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G00226249

Innovation Insight: Mobile Robot Innovations Move New Business Opportunities

Published: 22 November 2011

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Mobile robots are reaching a level of price/performance that is driving a surge of market activity and corporate interest. Organizations that are comfortable with the risk of early-stage adoption should examine the value proposition of mobile robots for internal operations, collaborative processes and customer interactions.

Key Findings

- Mobile robots that are capable of self-navigation or offer Web-based remote operation are available for less than $10,000. They create a base on which screens, sensors and cameras can be attached.
- Several companies are focusing on mobile telepresence (videoconferencing) in particular. Other applications include mobile RFID readers for asset management.
- More-functional mobile robots for task automation and interaction with humans (for example, for elder care) are still under development but progressing fast. Task-specific mobile robots (for example, for cleaning or mowing lawns) are already finding profitable niches.
- Widespread adoption of mobile robots will be slow, due to the fundamental shifts in work patterns and processes, and will occur first in specific applications and industries, such as telepresence, healthcare and agriculture.

Recommendations

CIOs and technology planners:

- Evaluate mobile videoconferencing applications for remote consultation, management, collaboration and security.
- Prepare for mobile robots to appear as new endpoints in corporate IT networks.

Organizations in industries with "physicality" (manufacturing, logistics, retail, oil and gas):

- Evaluate mobile robots for delivery, warehousing, cleaning and other task-specific applications.

Type A (aggressive) healthcare organizations:

- Investigate and pilot healthcare-assistive robots for physician telepresence, in-hospital deliveries and equipment tracking.

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Innovation Description/Definition

Mobile robots move and navigate in a manner that is autonomous, teleoperated (that is, via remote control), or semiautonomous (autonomous with human teleoperation as needed), and have the ability to sense or influence their local environments. Mobile robots may be purely functional, such as vacuum-cleaning or warehouse robots, or may be humanlike in their appearance and capabilities.

To achieve their mobility and utility, mobile robots depend on four core technological capabilities: navigation, sensing, task execution and interaction.

Navigation

Some robots can navigate autonomously, using sensing technologies to determine where they are and what is around them. Sensors may include GPS and dead-reckoning technologies to determine location, and a combination of short-range sensing technologies — for example, sonar, infrared, laser, light detection and ranging (lidar), or radar — to detect local obstacles. Route-planning and 2D or 3D mapping software allows the robot to plan its own route to a given destination and replan as necessary if a route is blocked.

Semiautonomous robots have the option of being remotely controlled by humans when needed or desired to perform tasks, avoid or circumnavigate obstacles, do repairs, or perform detailed navigation maneuvers. Many robots are designed using a simple, low-cost wheel base that is suitable only for smooth surfaces. Others specialize in the movement and stability that are required for negotiating stairs or rough terrain (for example, Boston Dynamics' BigDog), while still others are specialized for movement, navigation and planning in the air or underwater. Teleoperated robots typically include cameras and other sensors, as well as remote-control effectors, to allow control from a user console at a remote site. Some robots, particularly those targeting consumers, take advantage of Internet connectivity to support remote control via a website.

Sensing

In addition to the navigational sensors, mobile robots may incorporate sensors with the primary purpose of collecting and transmitting information. The most common is a camera for telepresence (mobile videoconferencing) applications. Others might include an RFID reader or sensors that determine environmental conditions.

Task Execution

Mobile robots that take action or affect their environments are still typically controlled by human operators because of the complexity of grasping and manipulating objects with the flexibility needed in a constantly changing real-world setting. The exception is single-function robots, such as vacuum cleaners and lawn mowers, or robots dealing with relatively large objects in a controlled setting, such as a warehouse. Force feedback grasping and other actuators provide a sense of touch for teleoperators where finer-grained control is required.

