Asimovo

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Influencing the future of human-robot teaming

Teamwork makes the dream work - move Robots further with Asimovo

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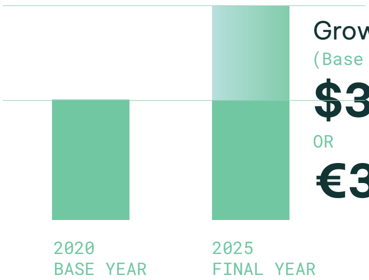
The rise of the robots

Robots have become increasingly prevalent in various areas of our lives, including industry, logistics, healthcare, and transportation. Recent advances in Artificial Intelligence (AI) have further expanded the potential applications of robotics. While robots have traditionally been controlled manually with limited AI capabilities, such as navigation and image processing, recent developments in AI have opened up new possibilities for enhancing robot performance. As AI continues to evolve, we can expect to see even greater developments in robot behavior in the near future.

GLOBAL SERVICE ROBOTICS MARKET 2021-2025

CACR of (2020-2025)
22.58%



Growth difference
(Base year - final year)
$35.27bn
OR
€32.29bn

The market is
fragmented
Many companies claiming initial market share

One if the key drivers of the market will be the **growing demand for robots to perform dull, dirty and dangerous tasks**

This data refers to the Service Robot global market, this includes both professional and personal robots. Different sources quote slightly different numbers (Data here from: Technavio, Service Robotics Market by Application, Environment and Geography - Forecast and Analysis 2023-2027)

The need for human-robot teaming

Nowadays, robots are primarily tools capable of performing simple, routine tasks. They're capable of performing highly standardized tasks within a highly predictable environment without the need for human interaction. Advancements in "smart robotics" are about to change the way people and robots interact. Robots will gradually evolve and become capable of performing more comprehensive, non-routine, tasks, where they perform as part of a larger team. As a result, the experience of working with a robot will gradually shift towards that of working with a teammate. This new way of human-robot interaction is commonly known as "human-robot teaming" (Lyons et al., 2021). In the next five years, this trend will continue to develop and create new opportunities for human-robot collaboration.

This new perspective on human-robot interaction introduces new functional and technical requirements for robot technology that build on existing OpenCV and AI . For example, robots will need to understand and respond to human signals, such as gestures and facial expressions, or other relevant human behavior displayed during task performance. This will improve human-robot communication and facilitate collaboration between both parties.

The type of features and behaviors required for smooth human-robot collaboration will depend on various team characteristics. Important team characteristics that shape the requirements placed on the robot's team behaviors and performance are illustrated in the figure below (inspired by van Diggelen et al., 2019 and Johnson & Vera, 2019):

The mission / purpose
e.g. routine / non-routine, standardization / protocolization, impact, risks/hazards, dependencies, work cycles, time criticality, task decomposition, etc.

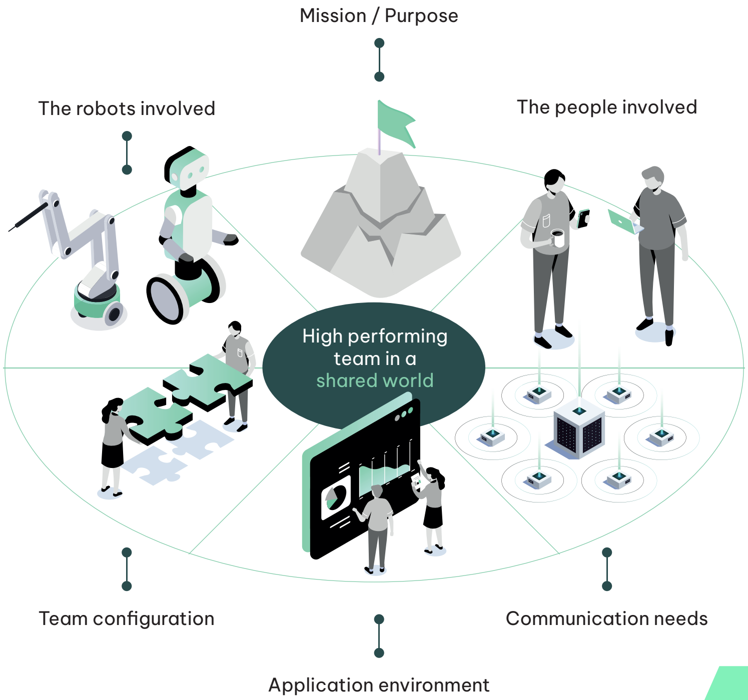
The application environment
e.g. predictable / unpredictable, collaborative / competitive,

The people involved
e.g. number, skill/expertise, health, etc.

