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Why Agricultural End Effectors Are Ripe For IP Protection

By **Marley Macarewich, Anna Yuan and Mike Ward** (August 24, 2023, 8:08 AM EDT)


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The field of agricultural robotics, particularly end effectors, has taken off in recent years, making it ripe for investment and intellectual property protection.

Thus, it is essential that IP practitioners stay current on the key innovations and trends in the space.

This article chronicles the evolution of agricultural end effectors and their associated patent strategies.

Development of agricultural end effectors plays an important role in ensuring that the agricultural throughput meets the demands of a growing population.

By one estimate, the human population is expected to grow to 9.7 billion by 2050, requiring double the amount of fruit production alone relative to the current production level.[1]

However, there are many challenges to meeting such a demand as many crops are labor-intensive, the harvesting employment may only be seasonal and there is an increasing lack of labor supply.[2] Thus, agriculture is a ripe area for the use of robotics to supplant human labor.

An essential part of the incorporation of robotics into agriculture is the development of end effectors. End effectors are the part of a robot that interacts with the environment to perform its designated task.[3]

They include components such as grippers and process tools designed to help automate processes such as harvesting, weeding, pruning, sowing, detection of pests and diseases, or tackling multiple tasks at a single time.[4] Improving the design of end effectors is important for agricultural robots given the wide range of tasks, targets and conditions the robots must handle.

Robotics in agriculture is not a new phenomenon. There are mentions of automation in agriculture as early as the 1920s.[5]

Innovations in agricultural automation continued to emerge throughout the mid to late 1900s, notably the tomato sorting and loading machine developed by the University of California, Davis, in 1959, which is still used today.[6]

However, only in the past two decades has there been a rise in the development of significantly more elaborate systems. Scientists and engineers are dedicating more time to developing these systems — the number of papers on agriculture robotics has more than tripled in 2020 compared to 2015, many of which are directed specifically to developing better end effectors.[7]

Further, investors are also investing more in this field — the U.S. Department of Agriculture alone provided $3.4 billion from 2010 to 2018 to 280 projects involving automated crop processing and production.[8]

Along the heavy interest and investment in the field, we see significant activities in the patent space.

While earliest end effector patents involved simple, imprecise devices, there is now a focus on precision agriculture that leverages cutting-edge technologies such as artificial intelligence and Internet of Things, or IoT.[9]

Further, patent applicants are seeking protection over a diverse range of aspects of these complex systems. Between 2005 and 2019, 1,556 agriculture robotics patents were filed, including those for end effectors.[10]

The development of agricultural end effectors is a rapidly growing field, ripe for innovation, investment and IP protection. This article chronicles the trends in the innovations related to end effectors and their associated patent protection.

Early Patented End Effectors

Agricultural robotics has been developing since the 1920s, beginning with automatic vehicle guidance systems.[11]

A smaller number of patents appeared as early as the 1960s and 1970s.[12] However, the number of early agriculture robotics patent fillings appears to have begun taking off in the 1980s, many in Japan.[13]

Many patents in this space were directed to the broader mechanical systems.[14] The patented harvesting end effectors were sometimes directed toward bulk-harvesting, such as tree shaking.[15]

Many end effectors were sweeping systems that did not target particular crops, end effectors such as sprayers and heaters.[16] While most systems did not incorporate computer technologies, there were some examples incorporating the use of color-detecting cameras.[17]

Example Patents

U.S. Patent No. 3,121,304 titled "Tree Shaker" from 1962 is an example of the earliest end effectors that are used for general tree agitation.[18] The patent describes a device with an end effector for "shaking fruit and nut bearing trees," and for catching the fruit when it falls.

U.S. Patent No. 3,200,575 titled "Automatic fruit picking machine" from 1964 is an example of an end effector in a semi-automatic system incorporating early computer technologies.[19]

The patent describes an automatic fruit picking machine that can detect the light of a certain wavelength reflected off a fruit and that includes a tubular arm with a picking mechanism to pick the detected fruit.

