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DIFFERENT APPLICATIONS OF ROBOTICS FOR MOBILE COMMUNICATION

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ABSTRACT

This overview paper discusses some of the major focuses of current mobile robotics research, introduces a specific application of mobile robotics — automated inspection using autonomous novelty detection — and presents one of the future challenges of mobile robotics research: that of applying quantitative methods in mobile robotics, in order to change the discipline from an empirical one to a more precise science

1. INTRODUCTION

In recent years, mobile communication technology has given rise to a large number of available mobile tools and their emerging applications are becoming more and more sophisticated by years. Therefore, many mobile robot platforms use mobile communication technology to communicate with off-line computing resources, human machine interfaces or others robots. Many mobile robots have equipped with mobile communication technology such as Bluetooth, Wi-Fi, Wireless LAN etc.

A. Mobile Communication

Review of technology for mobile devices has also been carried out starting from the 1G (first generation) until 3G (third generation) [8]. 1G wireless communications network is used for analog voice services with speeds up to 2.4 kbps. In this 1G, Frequency Division Multiple Access (FDMA) is used as an analog frequency modulated using a mobile radio system frequency band 824MHz - 894MHz. 2G is based on digital technologies such as Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA). In this generation of Global Systems for Mobile Communications (GSM) is a popular wireless technology, a combination of FDMA and TDMA. 2G + will use the technology of High- Speed Circuit-Switched Data (HSCSD), General Packet Radio Service (GPRS) and Enhanced Data Rates for Global Evolution (EDGE). 3G wireless technologies is the concentration of various 2G wireless telecommunications systems into a single global system that includes certain components and satellites. One of the most important aspects of 3G wireless technology is the ability to unify existing cellular standards such as CDMA, GSM, and TDMA on the one umbrella.Telecommunication network or a line of 3G is faster than the previous range of technologies such as GSM, GPRS and EDGE technology, better known as 1G and 2G. This factor allows it to do various things that cannot be done by the previous technology generation. For example, a video call, only 3G technologies that allows callers to make video calls that can view video images of friends and chat with[9]. But, the caller and call recipient must have a 3G phone and subscribe to 3G services from existing telecommunications companies. According to [10], apart from that, this 3G technology also incorporates other media of communication such as wireless communications and global internet.

1) Bluetooth

Most wireless technologies such as Bluetooth and IrDA standard provide the ability to strengthen the local wireless network. Bluetooth technology was created by Ericsson in 1994 and is used to replace the cables in the office, in laboratories or at home [11]. Bluetooth is a radio frequency cable with a short distance to replace the unlicensed technology with 2.4GHz bandwidth in the scientific industry. Typically, Bluetooth devices have a range of approximately 10 meters and it can support both voice and data communications with broadband 1 MB per second [12]. Because of the advantages of Bluetooth, such as low costs and low power and nature can be pointed to different directions, parts of Bluetooth has been integrated into various types of mobile devices such as mobile phones, PDAs and other wireless set. Research from In-Stat / MDR and Frost & Sullivan has estimated the use of Bluetooth will be sold around 200 millionunits in 2001 and will increase to one illion in 2006. Therefore, currently the usage of Bluetooth technology was developed for mobile robot controller. With Bluetooth, mobile robots then can be easily handled with a push of button from our common electronics gadgets such as hand phones or PDA. Fig. 1 shows the architecture for a Bluetooth enabled autonomous mobile robot [6].

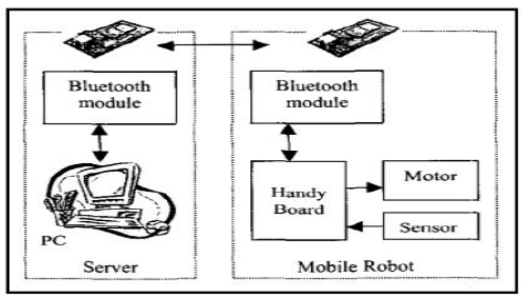

Figure 1 Hardware Architecture[6]

In this project, a Bluetooth device in the server connected to the serial port of the PC. Then, for the mobile robot, a Bluetooth device is connected to the RS232 of the Handy Board. During the navigation of the mobile robot, all the sensor readings can be viewed from server (PC). At the same time, PC can send direction command to the mobile robot.