The robots involved
e.g. number, capabilities, physical proximity to other teammates,

Team dynamics and configuration
e.g. roles, rules, variability, communication, hierarchy/network structure, temporal scope, team maturity, responsibilities, etc.

The communication needs
e.g. streams (many-to-many, one-to-one, one-to-many, etc.), information richness, quality of infrastructure (bandwidth, reliability, range), continuity requirements (batch, live, other), etc.



Bringing the theory to life

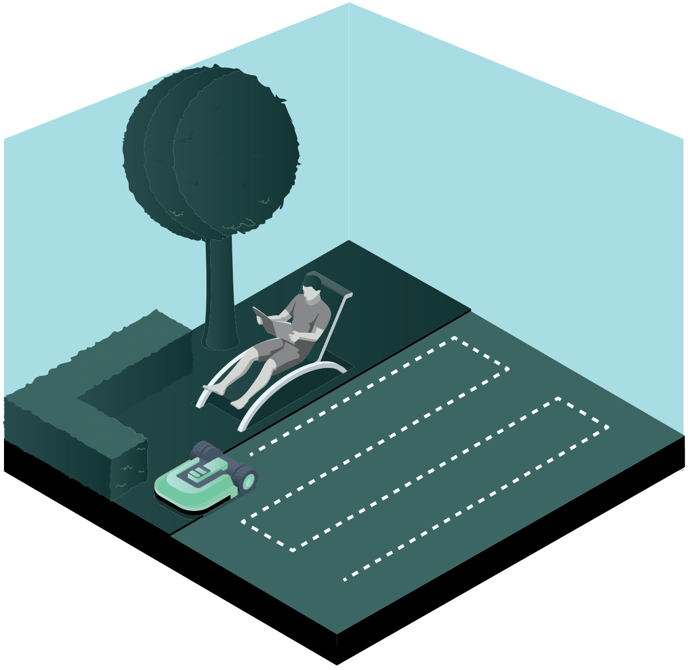
Three examples of human-robot teaming

Example 1:

lawn mower robot in a domestic environment

Lawn mower robots by now are relatively common as over-the-counter consumer goods. The task is pretty simple: keeping the grass at a certain length, and the application environment is predictable enough for the robot to be able to perform its task to the user's satisfaction. In fact, the task and the environment are simple enough for the teaming behaviors to be implemented in an **implicit manner**. In other words, the teaming behaviors are envisioned based on assumptions made by the producer and encoded directly into the task-related behavior of the robot. If we were to examine this example from a human-AI collaboration point of view, we would be able to recognize these implicit teaming behaviors and team member dependencies that are presented as part of the basic instructions laid down in the user guide:

- **Task delegation and specification:** The human marks the edges of the area to be mowed, to assist the robot in building its task environment representation.
- **Shaping work conditions:** The human ensures a power source for the robot to be able to recharge.
- **Task performance:** The robot mows the lawn at a length desired by the human.
- **Safety and trust:** The robot takes into account safety and security measures to protect the human and their loved ones from unintended harm or danger. For example operating only very slowly.
- **Help seeking behavior and communication:** The robot may request for the human to prune certain areas to ensure the robot is able to reach the areas it needs to mow.
- **Transparency, explainability,** and human oversight: In case the robot breaks down, or runs into some other issue, it provides information and instructions for the human to step in and repair.



The example of the lawn mower demonstrates that teaming behavior decisions are implicitly embedded in the robot's behavior and usage instructions. Since the consumer purchasing the robot may have little to no knowledge or expertise in robotics or lawn mowing, it is essential that the human-robot teaming behavior is straightforward, well-defined, and unambiguous. The instructions provided must be adequate to educate the consumer to the point where they can operate the robot safely and effectively.

Example 2:

Delivery robot operating in a public place

Delivery robots offer various services, including delivery of goods and services to peoples homes, or within a public space such as a supermarket or airport. They will have a two way interaction with multiple people as they deliver their goods or move goods about.

The tasks are more diverse and the environment in which these robots operate is less predictable and may at times even be hostile. In other words, the robot's teaming behaviors need to be more adaptive and robust in a variety of situations.

