View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by IntechOpen

We are IntechOpen, the world's leading publisher of Open Access books

Built by scientists, for scientists

4,800
Open access books available

122,000
International authors and editors

135M
Downloads

154
Countries delivered to

Our authors are among the

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

9

Development of Deminer-Assisting Robotic Tools at Tokyo Institute of Technology

Marc Freese, Paulo Debenest, Edwardo F. Fukushima and Shigeo Hirose
Tokyo Institute of Technology
Japan

1. Introduction

Robot operation and interaction in unstructured environment is difficult. The problem becomes even more difficult if the environment is hazardous, presents a potentially wide temperature range, and is subject to rain, dust and other natural factors. Such conditions are typical in minefields. Current demining technology is slow, costly and dangerous, and has virtually not evolved in the last 60 years except for heavy and armoured soil-digging machines that are limited to well-conditioned terrain. Assisting human deminers in the mine searching task, or giving them better means of protection during the dangerous task of soil prodding and mine neutralization is challenging. However it is worth pursuing this goal: not only will deminers benefit from the development, but the demining *industry* itself will benefit from it with eventually faster paces, more efficient detection and removal rates, and this at reduced costs.
The Tokyo Institute of Technology started developing robotic tools and machines for humanitarian demining more than a decade ago. The first steps were performed literally, with a quadruped walking robot named TITAN VIII (cf. Figure 1) that was able to adapt its gait to navigate on difficult terrain and use one of its legs as a manipulator to scan the soil for mines, cut vegetation or even dig the ground [Hirose & Kato, 1998; Kato & Hirose, 2001]. A sophisticated system including a tool-changer and tele-operation functionality allowed the robot to perform the most dangerous tasks without proximate assistance of humans. Scenarios in which one of the robot's legs was blown off by accidentally stepping onto a mine were overcome by appropriately readjusting its walking gait for 3 legs. Other research institutions and laboratories have followed into Tokyo Institute of Technology's footsteps by developing legged robots for humanitarian demining; one example is COMET-1 [Nonami et al., 2000], a 6-legged walking robot equipped with several cameras, an attitude control sensor mechanism, and 6 small metal detectors integrated into the extremity of each leg. Another legged example is the pneumatic multisensor demining robot [Rachkov et al., 2005], that can be equipped with a metal detector, an infrared detector and a chemical explosive sensor for mine detection.

Source: Humanitarian Demining: Innovative Solutions and the Challenges of Technology, Book edited by: Maki K. Habib, ISBN 978-3-902613-11-0, pp. 392, February 2008, I-Tech Education and Publishing, Vienna, Austria

Open Access Database www.intehweb.com

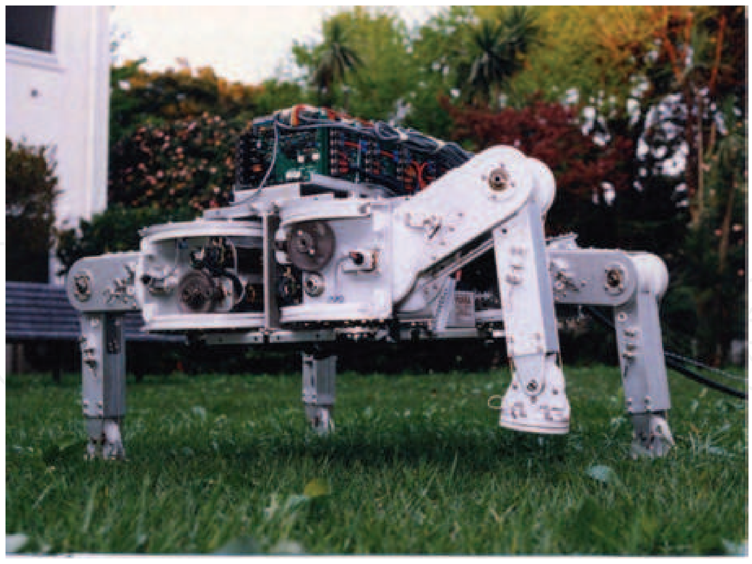


Fig. 1. Titan VIII

However, walking robots, usually equipped with a large number of actuators, still have several serious challenges to overcome: they are difficult to control, expensive and prone to technical malfunction. On the other hand, machines that roll on tracks or wheels can be quite inexpensive, much faster and more stable than legged devices [Shiller & Mann, 2004]. Some early demining-related examples include PEMEX-B [Nicoud & Maechler, 1995], a simple, lightweight two-wheeled vehicle, carrying a sensor to detect mines, and light enough not to trigger surface or buried mines. There are also other robotic systems based on alternative locomotion means. One such system for mine clearance has been proposed by Trevelyan [Trevelyan, 1996] and consists of a tool carrier suspended by cables and controlled by winches on poles at the corner of the minefield. This approach allows covering a wide span of terrain but is limited to relatively flat and vegetation-poor surfaces. In [Fukuda et al., 2006] an adaptive mine scanning framework, attached as payload of a long reach crane, was developed. The system is able to reach locations otherwise hardly accessible for other devices and can operate adaptively on very steep slopes.
The Tokyo Institute of Technology took, since the development of TITAN-VIII, a more pragmatic and practical approach. A more careful analysis of the common important characteristics to consider during the design of a robotic demining vehicle, as weight, level of autonomy and self-recovery to name only a few [Havlik, 2005], has lead to the development of two practical robotic tools that can assist and protect the human deminer in the mine-searching or mine-removal/mine-neutralization tasks: *Gryphon* and *Mine Hand*. While *Gyphon* is a semi-automatic robot capable of autonomously scanning the terrain that surrounds it, generating high-quality sensor images, and also allowing the marking of suspected mine locations, *Mine Hand* is meant to be used afterwards, to inspect positions previously marked by *Gryphon*, prodding the soil and neutralizing potential mines.