2) Wi-Fi or Wireless LAN

Wi-Fi or WLAN (Wireless Local Area Networks) is a wireless network based on a series of specifications from the Institute of Electrical and Electronics Engineers (IEEE) called 802.11. Wi-Fi uses unlicensed radio frequency, mostly in the 2.4GHz band. It enables a person with a wireless-enabled computer or PDA to connect to the Internet via a wireless access point. The geographical region covered by one or several access points is called a hot spot. Wi-Fi was intended to be used for mobile devices and local-area networks, but it is now often used for Internet access outdoors. There are several types of Wi-Fi:

• 802.11a (offering transmission speeds of 24mbps to 54mbps)

• 802.11b (6mbps to 11mbps) and 802.11g (24mbps to 54mbps)

• 802.11n (50mbps to 100mbps) is a proposed specification that will become a Wi-Fi standard once it's finalized by the IEEE, and the Wi-Fi Alliance completes its interoperability testing.

WLAN has changed the interaction manner through wire line between operators and robots in the past.

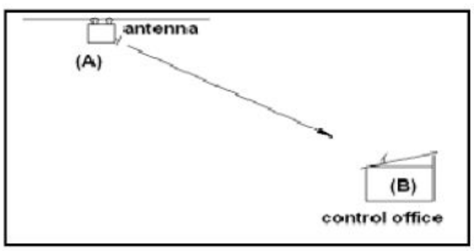

Figure 2 Schematic of the mobile robot and the control office.

2. NETWORK CONFIGURATION FOR THE ROBOTS MONITORING AND CONTROL SYSTEM

After considering a number of configurations of communication networks for the robots monitoring and control system, it seems that the best solution is heterogeneous communication system that uses different hardware architectures. The proposed solution is combination of the standards IEEE 801.11 (Wi-Fi) and IEEE 802.15.4. On the figure 1 is shown the general proposal of the communication network configuration. On the picture each node represents a robot equipped with sensors. All robots are connected with the main robot which uses IEEE 802.11 standard. In the case of low energy nodes the IEEE 802.15.4 standard is used. For more powerful nodes it is better to use IEEE 802.11 Wi-Fi hardware. The bridge node is used for interconnection of booth networks standards.

Standard IEEE 802.15.4 describes PHY (physical layer) and MAC (media access control) hardware for wireless personal area network (WPAN). It is especially designed for interconnection of low power devices. Many manufacturers offer special chips or modules for communication in the described standard. The frequency of communication channel is different depending of part of specification. Depending on the requirements and frequency of communication it is possible to choose different options. For nodes spaced at large distances a solutions operating in the sub-1 GHz band can be used which utilizes less crowded, lower frequency bands (169 MHz, 315 MHz, 433 MHz, 500 MHz, 868 MHz, 915 MHz and 920 MHz). It does not exchange standard Ethernet frames and has own physical frame-format which is described in the standard specification. This is due to the fact that PHYs only support frames of up to 127 bytes. For upper layer it is possible to use different protocols such as ZigBee, 6LoWPAN, ISA100.11a, WirelessHART. From this protocols the most interesting is 6LoWPAN because it is the standard Internet protocol. 6LoWPAN is an acronym of IPv6 over Low power Wireless Personal Area Networks. The 6LoWPAN uses encapsulation and header

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compression mechanisms that allow IPv6 packets to be sent to and received from over IEEE 802.15.4 based networks. The main robot can work independently or can be remotely controlled from other systems connected to the internet network. Advantages of the system are: easy maintenance; low cost; low energy consumption; reliability and security; easy connection to the Internet. The system can also be very huge, in this grid it is possible to use more than 1000 nodes.