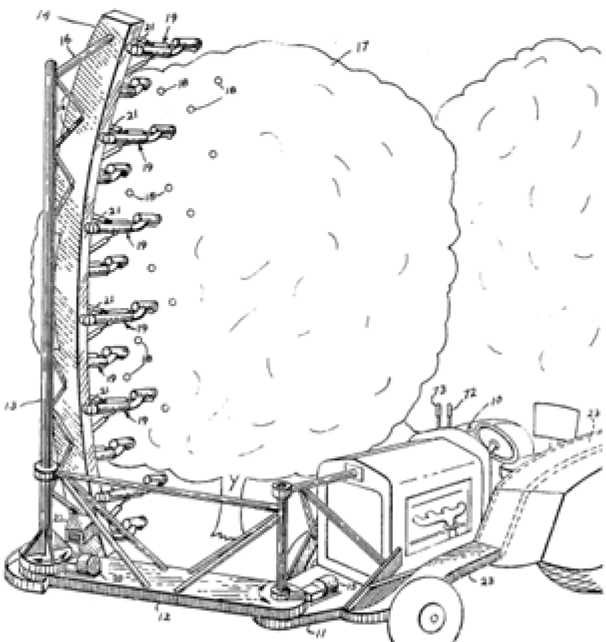


Fig.1

U.S. Patent No. 4,015,366 titled "Highly Automated Agricultural Production System" from 1977 is an example of an early end effector used for bulk spraying rather than precise targeting of crops.[20]

The patent describes a computerized system having a series of sensors to detect a variety of relevant conditions in homogeneous agricultural areas and a series of end effectors for assisting with controlling those conditions for agricultural production, such as frost-protectant sprayers and heaters.

Intermediary Patented End Effectors

Beginning in the late 1980s, there was a rise in implementation of computer technologies, such as machine vision, in agricultural end effectors.[21]

Further, toward the end of the 1990s, there was a shift toward precision agriculture.[22] Precision agriculture involves measuring and responding to variabilities in the environment in order to process and produce crops.[23]

There was also a rise in specifically shaped end effectors for different kinds of produce. During this period, China rises as the leader in the sheer number of robotics patents.[24]

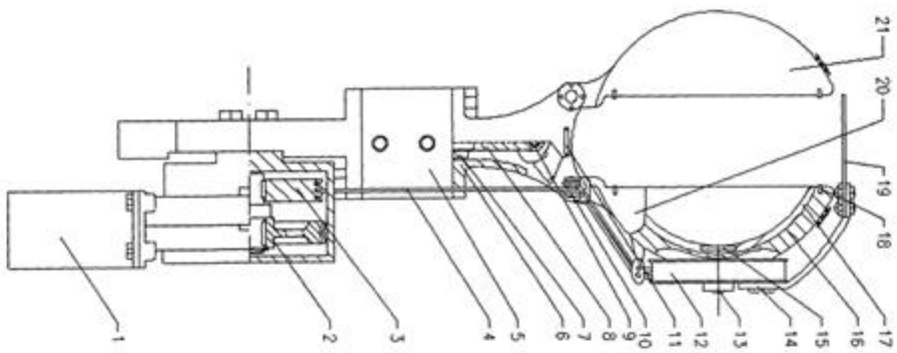
At the time, there was an increasing number of patents directed to individual end effectors, including those developed for both selective and bulk harvesting.[25]

There was also a rise in patents directed to computer detection systems.[26] The systems were becoming increasingly more autonomous, some fully autonomous.[27]

However, the vast majority of robots incorporating end effectors were not at a commercial level of readiness and were not used in the field.[28]

Example Patents

CN Patent No. 101395989 titled "End effector of apple picking robot" from 1998 is an example of an end effector that is specifically designed for a particular crop and that incorporates more precise computer technology, e.g., a vision sensor.[29]



U.S. Patent No. 20040216442 titled "Tree shaker apparatus" from 2003 is an example of a more advanced tree-shaking device that still is designed for bulk harvesting.[30]

The patent describes a harvester with an agitator, conveyor assembly and a shaker device for gathering produce. It demonstrates a continuity from the early patents where there is an emphasis on bulk harvesting rather than targeted harvesting.