2. Gryphon

The development of *Gryphon* started in early 2001. Wanting to switch to a more reliable, less expensive and faster system for mine detection, an experimentation platform was developed [Fukushima et al., 2001].

2.1 Early Developments

Based on a commercially available 4-wheel buggy, the platform features a combustion engine that can be employed for locomotion and also for on-board electric energy generation, and mechanical adaptations that allow the remote control of its steering, throttle, gearshift and brakes. The *hyper-tether* concept was developed at the same time, allowing the transmission of the generated electrical energy to other robots and tools. As such, the following demining scenario became conceivable: a mine-sensing tool, suspended on the *hyper-tether* between the buggy and some auxiliary vehicle, scanning the terrain without touching it (cf. Figure 2), and receiving electric energy through the tether. This allows for good autonomy, large workspace and limited exposure to accidental mine explosion. However, this scenario suffers from similar handicaps as Trevelyan's tool carrier.

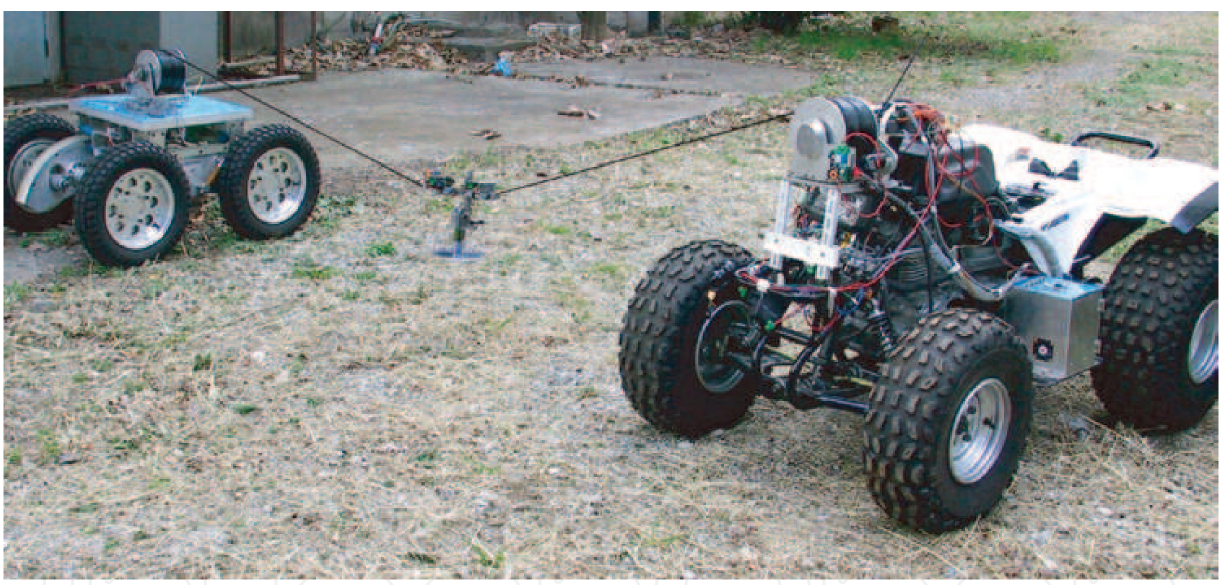


Fig. 2. Mine detection concept with *hyper-tether* and two mobile platforms

The next version of *Gryphon* was more elaborate [Debenest et al., 2005], and featured a 3 degree-of-freedom manipulator, named *Field Arm* (cf. Figure 3). For field applications in remote areas, it is important to consume little electric energy since it may be limited. *Field Arm*, a pantographic manipulator, especially devised for such applications, is theoretically in perfect balance for any given base posture or arm configuration: the arm payload is balanced by a counter-weight (housing batteries) in the rear, thus requiring power only in dynamic situations. In reality, however, the mass of the various links and joints cannot be ignored, and the arm is never perfectly balanced. In spite of that, experiments showed that the nearly-perfect balance implies a considerable reduction of power consumed in static and quasi-static cases. The use of a counter-balanced manipulator will also help reduce the

www.intechopen.com

dependence of the buggy's posture on the *Field Arm*'s configuration. Even though the buggy's suspension is fairly compliant, its inclination is drastically reduced when *Field Arm* reaches far out. Additionally, a two degree-of-freedom wrist mechanism was attached to the tip of *Field Arm*, allowing the positioning and orientation of any type of sensor over the ground.