From a human-AI collaboration point of view, the requirements placed on this type of robot are far more intricate:

- **Communication:** The human must be able to lay down their needs and constraints, so the robot can offer appropriate service.
- **Coordination:** The robot must be able to navigate around and within groups of people that may behave in unpredictable ways at times.
- **Safety and trust:** The robot takes into account safety and security measures to protect the people and assets from unintended harm or danger
- **Help seeking behavior and communication:** The robot may request for the human to provide additional information or to repeat themselves for clarity. It may also ask people to make way so it can move. Or it may request for back-up in cases where people become hostile and start harassing the robot.
- **Transparency, explainability, and human oversight:** In case the robot breaks down, or runs into some other issue, it provides information and instructions for a human mechanic to step in and repair.

This example shows the importance of predictability: predictability of the task, of the task environment, of other actors in the environment, and also of the robot itself towards others.

No public place is a static environment. The physical parts of the environment may be predictable, however, the robot may encounter people from different areas, who speak different languages, have different accents, customs, cultural backgrounds, appearances, and so on.

Predictability, can be translated into something you can calculate for. It is important to be able to simulate the environment and then be able to train the robot to be adaptive to its surroundings

Therefore, it must be highly robust in recognizing and processing human behavior and instructions. The main challenge, in fact, is the robot's team behavior performance, and the extent to which the robot is capable of teaming with a large variety of fairly unknown teammates in a relatively short amount of time.

Example 3:

Robot-assisted professional warehouse environment

In contemporary warehouses, a diverse range of robots is employed to undertake various tasks. These include autonomous forklifts that retrieve storage boxes from stacks, robotic arms that retrieve products from boxes or assemble parts into products, and autonomous carts that transport goods around the warehouse.

While robots can automate many tasks in a warehouse, humans are still an essential component of the process. As a result, most warehouses can be viewed as "socio-technical systems" where people and technology work together in the same space to achieve a common goal. This example highlights how human-AI collaboration is an integral part of the system design:

- **Task delegation and instruction:** Updates to the lay-out of the warehouse, stock supply, product assembly, and so on, all need to be provided to the robots.
- **Coordination:** The robot must be able to navigate around and within groups of people and robots that may behave in unpredictable ways at times.
- **Safety and trust:** The robot takes into account safety and security measures to protect the people and assets within the confinements of the warehouse from unintended harm or danger.
- **Help seeking behavior and communication:** The robot may request for the human or robot to make way so it can move. Or if it runs into issues it may ask for assistance.
- **Transparency, explainability, and human oversight:** In case the robot breaks down, or runs into some other issue, it provides information and instructions for a human mechanic to step in and repair.

This example demonstrates how robot technology is used in an environment where individuals are trained to operate and navigate alongside robots, which play a significant role in the work being done.The environment is highly standardized and relatively predictable, as is the behavior of the humans operating in the shared work environment. Both humans and robots are well-accustomed to each other's behavior, able to rely on each other in case of emergencies, problems, or changes to the work environment. It requires deep expertise on the side of the people monitoring, maintaining and operating the robots, as well as highly tailored solutions on the side of the robot behaviors.