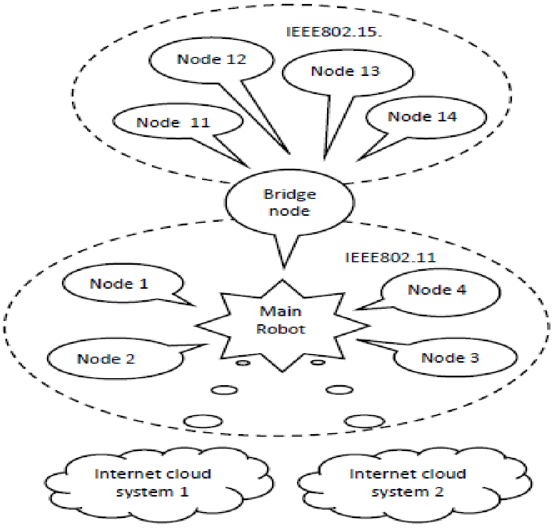

Fig. 1. The developed and investigated sensors network

3. GENERAL APPLICATIONS OF A ROBOT

As more and more robots are designed for specific tasks this method of classification becomes more relevant. For example, many robots are designed for assembly work, which may not be readily adaptable for other applications. They are termed as "assembly robots". For seam welding, some suppliers provide complete welding systems with the robot i.e. the welding equipment along with other material handling facilities like turntables etc. as an integrated unit. Such an integrated robotic system is called a "welding robot" even though its discrete manipulator unit could be adapted to a variety of tasks. Some robots are specifically designed for heavy load manipulation, and are labelled as "heavy duty robots".[20]

Atlas Robot a humanoid robot designed to aid emergency services in search and rescue operations

Current and potential applications include:

- Military robots.
- Industrial robots. Robots are increasingly used in manufacturing (since the 1960s). According to the Robotic Industries AssociationUS data, in 2016 automotive industry was the main customer of industrial robots with 52% of total sales. In the auto industry, they can amount for more than half of the "labor". There are even "lights off" factories such as an IBM keyboard manufacturing factory in Texas that was fully automated as early as 2003.
- Cobots (collaborative robots).
- Construction robots. Construction robots can be separated into three types: traditional robots, robotic arm, and robotic exoskeleton.
- Agricultural robots (AgRobots). The use of robots in agriculture is closely linked to the concept of AI-assisted precision

agricultureand drone usage.[26] 1996-1998 research also proved that robots can perform a herding task.

- Medical robots of various types (such as da Vinci Surgical System and Hospi).
- Kitchen automation. Commercial examples of kitchen automation are Flippy (burgers), Zume Pizza (pizza), Cafe X (coffee), Makr Shakr (coctails), Frobot (frozen yogurts) and Sally (salads). Home examples are Rotimatic (flatbreads baking)[29] and Boris (dishwasher loading).
- Robot combat for sport – hobby or sport event where two or more robots fight in an arena to disable each other. This has developed from a hobby in the 1990s to several TV series worldwide.
- Cleanup of contaminated areas, such as toxic waste or nuclear facilities.
- Domestic robots.
- Nano robots.
- Swarm robotics.

3.1 New Applications for Mobile Robots

Mobility promises to be the next frontier in flexible robotics. While fixed robots will always have a place in manufacturing, augmenting traditional robots with mobile robots promises additional flexibility to end-users in new applications. These applications include medical and surgical uses, personal assistance, security, warehouse and distribution applications, as well as ocean and space exploration.“We see increased interest in mobile robotics across all industries. The ability of one mobile robot to service several locations and perform a greatly expanded range of tasks offers a great appeal for specialized applications,” says Corey Ryan, Medical Account Manager at KUKA Robotics Corp. (Shelby Township, Michigan).

Mobile Apps

Autonomous mobile robot on the job, courtesy Adept Technology Inc.