Fig. 3. *Field Arm* mounted on top of the mobile platform

2.2 Later Developments

Today, *Gryphon* became a robust, well-thought and practical robot that has undergone several field tests in Japan, Croatia and Cambodia. Compared to the previous version, it has increased in size, and was added many features making the mine-searching task easier and faster. As shown if Figure 4, the current *Gryphon* is based on a bigger buggy, a so-called All Terrain Vehicle to which a larger version of *Field Arm* was added. The robot is equipped with a stereo vision camera to acquire topographical information of its surrounding environment. The 3D model of the terrain is then used to autonomously move a mine-detecting device (hereafter called mine detector) at close distance from the ground – that is not necessarily flat – while describing a precise scanning motion over an effective surface of approximately 3 square meters. The recorded mine detector data is then presented to the operator who, after careful inspection and evaluation, can indicate suspect spots that will be marked directly onto the minefield with an onboard paint- or plate-marking system.

For maximum safety, Gryphon always operates along the minefield borderline and from the cleared side. Only the mine detector and a part of the manipulator are operating over the dangerous area – hovering at close distance to the ground without ever touching it – during the scanning motion. Additionally, most operation steps are fully automated and Gryphon can be operated and monitored from a safe distance by means of a portable control box. Figure 5 shows *Gryphon*'s control system. From the beginning on, more than just a research project, *Gryphon* was meant to be a practical robot, with the idea to undergo practical tests in near to real-world conditions. Thus, emphasis was put on system integration, robustness (water-proofing, extended temperature range, etc.), cost and easy operation/maintenance.