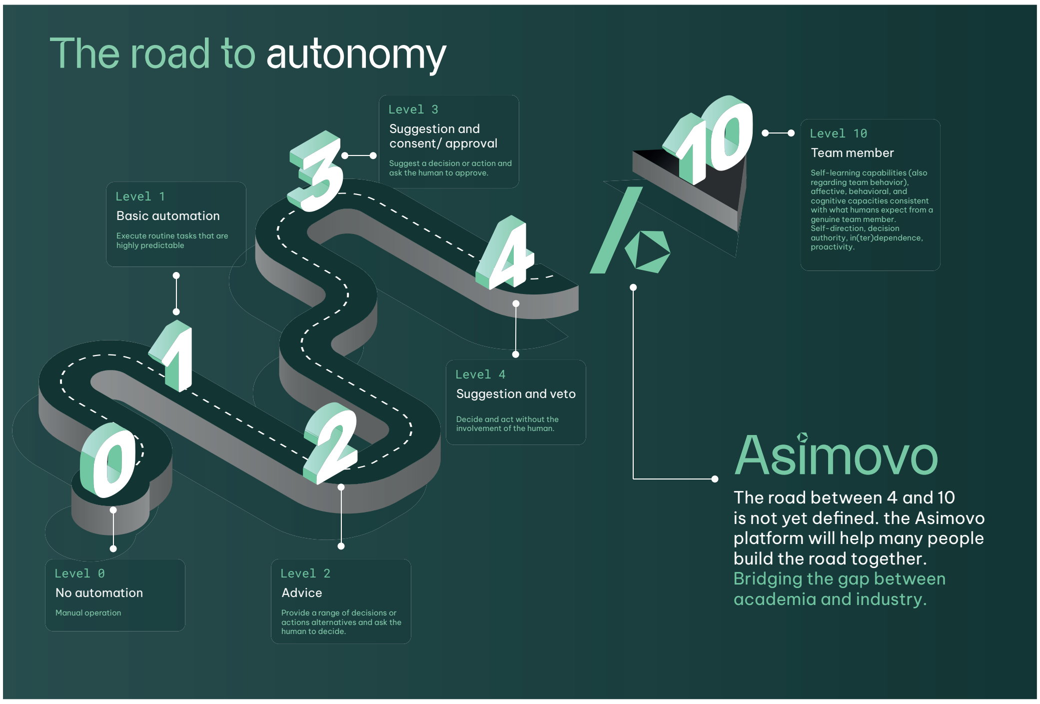
Human-robot teaming behaviors

Teaming of robots will have a huge influence on the development speed and adoption of robotics. With every new technology, once it becomes democratised, the adoption rates significantly increase.

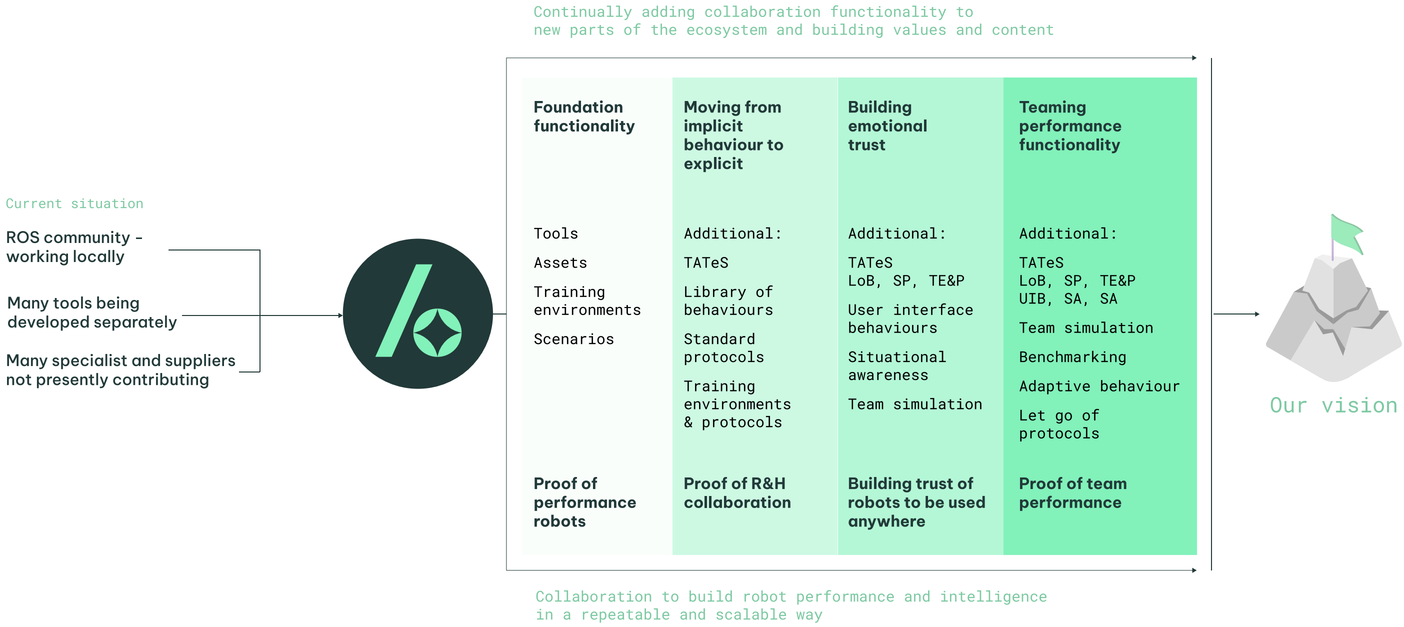
The examples illustrate that collaboration between humans and robots offers unique advantages, such as increased productivity, efficiency, and safety. However, human-robot teaming also poses several challenges, such as trust calibration (Chiou and Lee, 2021; de Visser et al., 2020; McNeese et al., 2021; Okamura & Yamada, 2020; Textor et al., 2022), effective communication (van Zoelen et al. 2020), task coordination (Mioch et al., 2018), troubleshooting (van Diggelen et al., 2019), shared situational awareness and the automation conundrum (Endsley, 2016; McNeese et al., 2021; van Diggelen et al., 2019), information sharing (van Diggelen et al., 2019), social skills (Walliser et al., 2019), and shared decision making (Textor et al., 2022; van Diggelen et al., 2019). For good human-machine teaming, robots must acquire a range of capabilities and behaviors that aren't merely task-related, but cover team performance aspects as well (van Diggelen et al., 2018). The development of these capabilities and behaviors will contribute to the successful integration of robots into our daily lives and maximize the potential of human-robot teaming.