Mobile robots are proliferating says Rush LaSelle, Vice President and General Manager with Adept Technology Inc. (Pleasanton, California). “In the industrial space, mobile robots are redefining the playing field for autonomous guided vehicles (AGVs) in that modern mobile platforms are capable of operating in areas without requiring alterations or investment into existing infrastructure. Mobile robots overcome a historical impediment of AGVs, their inability to dynamically reroute themselves. Mobile robots are outfitted with advanced sensory and enhanced intelligence systems.”

Reduced costs enable deploying both large and small fleets of vehicles in warehouse distribution and line-side logistics applications, LaSelle adds.Mobile robots can be particularly useful in painting and de-painting applications, says Erik Nieves, Director of Technology in the Motoman Robotics Division of Yaskawa America Inc. (Miamisburg, Ohio). “Mobility is a force multiplier for robots and I see that in de-painting very large structures such as C-130 aircraft. Two fixed robots cannot de-paint an entire aircraft between them because they

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cannot reach everywhere." More than two fixed robots constitutes too much hardware with very little throughput. "Each robot is painting a little piece then sit idle, parked more than moving," says Nieves.

Nieves suggests that rather than adding additional fixed robots around the aircraft, end-users needs a way to have two robots deal with an entire aircraft. "To de-paint an entire aircraft with two robots, those two robots need to move." Putting the robots on servo tracks or a gantry is unfeasible due to aircraft's geometry. "Putting two seven-axis robots on mobile platforms and driving them around the aircraft" is a better solution, Nieves says.

Likewise, Paul Hvass, Senior Research Engineer with the Southwest Research Institute (SwRI, San Antonio, Texas) says mobile robots facilitate cost-effective paint removal from large aircraft. "The motivation behind the development of our Metrology-Referenced Roving Accurate Manipulator (MR ROAM) was to demonstrate high-accuracy, industrial-grade mobile manipulation for very large workspaces, an enabling capability for applications like aircraft paint stripping. SwRI has a 25-year history of developing, deploying, and supporting custom robots for fighter jet paint stripping and other large scale applications."

Mobile robot working on aircraft wing, courtesy Southwest Research Institute.

Hvass goes on to say, "To economically strip paint from larger planes, mobile automation is needed. In the future, we envision mobile robots developed for large-scale tasks including aerospace, off-shore, and road, bridge, and building construction. These robots will initially undertake light-duty tasks such as painting, cleaning, and inspection before moving on to heavier-duty tasks as mobile robotic technology matures," Hvass concludes.

Medical/Surgical Applications

Corey Ryan talks about potential uses of mobile robotics in medical and other life sciences applications. "Medical applications are always a growing field with huge untapped applications like drug delivery, or the development of mobile treatment systems for specialized equipment."

People and mobile robots working collaboratively, courtesy RMT Robotics Ltd.

Autonomous mobile robots (AMR) can play a role in assisting doctors in surgical procedures, says, Bill Torrens, Director of Sales and Marketing with RMT Robotics Ltd. (Grimsby, Ontario, Canada). "AMR technology is applied in surgical applications. Based on inputs, the robot arm assists the surgeon to perform a task. Path-planning algorithms move the robot autonomously."

Sean Thompson, Applications Engineer at MICROMO (Clearwater, Florida) sees an increase use of robotics for automated

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prosthesis fabrication. "Minimizing motor size helps make prostheses more related to the natural human form. That comes down to applying power to build prostheses that more closely emulates the body's natural capabilities."

Danger Seeker

Mobile robots can access areas dangerous to humans, says, Andrew Goldenberg, President of Engineering Services Inc. (ESI, Toronto, Ontario, Canada). "Mobile robots are used to reach inaccessible areas such as nuclear power plants. Mobile robotics are very useful in nuclear environments with high levels of radiation, particularly during a disaster or threat of a disaster."Goldenberg goes on to say, "Some companies are using robotics underwater while others want to develop robotics for military applications, shoreline exploration of mines, and for repairing a ship's structure." ESI is involved with mobile robots for space exploration, such as rovers remotely moving on Mars.