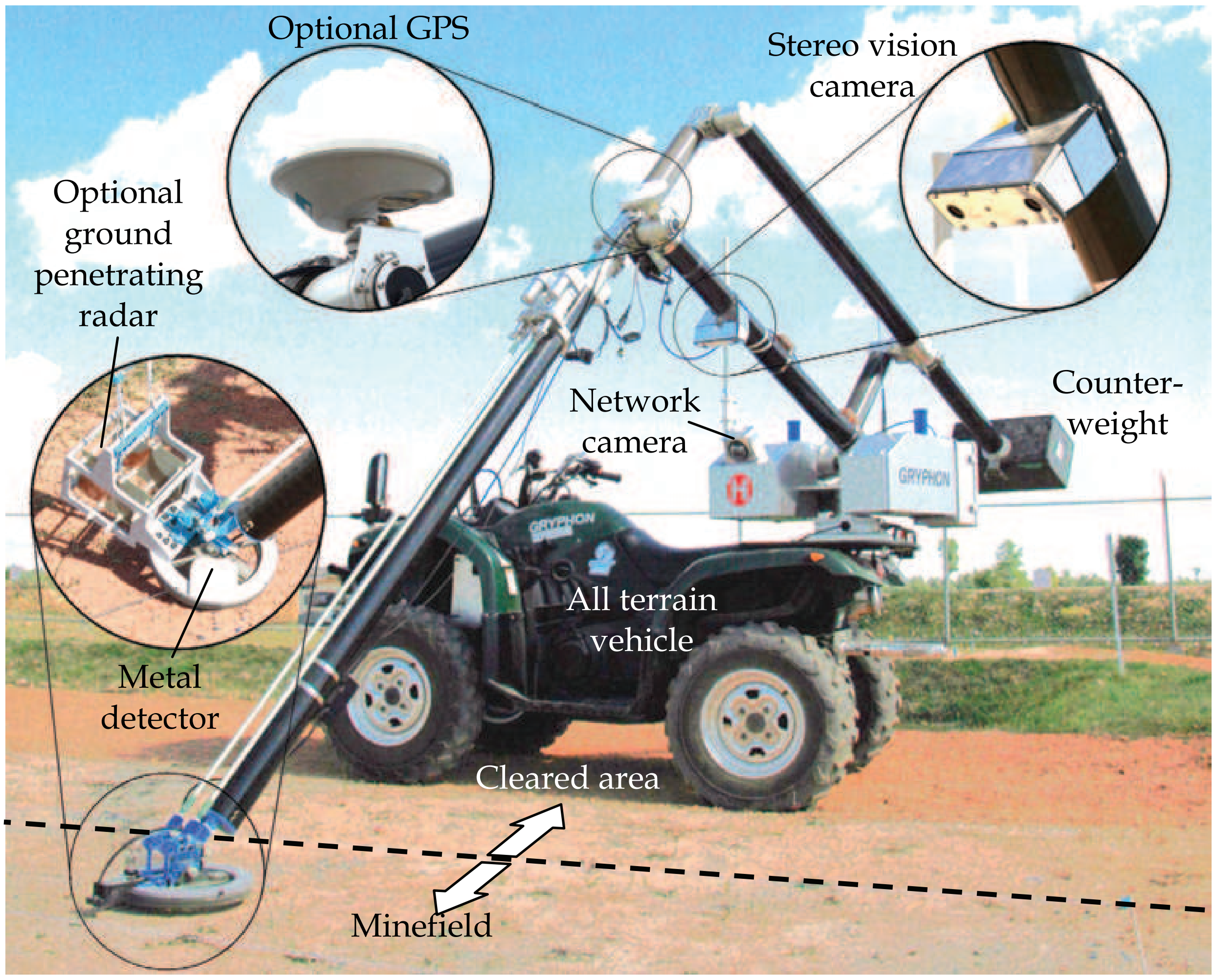


Fig. 4. Overview of *Gryphon*'s main elements

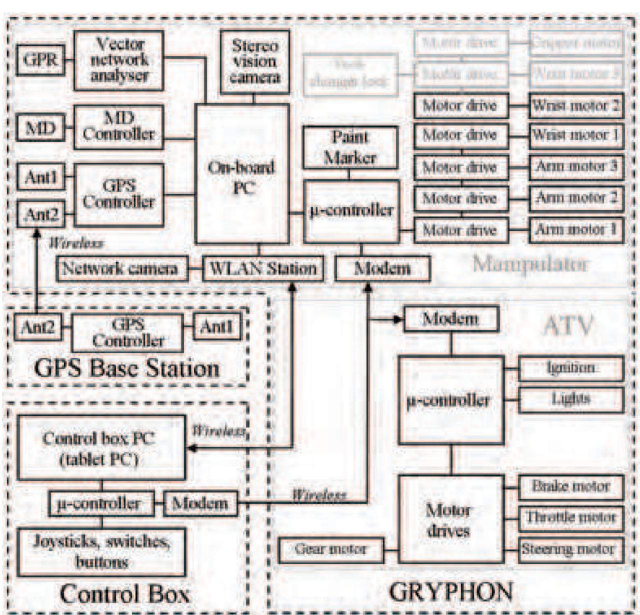


Fig. 5. Overview of *Gryphon*'s control system

THE WRIST MECHANISMS

Two new wrist mechanisms have been developed (cf. Figure 6, (a) and (b)). The first one, entirely made of metal-free materials with remotely positioned actuators, has two degrees of freedom and is ideally suited to orient an inductive metal detector over the terrain. Indeed, a metal detector's performance can be drastically reduced if used in proximity of interfering metallic objects. The second wrist mechanism that can be attached to *Field Arm*, possesses one additional degree of freedom. It was originally developed as the ankle mechanism of a walking robot [Ogata & Hirose, 2004], but serves nicely its purpose here too: carrying and orienting heavier payloads. Additionally it has a tool-changer mechanism integrated, allowing *Gryphon* to seamlessly switch tools when needed. Figure 6 (c) shows a gripper compatible with the tool-changer.

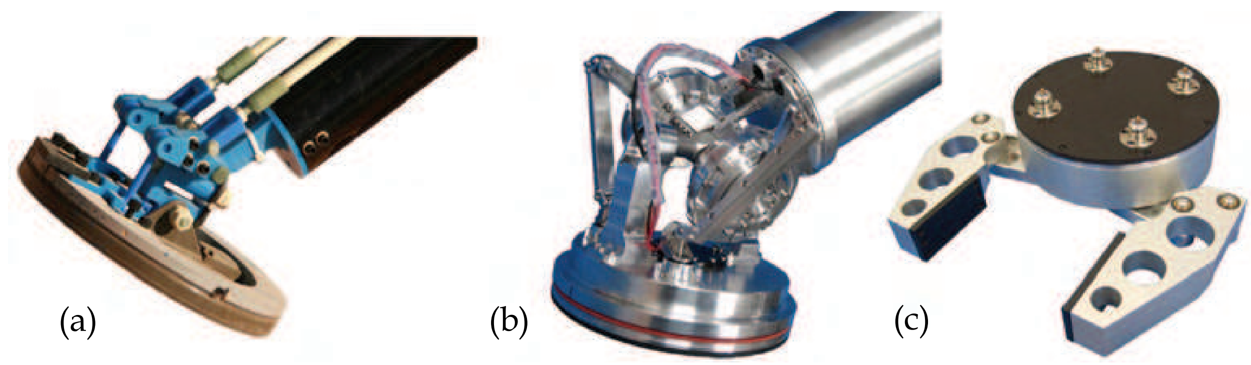


Fig. 6. Metal-free wrist mechanism with metal detector (a), heavy payload wrist mechanism with tool-changer (b), gripper compatible with tool-changer (c)

THE STEREO VISION CAMERA

Gryphon is operating in a model-centric manner in order to avoid traditional traps a reactive control system is facing, namely local minima. This enables *Gryphon* to plan the whole scanning procedure in advance and recognize potential problems before even starting to scan. This approach also takes advantage of the static nature of the terrain in typical minefields. In order to compute the trajectory of the detector over the terrain, a model of the terrain to scan is constructed by using a stereo vision camera (BumbleBee model no. BB-HICOL-60, Point Grey Research, Vancouver, Canada); the camera is attached to the manipulator's first link, at a position allowing for easy topographic data acquisition around the vehicle's position without suffering interferences from the manipulator or vehicle themselves.