Researchers and commercial robot providers are making progress in the area of automated task execution. For example, the Frida robot from ABB has a humanoid (but headless) two-armed torso that can be placed into an assembly line alongside human workers to grasp and manipulate electronic components and other small parts. A typical approach relies on a relatively simple set of sequential steps often assisted by sensor-specific markers for locating and selecting objects and navigation. This type of deterministic following of a plan may be augmented by teleoperation when finer control is needed or unexpected obstacles are encountered. More-complex task planning and execution capabilities are a current topic of research, with robots being tasked to plan goal-oriented tasks, perform household tasks or bake cookies.

Interaction and Personality

Most commercial mobile robots are controlled through traditional means, such as a computer terminal, mobile device or remote control. The desire for more humanlike interaction — for example, through speech and gesture — is triggered by the practical difficulty of interacting with a robot in motion for anyone other than the holder of the controlling device, and by the desire to anthropomorphize robots. Humanlike robots are especially important for roles in which physical appearance for interpersonal engagement is important, such as a receptionist, caregiver, companion or educator. However, humanlike interaction is still mostly limited to research including human-looking skin and features, and portraying emotion through facial expressions, gestures and movements.

Researchers are also working on human-robot and multirobot cooperation issues. For example, the Chris project is examining the issues surrounding human and robot interactions in performing physical tasks requiring cooperative object manipulation. Multirobot cooperation research looks at the issues of cooperative planning and coordination among autonomous robots in application areas such as surveillance, monitoring and military reconnaissance.

Business Impact

Mobile robots have emerged from the military and government where they were performers of "dirty, dull or dangerous tasks" in places or situations where people cannot or do not want to go. Those applications remain, and the robots that perform them are becoming lower-cost and higher-performing. At the same time, commercial applications are opening up where the motivation is cost-efficiency rather than safety.

There are four main classes of applications for mobile robots that build on the four core capabilities described above.

1. Moving Things or People

Several organizations are reporting value from a recent application of mobile robots in warehousing, in which free-moving robot bases deliver shelves to human packers, rather than the packers moving around the warehouse, as in Staples' use of Kiva Systems' technology. This has allowed Staples to design the warehousing process to improve the value-added capabilities of its employees, because robots are not yet good enough at picking and packing — at least not at the right price point.

Using an autonomous robot to transport items can avoid the cost of human delivery. For example, Aethon's Tugs are used in hospitals to deliver food or medicine, freeing up employees for high-value work with patients. In heavy industries, autonomous vehicles can also avoid putting people in hostile environments, such as the use of ore-hauling robots in mining.

Within the next three to five years, we anticipate that robots will be able to safely lift people. This will open up additional applications in healthcare and nursing, as well as in military and first-responder rescue or evacuation operations.

2. Telepresence and Remote Sensing

One of the most striking recent developments in mobile robots is the availability of mobile telepresence robots at less than $10,000. These units, such as Anybots' QB, VGo Communications' VGo or Gostai's Jazz, are remotely controlled robots with a wheel base, a simple upright body, and a "head" that consists of a video screen and camera for videoconferencing. These robots work "avatar"-style by allowing the user to control and guide the robot from a remote location and to interact with others through the videoconferencing interface. For example, the user could attend a meeting and be present (through the robot) at the meeting table, zoom in to view what's being written on the whiteboard, turn to see who is talking, and visit a manager's office afterward. The robots can be shared among many users — once logged in to the control site, users simply "check out" an available device and take over control.

The subtle but important value of these units is that having a physical object associated with participants' remote presence improves the ability of people to recognize their presence and therefore actively include them in the conversation as though they were physically present. This contrasts sharply with videoconferencing or audioconferencing solutions, in which the virtual presence of a remote participant is all too easily overlooked.

Because of this increased sense of presence, and the flexibility in deciding where to go and what or who to see, mobile telepresence robots may be used to avoid travel, although in most cases the value is in driving a richer interaction for a session that was already going to involve a remote participant.