As a caveat, Goldenberg says, "Current robotics are not quite sufficiently designed to withstand high radiation affecting their electronic circuitry. Some attempts to design mobile robotics specifically for use in this environment have been made."

Mobile robot bristling with sensors on tracks, courtesy Engineering Services Inc.

Wireless communication with mobile robots is still a challenge, says Goldenberg. "If mobile robots go underground or in areas of low connectivity like subway tunnels, control of the robot could be lost."Hvass also talks about communication to and from mobile robots. "If the robot communicates with infrastructure over a wireless link, that link is vulnerable due to bandwidth sharing, variable distances between radios, obstructions, and non-deterministic protocols."Mobile robots for use in inaccessible areas is also on the mind of Sean Thompson. "We see more interest in undersea robotics with smaller non-tethered robots used by research facilities. Aerial robotics tends to go either way, smaller platforms and larger platforms, depending on the mission. Camera packages have gotten smaller which allow aerial robots to roam at lower altitudes in shorter distances on smaller aircraft. These remote-controlled aircraft are collecting highly-detailed and accurate video."Thompson speaks of other military applications of mobile robotics. "Troopers could carry heavier loads with robotic pack dogs and exoskeletons. This technology is different from replacing a service dog but will be commonplace in five to 10 years."

LaSelle also sees mobile robotics utilized for patrol and monitoring applications. "Another key expansion of mobile robotics has been in monitoring, security and patrolling. Patrolling applications provide users with the ability to monitor intrusion, thermal and other environmental conditions. A key area of activity has been the monitoring and patrol of vacant properties as well as warehousing spaces." This increased ability is due to the reliability and low costs

attributed to autonomous vehicle patrol capabilities, LaSelle says.
Thermal monitoring is of special interest to Internet server farms and other sensitive electronic or mechatronic systems. Water ingress is also commonly monitored by way of mobile robotics, LaSelle notes.

Mobile robots are finding their way into other non-industrial applications. “The reduced cost of deployment and ownership mobile robots have extended their reach into non-factory applications. The current generation of smart vehicles is leading hospitals, laboratories, and some offices to employ mobile robots to alleviate the use of skilled labor for mundane transport tasks.”

Continuing, LaSelle adds, “Mobility is already the norm in service applications and this sector is primed for tremendous growth. Service robotics is expected to overshadow the industrial robot sector in a matter of a few years. Adept believes mobile robots will be an exciting area in coming years,” reports LaSelle.

Mobility=Lean

The vision of truly lean manufacturing is being realized through mobile robotics says Torrens. “Mobile robotics connect islands of automation. The last frontier of lean manufacturing facilitates the connection between manufacturing work cells. Mobile robots are now used for transporting materials from donation areas and taking these raw materials to a work cell.”

Torrens says mobile robotics provides a much higher level of flexibility for manufacturers. “For example, a manufacturing facility normally delivers a bin of 100 parts for a machine to work on. This is an example of batch processing, not lean manufacturing. Lean manufacturing embraces a piece-work philosophy, or a smaller batch philosophy. If taking one piece at a time to a machine, manufacturers have more flexibility with robotic transport between manufacturing cells. That approach is lean manufacturing as originally intended.”
Torrens believes “mobile robots have finally achieved the goals of what the factory of the future was supposed to look like. The machines were in place but the transport logistic was not.” Mobile robotics provides that logistical support, argues Torrens. “To realize lean manufacturing, robots must be highly intelligent and able to autonomously deliver parts from any random origin to any random destination. Mobile robot technology up to this point has been unable to deliver materials in a just-in-time way.”
LaSelle anticipates mobile robotics serving the ends of lean manufacturing through processing of optimal batch sizes in warehouse and palletizing applications. “Adept sees the combination of mobility and manipulation as a powerful combination as evident in the increasing demand for case-picking applications. Companies want to move smaller batch sizes throughout their facilities.” End-users want to move less than a full pallet from a warehouse to a production line, concludes LaSelle.
“Companies look for solutions to pick cases or parts individually within a warehouse as compared to pulling a full rack. As this trend continues, expect to see more demand for systems encompassing mobility,

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manipulation, and vision. Given the rate of technological advancement and drive for smaller batch sizes in manufacturing, we will see mobile robots become a staple in a large cross section of manufacturing within the next six to seven years," foresees LaSelle.