U.S. Patent No. 7,854,108 titled "Agricultural robot system and method" from 2009 is an example of a fully autonomous system incorporating early versions of machine vision. It is a system that can work with other robots to perform multiple tasks.[31]

The first sends one robot to map and create an action plan, then sends another to perform another function, such as pruning.

Modern Patented End Effectors

With the most recent end effectors, there appears to be a move away from bulk harvesting to selective harvesting, with a focus on precision agriculture.[32]

Engineers are designing systems having more precise components and more sophisticated detection algorithms.[33] Many of these more intelligent robots and end effectors are now commercially ready as the technology becomes more scalable.[34]

There is a significant uptake in the number of patent applications filed, the bulk of them filed in China.[35] These patents are incorporating techniques such as AI, IoT and systems for coordinating among multiple robots.[36]

They involve scientific advances such as fuzzy logic, artificial neural networks and genetic algorithm, as well as more advanced cameras, sensors and processors.[37]

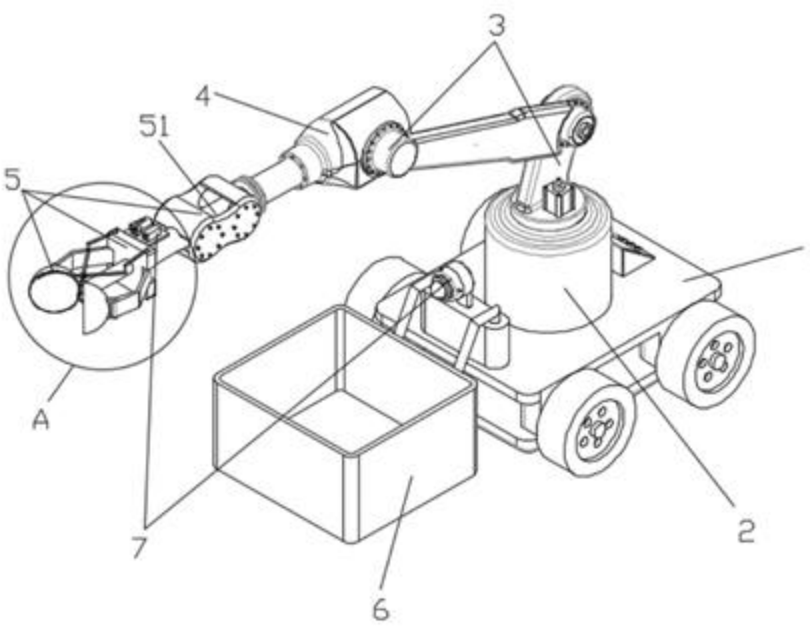
Example Patents

U.S. Patent No. 11,533,850 titled "Self-propelled robotic harvester for selective picking of high quality agriculture row crops" from 2018 is an example of a fully autonomous, specialized system that has advanced computer technologies.[38]

The patent describes a self-propelled field crops harvester having a chassis with robotic hybrid harvesting arms — coupled with a computer system — that transport the harvested crop toward the harvester and that use crop-identification optics, grippers and suction to pick crops.

CN Patent No. 116267232 titled "Multifunctional fruit and vegetable picking robot with replaceable execution tail end and application method thereof" from this year is an example of a multifunctional, autonomous system that uses advanced computer technologies such as 3D special crop detection.[39]

CN Patent No. 116277031 titled "Inspection robot based on artificial intelligence and inspection method thereof" from this year is an example of a system that has an end effector using AI to precisely detect and collect diseased leaves and fruits.[40]



Takeaways

There has been a significant increase in patent filings directed to agricultural robotics, particularly end effectors.

This uptake in the number of patent filings may be attributed to increases in the level of research and investment in agricultural robotics as the world population continues to grow.

Although China has been leading the pack in terms of patent filings, we foresee an increase in the number of patent filings in the U.S., given the strong level of investment and research here.