In addition to remote meetings and office collaboration, other uses include security and surveillance, inspection, remote physician consultations (for example, a busy surgeon could check on patients on the other side of a hospital between surgeries), and remote education (such as allowing children whose immune systems require them to be isolated to "attend" school via their robots). They will also continue to be used for traditional telepresence applications in hazardous environments (for example, military reconnaissance and biohazard investigations), although these robots tend to be specially designed for additional robustness and movement (such as climbing stairs). Many other creative applications will evolve in this space during the next few years.

The camera can be viewed as one particular type of sensor that is mounted on a mobile robot to facilitate two-way communication for telepresence. Other remote sensing applications may use the camera as a one-way source of information (for example, for surveillance, inspection or monitoring) or may use other sensors (for example, to detect chemicals, heat or radiation).

One ingenious application of remote sensing uses a robot-mounted RFID reader for asset management in hospitals. Hospitals have critical medical equipment that can be wheeled to where it is needed. The downside of this mobility is that administrators may lose track of where the equipment was last used and be unable to locate it when needed in a hurry. A solution that is typically too expensive to implement would be to blanket the hospital with RFID readers. To deliver this functionality at a much lower cost, mobile delivery robots with an attached RFID reader (from vendors such as Aethon) can take inventory of equipment locations as they move around the hospital.

The value in remote sensing applications resides in increasing the types, frequency, accuracy and timeliness of information about objects, places or people that are relevant to business applications.

3. Automation

Single-function robots are starting to proliferate for a range of tasks, including golf ball collection, animal waste cleaning, lawn mowing, pool cleaning, cow milking and weeding. More-complex robots can autonomously function as mobile monitoring, surveying, search-and-rescue, and reconnaissance platforms where sensor input is used to guide path planning to seek out and positively identify the subject of the task or, failing a positive identification, to return to the original path plan.

4. Human Interaction

Humanoid robots have attracted large amounts of funding in Japan and South Korea, where robots have been developed with impressive physical, cognitive and interactive skills. Applications include autonomous human-looking robot receptionists and home helpers.

At the high end of the market, Honda and other companies have developed human-looking robots that can walk, run, jump, and respond to gestures and voice commands. A number of academic institutions are also experimenting with medical applications of this technology. These are still research prototypes, however, and they are not yet available at commercially viable prices, but they indicate the level of physical performance and responsiveness that will be available in the next decade. Widespread shortages of healthcare professionals such as nurses, the physically demanding aspects of many healthcare services, the growing senior population in many countries (many of whom live in isolation), and the potentially therapeutic benefits of socially assistive robotics make healthcare a potentially large global market in which to focus these technologies.

Robotic pets that respond to human interaction are being used for patient therapy and behavioral problems in places such as hospitals and schools where live animals are not permitted (for example, Paro and, previously, Aibo). Others are designed to be conversation partners for the elderly (Tama robot cat), medication reminders (MIT's Pill Pets), or deliverers of messages and news (the discontinued Nabaztag from Violet).

