

Charting the Rapid Recent Commercialization of Robotics Technologies

By Andra Keay ^{ID}

At the moment there is no canonical global source of robotics commercialization information. However, the general tracking of investment data over the last decade can show significant overall trends, even if each dataset or analytics company provides different figures.

Before 2013, there were almost no investment data to speak of, although the acquisition of Kiva by Amazon, followed by Google's spending spree, created excitement. From that point onward, starting in Silicon Valley, which remains the largest global source of venture capital (VC), seed stage investment in robotics, drones, and autonomous vehicles started climbing rapidly. By 2015, robotics had attracted more than US\$1 billion in investment, and approximately one-third was seed stage. Investment has continued on an exponential curve, with many new robotics investors and funds. But while the amount invested in robotics has grown and spread around the world, the overall number of deals has declined. This is a signal of consolidation as winners start to emerge, with larger later stage investment rounds.

According to Crunchbase, in 2021, more than US\$17 billion poured into VC-backed robotic startups, nearly triple the investment in 2020. By May 2022 (Figure 1), the sector had already seen more than US\$5 billion flow to startups. In total, 2022 looks to have exceeded US\$12 or US\$13 billion, but the dust hasn't settled yet.

In spite of the pandemic, robotics has continued to attract investment. It's by no means easy for startups to survive the process, but overall, the future for the emerging robotics industry is looking bright and undervalued, particularly compared to segments like cryptocurrency, mobile apps, and nonfungible tokens.

The IEEE RAS Industrial Activities Board (IAB) is working on a Robotics Industry Report comprising investment data; snapshots of emerging market segments; and case studies of successful robotics deployments. Help us by letting us know what sort of data would be of most use to you.

Are you looking for country comparisons? Case studies? Analysis of trends? Or something else? Robotics sales reports exist, but the majority of robotics companies today are less than six or seven years

old, and very few of them have meaningful revenue yet. Revenue or sales data are only relevant information if you want to track existing sections of the robotics industry. Investment data and mergers/acquisitions show where the robotics industry is going to grow and where a few category-leading companies will emerge, just as iRobot emerged in the robot vacuum cleaner sector, DJI in the unmanned aerial vehicle/drone sector, and Blue River in the agrobotics sector.

SOME SNAPSHOTS OF RECENT ROBOTICS INVESTMENT AREAS

FOOD SERVICE ROBOTS AND MACHINES

Companies in this space are developing automated machines for the purpose of assisting food service in the areas of

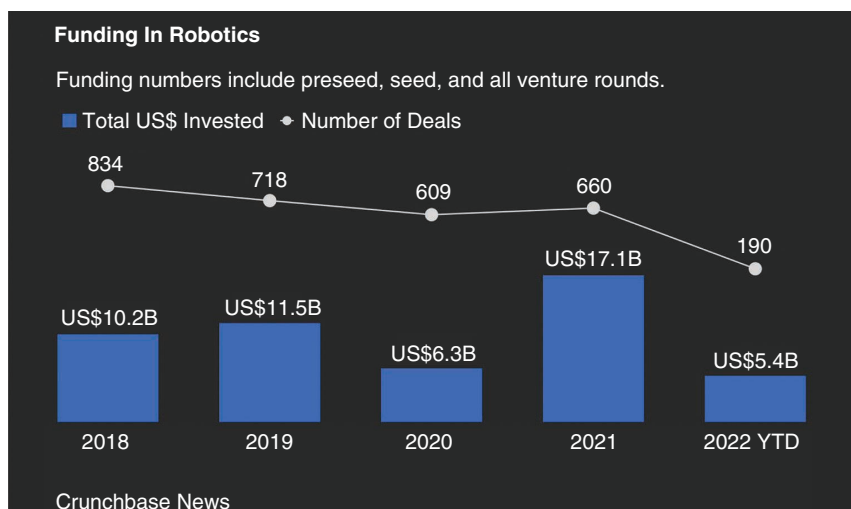


FIGURE 1. Funding in robotics as of May 2022. B: billions.

food preparation, food running, and vending. These robots primarily aim to address labor shortages by partially automating (sometimes fully) various food service tasks. Automation applications have so far included food portioning and all-in-one food prep and vending machines as well as robot mixologists, among others. The following list provides details on this industry:

- Number of companies: 52
 - Number of deals: 183
 - Amount of capital invested: US\$1.42 billion
 - Number of investors: 332.
- These six companies (Figure 2) have 45.2% of all capital invested in food service robots and machines.
- Miso Robotics, founded in 2016; total raised: US\$106.03 million

- Chowbotics, founded in 2014; total raised: US\$17.28 million
- Picnic, founded in 2016; total raised: US\$48.44 million
- RoboBurger, founded in 2019; total raised: US\$10 million
- Blendid, founded in 2015; total raised: US\$26.81 million
- Bear Robotics, founded in 2017; total raised: US\$126.19 million.