THE DETECTOR

Considering that a vast majority of mines contain a substantial amount of metal, the obvious choice and most commonly used mine sensing technology is still the inductive metal detector [Guelle et al., 2004]. However, such a sensor will not only detect buried landmines; it will equally well detect any other fragment of metal. This leads to a high false positive rate that slows down the demining pace and drastically increases the costs. Such shortcomings of the metal detector have given rise to a multitude of other technology. One of them is the ground penetrating radar, typically detecting bigger heterogeneities in the ground. While it also suffers from a high false positive rate, using it in conjunction with a metal detector can help reducing that number to a minimum. The detector – representing the sensor payload – in its standard configuration, as of July 2007, is composed of a metal detector (CEIA MIL-D1, Arezzo, Italy) that can optionally be completed with a ground penetrating radar [Takahashi et al., 2006]. Each individual sensor composing the detector has its data recorded together with its tracked position in order to generate precise sensor images, and one can imagine attaching a multitude of sensors to the detector – each with a specific sensing property – and so increase *Gryphon*'s overall detection performance. Figure 7 shows the sensor payload composed by the metal detector antenna and the ground penetrating radar antenna.

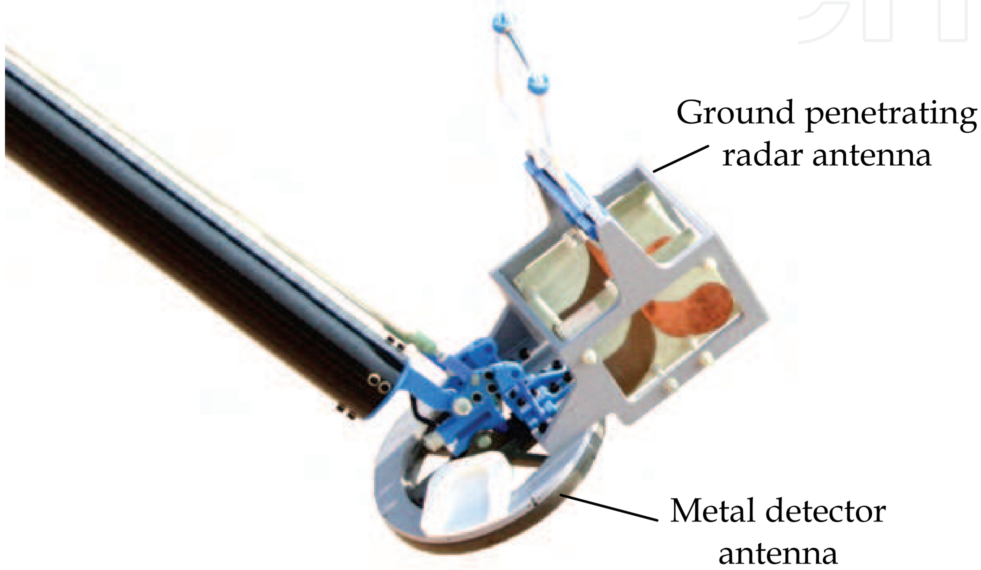


Fig. 7. Gryphon's payload composed by a metal detector and a ground penetrating radar

<u>THE MARKING SYSTEMS</u>

The standard version of *Gryphon* (as of July 2007) is an exclusively sensing robot, and as such, still requires manual prodding of suspected mine locations. This step is preferably done in a decoupled and independent manner from *Gryphon*, so that each operation on the terrain (e.g. sensing and prodding) can be performed at its own pace and time. To this end, two different marking systems have been developed and can optionally equip *Gryphon*. The first marking system is based on water-soluble color paint, and allows marking suspected landmine locations in a semi-permanent way. A paint reservoir with pump is located near the manipulator base and paint is conducted through a tube to a nozzle attached on the detector (cf. Figure 8 (a)). The paint marker is the most flexible of both marking system, providing more than just location information: suspected spots can be numbered or classified according to preliminary data evaluation, and additional information written directly onto the terrain. This can help in the following inspection and prodding step, with faster target identification. The second marking system is based on a marking plate dispenser that drops marking plates one-by-one on a holder fixed on the detector upon a push from the latter against a lever (cf. Figure 9 (b)). The detector then places itself appropriately closely above the spot to be marked and inclines itself so as to let the marking plate slide onto the terrain.

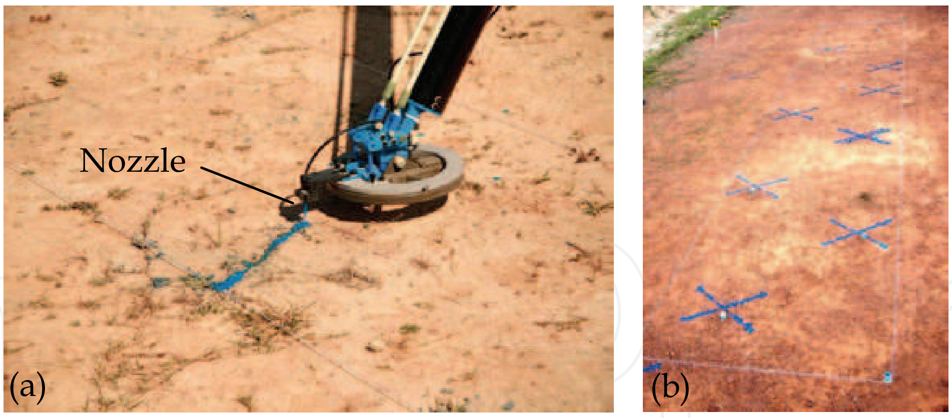


Fig. 8. Paint marker (a), marked suspected mine locations (b)