Key Benefits

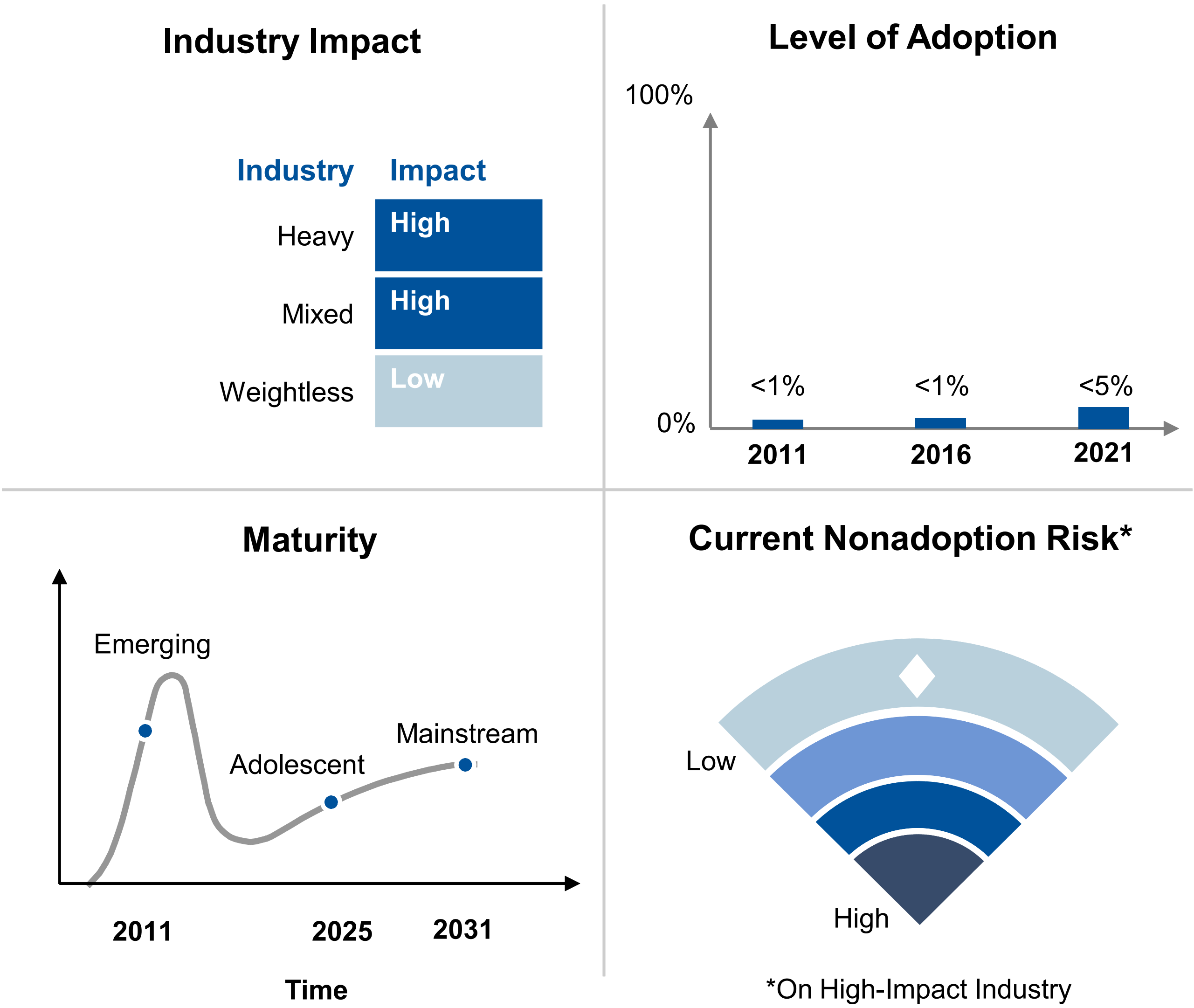
When looking for applications and business processes in which mobile robots may add value, enterprises should consider the following common benefits that underlie the applications discussed above:

- Performing repetitive tasks to eliminate the effects of inattentiveness and to free up employees for higher-value activities (for example, delivering medications inside a hospital, thus enabling nurses to focus on their patients, or bringing warehouse shelves to a human packer so that the human doesn't waste time walking around the warehouse).
- Performing tasks that have not been economically feasible before by making a high-cost item mobile, rather than having to purchase multiple items (for example, performing regular asset management by mounting an RFID reader on a mobile robot).
- Performing tasks that people are unable to do for themselves (for example, an in-home help robot that fetches items for an elderly or disabled person).
- Extending an individual's reach through telepresence or remote sensors (for example, physicians doing their rounds in multiple hospitals through robot telepresence, or security officers conducting video patrols).
- Avoiding travel time or cost (for example, a business owner attending remote meetings through robot telepresence).
- Reducing security risks by performing tasks such as cleaning in environments such as banks or secure facilities.
- Performing tasks, or collecting or sending information in environments that are unsafe or undesirable for humans.