Additionally, as more advanced forms of AI and IoT are integrated into agricultural robots, we foresee a significant increase in software-based patent filings in the future. This increase in patent filings will likely, in turn, lead to an increase in IP litigation.

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[1] Vrochidou, Eleni, et al. "End Effectors in Agricultural Robotic Harvesting Systems." Encyclopedia, 8 July 2022, https://encyclopedia.pub/entry/26654.

[2] Id.

[3] Unidex Inc. "End Effector: What It Is, How It Works, Types, Applications." UNIDEX, 12 Jan. 2022, www.unidex-inc.com/blog/end effector-what-it-is-how-it-works-types-applications/.

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[9] Mesías-Ruiz, Gustavo A., et al. "Boosting Precision Crop Protection Towards Agriculture 5.0 via

Machine Learning and Emerging Technologies: A Contextual Review." Frontiers in Plant Science, vol. 14, Frontiers Media SA, Mar. 2023. Crossref, https://doi.org/10.3389/fpls.2023.1143326.

[10] Konaev, Margarita, and Sara Abdulla. "Trends in Robotics Patents." Center for Security and Emerging Technology, Oct. 2021.

[11] See supra note 5.

[12] See U.S. Patent No. 3,200,575. Result obtained via Orbit research.

[13] Obtained via research on "agriculture end effectors" in Orbit. The date range was set to pre-1990, and the resulting patents were manually sorted through. Japan emerged as one of the earliest major filers in this search.

[14] See id. Result obtained via Orbit research.

[15] See U.S. Patent No. 3,121,304. Result obtained via Orbit research.

[16] See FR Patent No. 2242927. Result obtained via Orbit research.

[17] See supra note 14. Result obtained via Orbit research.

[18] U.S. Patent No. 3,121,304.

[19] U.S. Patent No. 3,200,575.

[20] U.S. Patent No. 4,015,366.

[21] See U.S. Patent No. 7,854,108. Result obtained via Orbit research.

[22] See CN Patent No. 101395989. Result obtained via Orbit research. See also Zhou, Hongyu, et al. "Intelligent Robots for Fruit Harvesting: Recent Developments and Future Challenges." Precision Agriculture, vol. 23, no. 5, Springer Science and Business Media LLC, June 2022, pp. 1856–907. Crossref, https://doi.org/10.1007/s11119-022-09913-3.

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[24] See supra note 10.

[25] See supra note 22.

[26] See supra note 22. See also Qiao, Yongliang, et al. "AI, Sensors and Robotics in Plant Phenotyping and Precision Agriculture," Volume II. Frontiers Media SA, 2023.

[27] See U.S. Patent No. 7,854,108. Result obtained via Orbit research.

[28] See supra note 21.

[29] CN Patent No. 101395989.

[30] U.S. Patent No. 20040216442.

[31] U.S. Patent No. 7,854,108.

[32] See U.S. Patent No. 11,533,850. Result obtained via Orbit research.

[33] Morar, C. A., et al. "Robotic Applications on Agricultural Industry. A Review." IOP Conference Series: Materials Science and Engineering, vol. 997, no. 1, IOP Publishing, Dec. 2020, p. 012081. Crossref, https://doi.org/10.1088/1757-899x/997/1/012081.

[34] See Gossett, Stephen. "16 Agricultural Robots and Farm Robots You Should Know." Built In, 19 Oct. 2022, builtin.com/robotics/farming-agricultural-robots; "Agricultural Robotics," supra note 4.

[35] See supra note 16. Confirmed in recent years via Orbit search.

[36] Wakchaure, Manas, et al. "Application of AI Techniques and Robotics in Agriculture: A Review." Artificial Intelligence in the Life Sciences, vol. 3, Elsevier BV, Dec. 2023, p. 100057. Crossref, https://doi.org/10.1016/j.ailsci.2023.100057.

[37] Id.

[38] U.S. Patent No. 11,533,850.

[39] CN Patent No. 116267232.

[40] CN Patent No. 116277031.