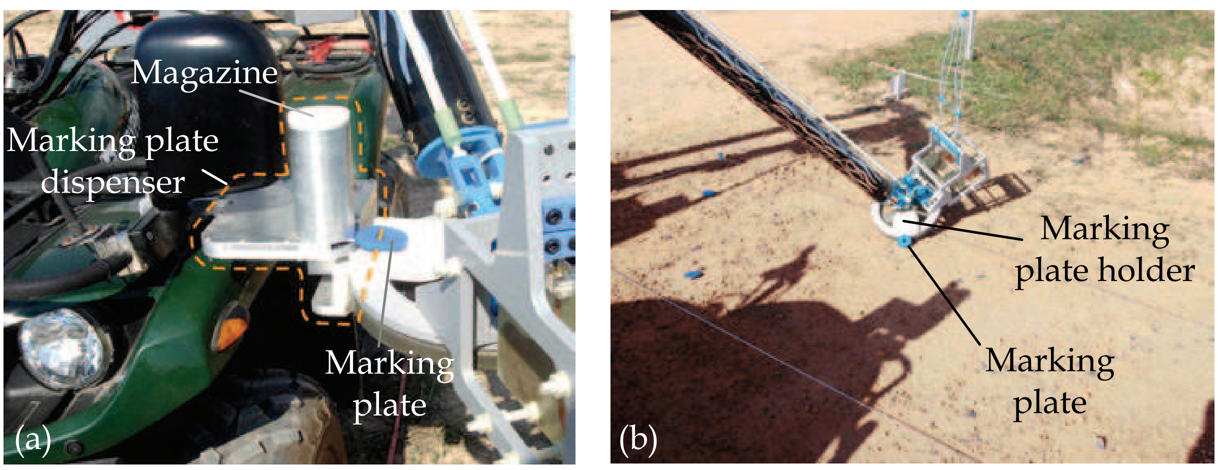


Fig. 9. Marking plate dispenser (a), marking plate dropping (b)

THE OPTIONAL GPS

In order to localize itself relative to the minefield, but also to mark suspect spots virtually as coordinates to allow a later resumption of work, Gryphon can be equipped with an optional satellite navigation system based on the currently most accurate form of Global Positioning System: Real Time Kinematics (RTK GPS), enabling centimeter-level accuracy for the mobile GPS antenna, relative to a base station. Gryphon optionally uses two RTK GPS units (MS750™, Trimble Navigation Limited, CA), one being configured as the base station (immobile), and the other one as the rover unit (mobile). Precision is typically 1cm horizontally and 3cm vertically. The GPS antenna is attached at the top of the first link of the manipulator. This placement gives good clearance to the sky and allows calculating not only the position of the vehicle but also its orientation by measuring a succession of positions at different manipulator configurations.

THE CONTROL BOX

The control box (cf. Figure 10), which is the remote user interface unit of *Gryphon*, is built – as is *Gryphon* – in a rugged and weather-proof manner. Its upper part contains an embedded tablet-pc that runs the higher-level control software of the manipulator. From there the operator can acquire topographical terrain information with the stereo vision camera, launch automatic movement sequences, monitor the system state, display acquired detector images and mark suspected mine locations. Communication with *Gryphon* is achieved by wireless LAN. The lower part of the control box contains – next to batteries for over 8 hours of non-stop operation – two joysticks and several switches. A modem communication transmits signals to *Gryphon* and allows controlling the manipulator and the all terrain vehicle manually.

Fig. 10. The control box

<u>THE MODUS OPERANDI</u>

The standard operation procedure of *Gryphon* can be described in 5 steps, which are repeated for each scanning position:

1) The all terrain vehicle is driven into position (manually or through the control box). Since *Gryphon* operates along the minefield borderline, the vehicle is positioned so as to be able to scan on its left or right side.
2) In case *Gryphon* is equipped with the optional RTK GPS, position and orientation of the vehicle relative to the minefield is calculated.
3) The surrounding terrain is geometrically modeled by acquiring several depth maps with the stereo vision camera (cf. Figure 11). In case *Gryphon* is not equipped with the optional RTK GPS, position and orientation of the vehicle is evaluated using artificial landmarks placed on the minefield borderline.
4) Autonomous scanning is executed; the detector data is processed and visualized in the control box.
5) After the evaluation of the acquired data, the suspected mine locations are marked using one of the onboard marking systems and/or registered with the optional RTK GPS.

Fig. 11. Environment modelled with the stereo vision camera

Gryphon uses a special overall calibration procedure combined with an advanced terrain-following method to guarantee ideal and precise sensor placement over the terrain [Freese et al., 2006]. Additionally, a robust feed-forward vibration control technique [Freese et al, 2007] allows competitive accelerations rates despite the system's rather compliant elements (*Field Arm* links and vehicle's suspension). This enables a maximum scanning speed of 0.8m/s. However, when recording metal detector data, the speed is limited to 0.5m/s to guarantee a good data density. When the detector is composed of the optional ground penetrating radar, the speed is limited to 0.08m/s. This results in scanning times for a 1 square meter surface of 1 and 6 minutes, respectively. These timings do not include moving the vehicle to the next position, mapping the terrain, evaluating the data and marking suspected spots. Terrain mapping and marking typically take less than 25s/m^2 and 20s/spot, respectively.