Innovation Impact Window

As depicted in the upper left of Figure 1, mobile robots will have a greater impact on industries that are more physical in nature, such as the heavy industries of mining and manufacturing, or the mixed industries of logistics and healthcare. However, mobile robots will experience slow maturity (see lower left), and their adoption level across industries will be slow, as shown in the upper right. The risk of not adopting the technology in the high-impact industries is relatively low as a result.

Figure 1. Innovation Window for Mobile Robots



Source: Gartner (November 2011)

Industries in Figure 1 are defined as:

- Heavy — for example, mining, engineering, construction, energy and utilities, military, automobile, and manufacturing
- Mixed — for example, consumer packaged goods (CPG), logistics, retail, pharmaceutical, local government, education and healthcare
- Weightless — for example, insurance, media, banking, advertising and intelligence

IT Impact

There is a large amount of unexplored potential in the switch from "mobile technology" as the technology a person uses while mobile, to technology that is itself mobile. In any situation in which the need for mobility is on a flat surface, navigation is relatively unchallenging, and only very simple human hand-eye coordination actions are required, modern robotics now can more frequently provide a serious economic alternative.

IT has a major role to play in identifying where it makes sense to use robots to redesign business processes and augment human capabilities, and in flattening the Hype Cycle curve to stay realistic. Mobile telepresence and rethinking collaboration are a good example. It is easy to regard mobile robotic telepresence systems as trivial and "gimmicks," and it is true that some current deployments reflect this.

Nevertheless, IT leaders should seriously evaluate these systems and consider the real value offered by an on-demand capability to move around a remote site and interact with individuals and observe the environment. This value is likely to be significantly greater than simple savings in travel costs and time.

Infrastructure

IT will also have a major role in providing infrastructure support, ranging from implementing structural support to managing it, such as wireless capacity, embedded navigation aids, teleoperation facility capabilities, teleoperation consoles and information, and computing access for autonomous robot use. Robot maintenance requires facilities and specialized skills to keep robots and their sensors, actuators and other hardware fully operational.

Managing mobile endpoints may entail mobile IT personnel servicing robots in the field. IT will also have a role in any needed facility adjustments to accommodate the limited traveling capabilities of these devices. (Climbing stairs and manipulating physical objects are not yet in their capabilities at these price points, and their success relies on the availability and reliability of the communications infrastructure.)

The development, customization and maintenance of mobile robot capabilities are becoming increasingly easier as companies, such as Microsoft (Robotics Developer Studio) and iRobot (Create), have introduced development tools that significantly reduce robotic software development barriers.

Additionally, a growing number of open-source robot blueprints, schematics, simulators, and hardware and software components are available. These include a robot OS and vision modules from Willow Garage and Urbi, an open-source robot application scripting language with plug-and-play voice recognition, simultaneous localization and mapping (SLAM), and other components. Although the usual due diligence is needed for applicability and reliability, open-source components and communities offer an efficient and effective means of development for those with the requisite computer science skills.

Adoption Rate

In the near future, adoption will likely be in practical, controlled and focused applications rather than general-purpose usages. However, as prices for mobile robots drop, the adoption rate will increase. Many of the technologies embedded in mobile robots and their ecosystems are no longer specialty items but available as off-the-shelf consumer technologies. Wi-Fi, digital cameras, embedded computers, smart batteries and battery controllers, motion detectors, and other sensors and other devices have dropped in cost as they became ubiquitous. Stereolithography, 3D printing and readily available mobile platforms have brought down the cost of design and prototyping and lowered the overall costs.

Further cost reductions will accrue from increased adoption of mobile robots. However, adoption will be slow overall, given the fundamental shift in business processes that most deployments entail. By 2025, although robots will still not have reached even 5% of their total potential adoption levels, they will be displacing manual workers in multiple industries. Moreover, the majority of robots will be working on tasks that were previously not performed due to a lack of resources (for example, home support for the elderly).

