, non-uniform lighting ranging from direct sunlight to overcast & twilight conditions, variable

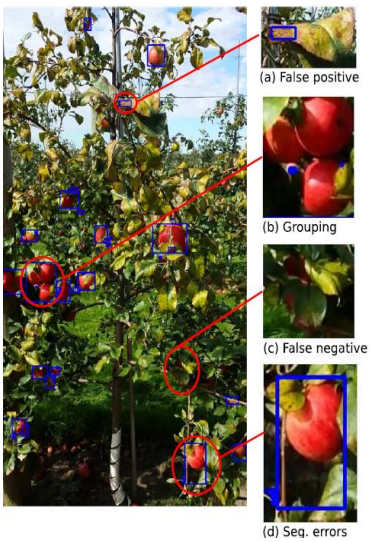


**Figure. 2:** Errors in fruit detection

(**Source:** Häni et al., 2020)

temperature & humidity, wet & dry conditions, variable fruit sizes and fruit maturity, non-uniform plant size, fruit position, fruit occlusions and limb obstacles affects the automation aspects of the mechanically automated machines or robots that otherwise tend to perform well in controlled environment, where the position and orientation of the target are known or targets can be set up in the desired position and orientation. Lack of appropriate cultivation practices further cause canopy occlusions and harvesting failure for mechanized/robotic activities.

**Economic implications of mechanization and automation**

One of the biggest hindrances in mechanization and automation is high initial investment cost for specialized machinery and equipment. It makes the implementation of mechanization and automation in fruit orchards unaffordable. The introduction of mechanization and automation in fruit orchards also brings about challenges related to the workforce. As automated systems and machinery begin to take over repetitive and physically demanding tasks may occur concerns about the displacement of manual labor and the re-training and re-skilling of the existing workforce. This transition requires significant investment in human resource management and training programs to ensure a smooth shift to mechanized and automated orchard environment.

**Opportunities**

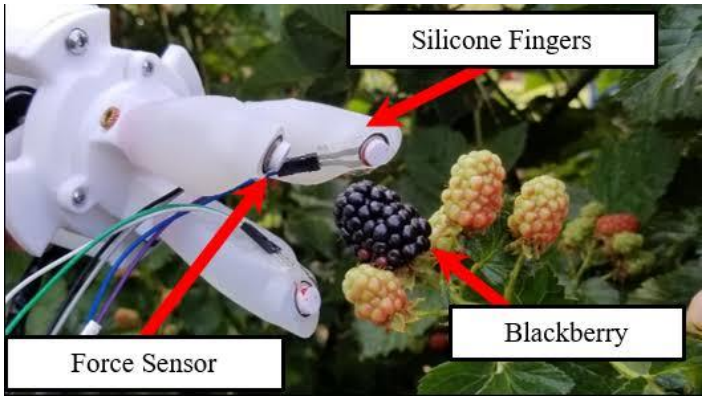


**Figure 3**: Soft robotic gripper for berry harvesting. (**Source:** Gunderman et al., 2022)

The challenges associated with the orchard mechanization and automation also present opportunities for innovation and advancement in the horticultural industry. For example, the development of specialized robotic arms and grippers designed to handle delicate fruits can lead to more efficient and gentle harvesting processes. Moreover, advancements in machine learning and artificial intelligence can be utilized for improving the accuracy of fruit detection, sorting and increasing overall productivity by reducing losses. Furthermore, the development of modular and adaptable equipment allows for the customization of machinery for different types of fruits.


**Figure 4:** (a) V-trellis and (b) vertical trellis (**Source:** Silwal et al., 2016)

Addressing the variability in orchard conditions is another important aspect of orchard mechanization and automation. Modifications and improvements in cultural practices for mechanization are continually being made through research and experience. In order to have a successful automated/mechanized system, the cultural practices need to be in machine friendly manner. Other major aspects related to cultural practices that affect fruit mechanical harvesting include plant population & spacing, and plant shape & size of the trees. Modern orchard system such as V-trellis; the branches are fixed on the trellis wire, allowing for the fruits to be distributed along the same wire can significantly avoid the occlusion of the fruits by branches and leaves thereby improving the reorganization efficiency and accuracy. Also, precision agriculture technologies, such as GPS-guided machinery and drones need to be integrated into orchard operations to improve the efficiency and accuracy of tasks like pruning, spraying, and harvesting. These technologies may help to optimize the use of resources and reduce the impact of orchard variations on farm operations.

**The way forward**

Recently, there has been a major breakthrough in development of electronic nose which can sense the aromatic compounds emitted by a ripening fruit through the use of volatile sensing of chemical markers. Such devices can be deployed for deciding the optimal maturity index of different fruits. For example, in mango, the level of limonene, pinenes, carenes, terpenes etc. associated with fruit ripening is being detected by the use of Molecular Imprinted Polymer (MIP) based sensors. Further, Quartz Crystal Microbalances (QCM) is now being tested for distinguishing the different volatile gases emitted by the ripening fruit. For development of input and resources efficient fruit production, need is there to find new ways to utilize information technology, sensors, bio-informatics and autonomous machines. Mechanization and automation module has the potential to take horticulture to new heights but it can be achieved with right coding of the machines and that right coding require precise information in plant function and responses to variable growing conditions. Therefore, integration of STEM (Science, Technology, Engineering and Mathematics) disciplines with pomology is needed to become competent in producing more while leaving smaller environmental foot prints. Additionally, investment in research and development to continually improve and adapt technologies to the unique requirements of orchard operations is crucial. By investing in ongoing innovation and collaboration, the challenges in orchard mechanization and automation can be effectively translated into fruitful future.

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