FIELD TESTS

Gryphon has been field-tested with a combined 95 days of testing on flat ground, bumpy terrain, and slopes. This includes operation on various test minefields, including evaluations conducted under the supervision of the Japan Science and Technology Agency in Japan in early 2005 [Ishikawa et al., 2005] and early 2006 in Croatia [Ishikawa et al., 2006]. Recently, two Gryphon robots also took part in extensive trials in Cambodia, organized by the Cambodian Mine Action Center. Operated by Cambodian deminers, the Gryphon machines performed tests for more than 150 hours of semi-autonomous operation (cf. Figure 12).

Fig. 12. *Gryphon* autonomously scanning a test minefield in Cambodia under the supervision of Cambodian deminers

Gryphon operates by scanning a 1 meter wide lane, 2 square meters at each vehicle position. Metal detector and ground penetrating radar sensing is performed simultaneously and the recorded data is presented as a series of images, which can be evaluated separately by the operator. Figures 13 and 14 represent a typical metal detector image and corresponding ground penetrating radar images respectively. While the metal detector data is relatively easy to evaluate (metal targets can easily be located between corresponding red and blue lobes), the ground penetrating radar data comes in several different layers, each associated with a depth layer in the ground, and requires a trained eye to spot possible landmines.

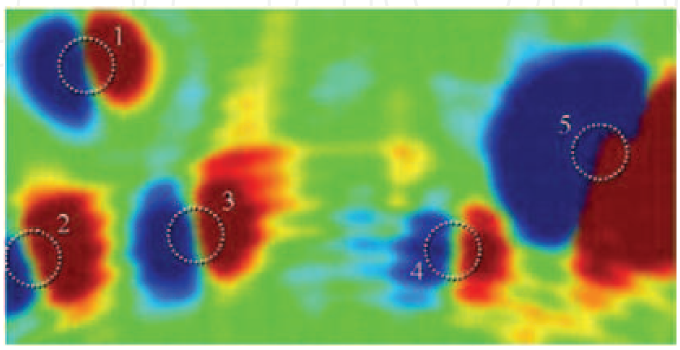


Fig. 13. Metal detector image of a 2 m^2 scan

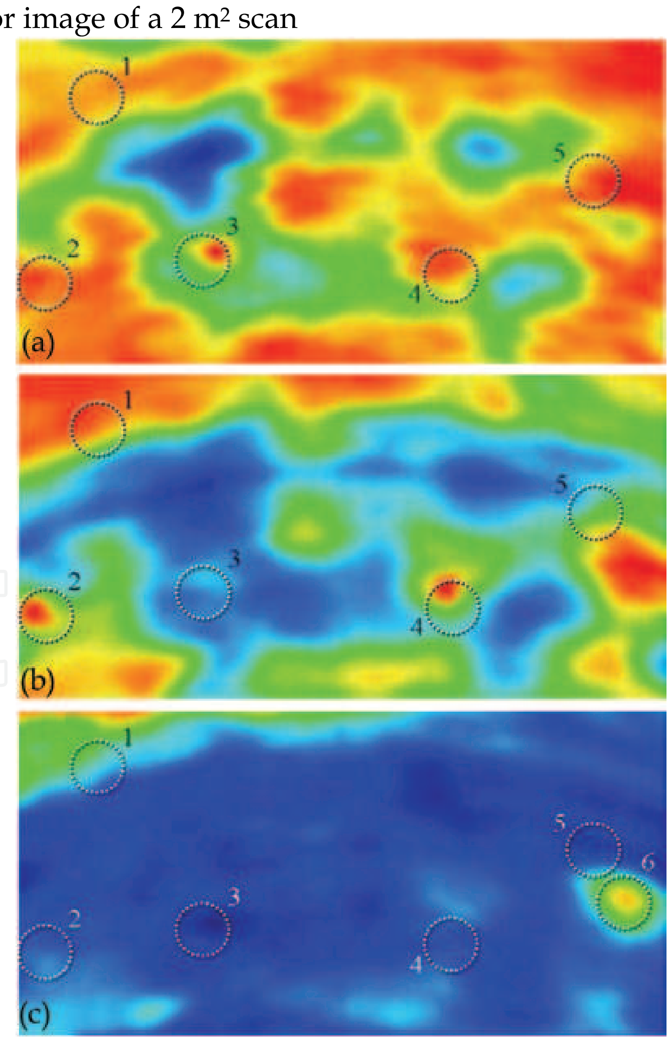


Fig. 14. Ground penetrating radar images of a 2 m^2 scan, layer 49 (a), 52 (b) and 55 (c)

Five metallic targets of 3 different types (cf. Figure 15 and Table 1) have been buried at a depth of 5 or 12.5 cm.