Mobile telepresence robots provide one of the more compelling adoption cases as global companies look to enhance collaboration and expand the availability of scarce skills. Remotely controlled video telepresence robots can be used to create a strong sense of "presence" for remote meetings, training, customer support, inspections or security. The technology will be of interest to CIOs and others designing the future collaboration and communications environments for their organizations, as well as solving time, expense and safety issues where a visual presence is needed.

As assistive robots start to reach price levels that are comparable to a person's salary, leading-edge health system CIOs should prepare for mobile robots to appear as new endpoints in healthcare IT networks — and possibly for their need to be represented in IT systems as "virtual" providers with unique identifiers and workflows.

Risks

The use of mobile robots beyond the confines of hobbyists and research laboratories is relatively immature, with risks specific to the particular mobile robot type and application. Given their current maturity, autonomous and, to some degree, semiautonomous mobile robots have safety and liability issues associated with deployments where interaction with humans is likely. Advances in obstacle detection and avoidance, local awareness and monitoring, and fail-safe, instant-stop routines will continue to mitigate some of these risks as the technology matures.

Robot deployments also run the risk of resistance from union and labor organizations if jobs are lost or deskilled. However, the risk may possibly be mitigated with a change management and communications effort to allay the fears of job loss and to focus on enabling employees to concentrate on other, more valued tasks.

There is a blend of additional behavioral and psychological issues with the use of mobile robots in any area that involves interacting with humans, whether passively when moving warehouse pallets or directly when tending to human needs. For many people, robots evoke movie scenes in which some robots are cute and childlike but most are large, mechanistic and lethal. Technologically astute segments of the population may be more aware of the more benign nature of robopets and be more comfortable with direct and mediated interactions with technology. Fears and concerns must be anticipated and allayed prior to the introduction of mobile robots, even in situations where stationary robots are already employed.

Regardless of the type or use, any introduction of mobile robots into the work stream can have unpredictable process implications. As with any new technology, unintended consequences that affect work efficiency, patterns, methods, the use of other associated technologies and so forth can alter work processes and outcomes. A monitoring plan must be in place to collect information on workflow, attitudes, efficiency and other appropriate measures, and a governance committee must be prepared to respond with an appropriate change management plan.

Key Technology Providers

Table 1. Commercial Mobile Robot Providers

Company	Applications	Industries
Adept Technology	Inspection, monitoring, mobile industrial applications	Medical, manufacturing, logistics
Aethon	Delivery, asset management	Hospitals
Anybots	Video telepresence	All
InTouch Health	Video telepresence	Hospitals
iRobot	Cleaning, military telepresence, situational awareness, porting	CPG, military, heavy industry
Kiva Systems	Warehousing, materials handling, e-commerce order fulfillment	E-commerce, retail
Mitsubishi	Humanoid receptionist, house sitter	Services
RoboDynamics	Video telepresence	All
Seegrid	Warehousing, towing	Logistics, transportation
VGo Communications	Video telepresence	All

Source: Gartner (November 2011)

Other providers offering technology for partnerships and research, or in early commercialization, include Aldebaran Robotics, Boston Dynamics, GeckoSystems, Gostai, Honda, PAL Robotics, Paro Robots, Sony, Suitable Technologies and Mobile Robotics Sweden.

Robot development environments are available from Gostai, iRobot, Microsoft, Urbi and Willow Garage.

Recommended Reading

Some documents may not be available as part of your current Gartner subscription.

"Hype Cycle for Emerging Technologies, 2011"

"Technology Trends That Matter"

"Business and Management Trends That Matter"

"Trends That Matter: 84 Technology, Societal and Business Trends"

"Executive Advisory: Six New Technologies That Will Reshape Your Business"

"Hype Cycle for Telemedicine, 2011"

"Cool Vendors in Emerging Technologies, 2011"

"Maverick* Research: Doing Business With 21st-Century Techno-Skeptics"

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