AutonomousLocomotion

Genuine independent mobility is necessary for robotics to add significant value to manufacturing says Erik Nieves. "Mobility moves robots from being machines to production partners. The robot has to move to the work but if the robot is bolted to the floor and has no work before that robot, the robot is adding zero value to the production process." Bringing a mobile robot to where production is rather than bringing production to a fixed robot is the philosophical underpinning of mobile robotics, Nieves says.

Any mobile platform must address issues relating to power, navigation, and calibration, says Nieves. "Instead of mobile robots tethered to a source of power through an umbilical, the robot will dock to a power source when reaching a point of interest, to recharge while working." On-board power simply keeps the robot mobile during transit. Nieves turns his attention to navigation, or "How the robot gets from A to B autonomously. Using simultaneous localization and mapping, the mobile robot can go from one station to the next largely on its own with without many changes to the facility. To change the mobile robot's path, [a number of guidance] labels are put somewhere else," describes Nieves.Calibration, the final element in Nieves' approach, is a measure of how close the robot gets to it intended destination. "The robot must calibrate itself to the machine in front of it every time it arrives at one. Calibration is done by some means, such as touching off on three points or using a vision sensor to allow the robot to determine its location."

Kiva Systems' (North Reading, Massachusetts) automated warehouse system is an example of mobile robots quickly and efficiently fulfilling customers' orders. The robot-based system impressed on-line retail giant Amazon.com (Seattle, Washington) enough to acquire Kiva in March 2012.

4. A CHALLENGE: SCIENTIFIC MOBILE ROBOTICS

In the established sciences such as physics or chemistry, to name but two examples, it is accepted practice that experimental results are independently verified. To facilitate this, precise (i.e. quantitative) descriptions of results are used. Because research on quantitative descriptions of mobile robot behaviour is still in its infancy, mobile robotics to date is still an empirical discipline that uses existence proofs extensively. Robot systems to perform certain tasks are implemented, but, for want of precise performance measures and behavioural descriptions, are not independently verified. The first step towards a science of mobile robotics, therefore, would be the development of quantitative, rather than qualitative descriptions of mobile robot behaviour. Some attempts have been made to introduce quantitative evaluations to robotics. Sch¨oner et al. [16] use dynamical systems theory to investigate robotenvironment interaction, and Smithers [17] discusses the use of quantitative performance measures as a tool of scientific mobile robotics research. In [13, 9, 2] we present quantitative evaluations of robot localisation systems (based on contingency table analysis). Current work at Manchester concentrates on the general, quantitative analysis of robot-environment interaction, irrespective of the specific task carried out or the control strategy used. This is done using measures from chaos theory, [15] presents the approach and results. In short, besides the technological challenges of mobile robotics — fundamental sensor-motor competences, robot navigation and application-oriented capabilities such as novelty detection — the scientific challenge is to move mobile robotics from a discipline of empirical practice towards a precise science.

CONCLUSION

This has been a review of several mobile technology utilization might be used to control mobile robots. It is important to compare this technology and the bandwidth, frequency, data rate to transfer data among the devices for better development for mobile robot controller. A mobile robot is a vehicle which is capable of an autonomous motion. The autonomous mobile robots are very interesting subject both in scientific research and practical applications. The vehicle has two driving wheels (which are attached to both sides of the vehicle) and the angular velocities of the two wheels are independently controlled.

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