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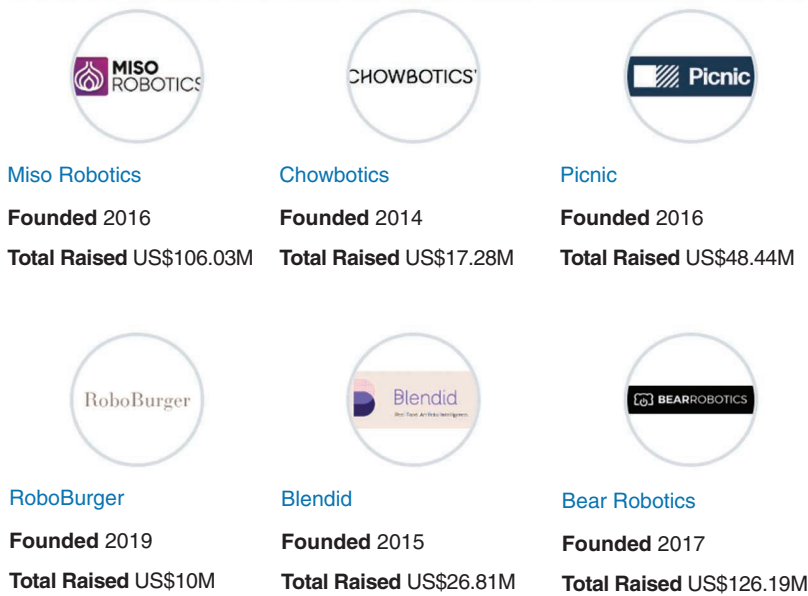


FIGURE 2. Major investments in food service robots and machines. M: millions. (Source: PitchBook Data.)

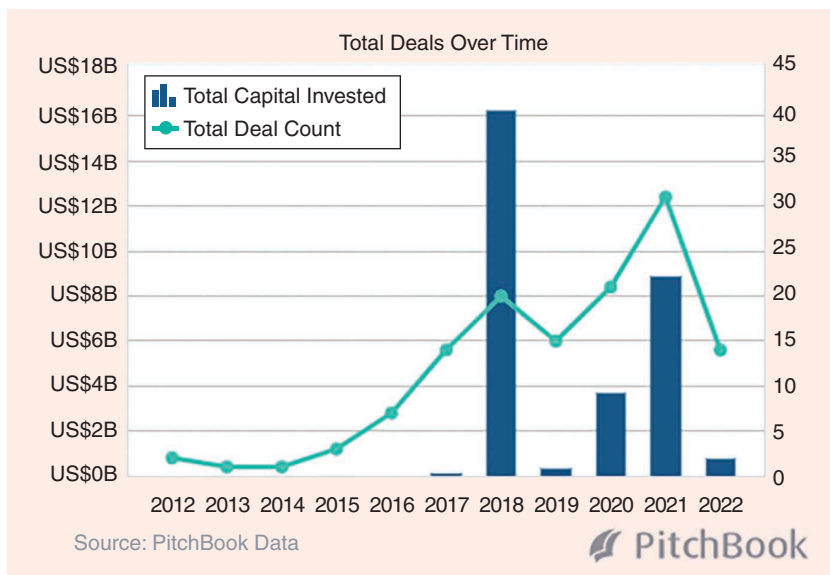


FIGURE 3. Deals over time in autonomous trucking. (Source: PitchBook Data.)

AUTONOMOUS TRUCKING

Autonomous trucking companies are using technologies such as lidar, computer vision, and artificial intelligence to automate the long-haul trucking industry (Figure 3). Self-driving trucks have the unique advantage of typically having well-defined routes to travel, making the challenge of full autonomy more realistic relative to their car counterparts. Autonomy is predicted to be a standard feature in first-mile logistics by the end of the next decade. The following list provides some details on this industry:

- Number of companies: 34
- Number of deals: 146
- Amount of capital invested: US\$30.27 billion
- Number of investors: 302.