Based on a review of the literature, we speculate the timeline as shown in the Figure below. It shows the progressive evolution of human-robot teaming (Beer et al., 2014; O'Neill et al., 2022; Rebensky et al., 2022;). A robot may display various tasks and behaviors, and they needn't all be at the same level, or may over time shift between levels of autonomy depending on the situational demands (Beer et al., 2014; Bradshaw et al., 2013; Roth et al, 2019; Salikutluk et al., 2023). For example, a robot's navigation skills may be at a different level of autonomy than its social situation assessment capability.

Looking at the state of the art in both academia and industry, one might say that the initial levels of automation and autonomy are relatively well-defined: what a robot can and cannot do and how it relates to a human is fairly clear. More advanced levels, however, are still quite fuzzy or blurry. Even the number of layers of autonomy is not fully agreed upon! THis is mainly because the academic research field is still uncovering both the challenges and the potential solutions observed in human-AI teaming and collaboration.



Asimovo's part in the future of high performing teams



Strategy
Create a go-to platform for the robotics industry. Not only a place to access all the tools and develop, but also a place to share knowledge and develop best practices.

Mission
Create a platform where many can develop robots and intelligent machines that we trust to be part of our everyday lives.

Vision
A world where robots are embraced by all, and where we can all benefit from the advances in technology that they bring. Where humans and robots work in synergy, to unleash a new level of performance and productivity.

Asimovo's founding team has a combined experience of over 40 years in the development of IOT products and robots. Throughout the years, they struggled with the existing lack of professional tools to support the development process. At this moment, we observe a significant acceleration due to advances in IOT, computing power, and AI. In addition, the Robot Operating System (ROS), and its accompanied tools are maturing and stabilizing.

Currently, ROS works well for the development and deployment of individual robots. However, to address a team of robots as a single entity, new roles and tools are needed that can act as an interface to the team. An analogy could be that of a teacher saying "class, lets all prepare for the next lesson", and all students know it is an instruction for all of them, and respond as such. RMF, the robots middleware framework, largely provides the basic required functionality, but does not provide the user experience we envision.

ASIMOVO aims for the team or group logic to run on top of RMF and ROS. This will allow robots to work with other robots and humans. Moreover, it enables you to address the right actor if and when needed. This has led Asimovo to develop the following strategy for building a platform and layers of service that will help accelerate both the development of robots, and also the development of best practices around robotics teaming.

We recognised that the first thing that was needed was a place to collaborate. Having access to tools, assets and environments all in one platform. This will enable many more disciplines to contribute to robotics development, and make it easier for specialists to get involved. That one of the first things when developing a robot should be to define the environment it will operate in; and understand how predictable it is. The ability to use scenarios, to simulate different potential behaviours in combination with virtual worlds is key here. It makes the process scalable and repeatable, which ultimately improves the performance of the robots being developed while reducing the cost and time to develop.

With Asimovo, we aim to start by building a platform that supports development of robots leveraging capabilities in the first couple of levels of autonomy. Our future roadmap accommodates the intermediate levels. Everything afterwards is still unclear, but we want to move forward as research findings advance and potential solutions progress. Most of all, we want to help define and accelerate the industry in their safe and responsible development and adoption of robots, and to be a part of the disruption in this pioneering field along with the rise of the collaborative robot.

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