One of the difficulties we are trying to reconcile is that investment data are market driven rather than technology driven. For example, autonomous mobile robots (AMRs) may sound like an industry segment, but AMRs are also selling into many new market areas that have not traditionally used robotics and do not track or report that information. AMRs are not just logistics for warehouses or factories but also food delivery robots that can range from deployments inside restaurants (Bear Robotics); inside hotels (Saviok); on sidewalks or campuses (Starship, Kiwi, and Cartken); or on roads (Nuro).

The IEEE RAS IAB aims to provide some insights into this evolving landscape as part of our mission to advance the commercialization of robotics research through the collection of industry and investment data; robotics road maps; the development

(continued on page 113)

More recently, noting that “Machine learning (ML) is changing the world, and in particular the world of automation,” at CASE 2022 in August in Mexico City, Mexico, Peter presented his latest research on integrating ML into the optimization of complex systems. Indeed, Peter had long been an important researcher and advocate on this topic; his most cited article (available at <https://ieeexplore.ieee.org/document/5340640>), published in 2009, is on wavelet neural networks applied to power systems, which advanced research on ML for automation.

Seeing Peter was always a great pleasure. It was an unforgettable experience to shake his hand and receive his warm smile. His encouraging feedback, whether in person or via e-mail, was so important. And with his remarkable capacity to work and dedication to the field, Peter often replied to e-mails and requests almost instantaneously.

Peter always found it important to support his colleagues. He devoted significant energy and countless hours to serving as a reviewer for various awards and IEEE Fellow nominations. And he particularly lent his support to the many young professionals in the automation community to help them progress in their careers. His deep engagement with his Ph.D. students is attested to in the many memories shared on his obitu-

ary at <https://www.dignitymemorial.com/obituaries/alexandria-va/peter-luh-11038683>. Peter also had a penchant for raising relevant and constructive questions at conferences and workshops. His remarkable intellect allowed him to quickly understand and offer feedback on research in many different fields. Indeed, Peter was a strong

believer in giving back to the research community. Many of us became volunteers when he first reached out to us early in our careers. He led by example, working tirelessly and selflessly for the greater good of the community.

On a more personal note, together with his family, Peter loved to travel both domestically and abroad, and to attend UConn basketball games. He was also a terrific swimmer and an avid fan of anything with chocolate. Above all else, Peter loved Jesus, his Lord and Savior. As is mentioned in his obituary, every action, decision, and conversation was filtered through his faith. For over 40 years he was an active and supportive member of the UConn Chinese Bible Study group.

We are profoundly indebted to Peter for his deep support, engagement, and encouragement ever since the first IEEE CASE conference in Edmonton, Canada 2005. He had also promised to be the Award Chair for IEEE CASE 2023 in Auckland, New Zealand; his pres-

ence and his contributions this coming August will be greatly missed. IEEE CASE will never be the same without Peter’s presence, but we will always remember him as a dear friend, and we promise to support his vision for a stronger automation presence within RAS and for increased research on ML for automation.

Peter is mourned by his wife Chwenhwa, his daughter Corene and son Adrian, as well as his four grandchildren, Sariah, Brinley, Lauren, and Lucas. We express our heartfelt and deepest condolences to them. The following is quoted from Peter’s obituary (linked above), which also contains many moving and fascinating testimonies and photos:

Donations may be made in memory of Prof. Peter Luh to the “Prof. Peter Luh Fellowship for Graduate Student Support” at the University of Connecticut Foundation, Inc. Online donations may be made using the following link: <https://www.foundation.uconn.edu/fund/professor-peter-luh-fellowship-for-graduate-student-support/>

Alternatively, checks made payable to the UConn Foundation, Inc., should include the memo “Peter B. Luh Memorial,” and can be mailed to:

*The UConn Foundation, Inc.
Attn: Data Services
2390 Alumni Dr., Unit 3206
Storrs, CT 06269-3206*



“
ABOVE ALL ELSE,
PETER LOVED JESUS,
HIS LORD AND
SAVIOR.
”

INDUSTRY ACTIVITIES *(continued from page 102)*

of standards; and entrepreneur/industry cluster support. The RAS IAB would like to know what figures and information would be of most use to you. We also invite you to contribute case studies of the success of category-creating

robotics companies. We are working with the Canadian Robotics Network and the University of Toronto to collect and share these case studies. These will be published in the first RAS IAB Industry Report in 2023, where we

intend to include case studies and snapshots of emerging robotics investment activity in certain sectors and provide comparisons between robotics investment and entrepreneurial levels around the world.