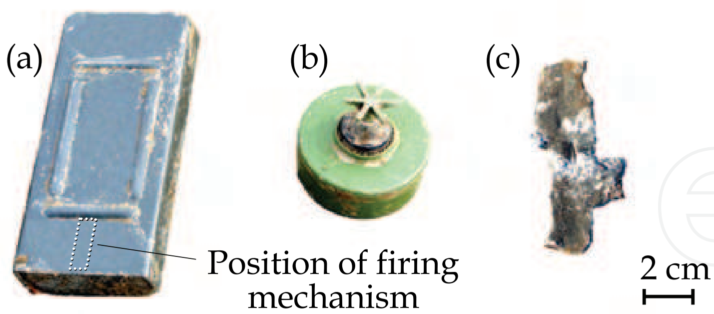


Fig. 15. PMA-1A and PMA-2 landmines, and metal fragment (shown to scale). The metallic part of the PMA-1A mine (the detonator) is not centered within the mine body

Looking at Figure 13, five metallic targets can clearly be recognized in the metal detector image and their locations have been reported on top of the corresponding ground penetrating radar images. Since ground penetrating radar data comes in several different layers, only relevant layers have been displayed; while layer 49 clearly shows correspondence with target #3 identified with the metal detector image, layer 52 allows matching two additional targets: target #2 and target #4. Small positional mismatches can be noticed between the targets identified by the metal detector and ground penetrating radar. Those differences can be explained by looking at table 1: targets #2, #3 and #4 correspond to a landmine type known as PMA-1A, in which the metallic part (the firing mechanism) is not centered within the mine body (cf. Figure 15(a)). While the ground penetrating radar did not detect target #1 (landmine type PMA-2, cf. Figure 15(b)), it detected an additional target (cf. Figure 14(c)) that corresponded, after verification, to some bigger stone buried in the ground. As expected, target #5 (cf. Figure 15(c)), a metal fragment, was not detected by the ground penetrating radar.

Target#	Target type	Depth [cm]	Detected by metal detector	Detected by ground penetrating radar
1	PMA-2	5	Yes	No
2	PMA-1A	12.5	Yes	Yes
3	PMA-1A	12.5	Yes	Yes
4	PMA-1A	12.5	Yes	Yes
5	Fragment	5	Yes	No
6	Stone	~10	No	Yes

Table 1. Target visibility in metal detector and ground penetrating radar images

Out of the 5 metallic targets, 3 could clearly be identified as landmines (detected by both sensors), while the remaining two targets needed further investigation.

3. Mine Hand

In parallel with the development of *Gryphon*, the Tokyo Institute of Technology searched for ways to improve the demining personnel's safety during the most dangerous phase of the demining operation: the manual inspection of a suspected mine location. This phase is particularly dangerous because it requires the deminer to be within a small distance to the potential landmine, typically less than 50 centimetres. This is mainly due to the meagre nature of current prodding tools, often just consisting of a simple metallic stick. This phase of the demining procedure has received little attention from the research community. Trevelyan proposed several simple and inexpensive tools, improving the deminers' safety compared to the traditional tools [Trevelyan, 1997]. However, deminers are still required to work in dangerous proximity to the landmine.

Mine Hand is a tool that was developed with the central idea of having the deminer operate from a remote and protected location for safety reasons (cf. Figure 16): *Mine Hand* is a mechanical master-slave hand allowing prodding the soil and removing landmines and UXOs.

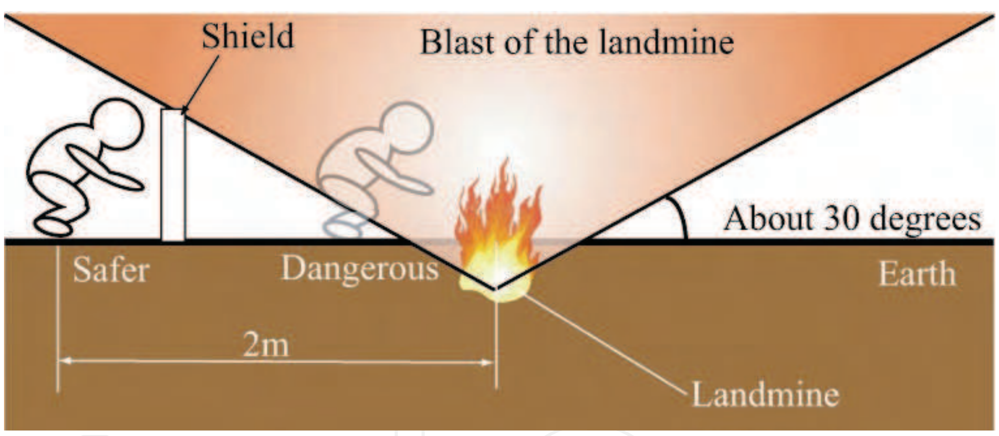


Fig. 16. *Mine Hand*'s concept: keeping the deminer at a safe distance from the landmine

3.1 Early Developments

The first version of *Mine Hand* was a sophisticated mechanical master-slave device [Furihata & Hirose, 2005]. It consists of an arm part and a weight compensation mechanism. The arm part mechanism is illustrated in Figure 17(a). It has two degrees of freedom in the wrist (pitch and yaw), plus one additional degree of freedom in the form of a grasp motion.

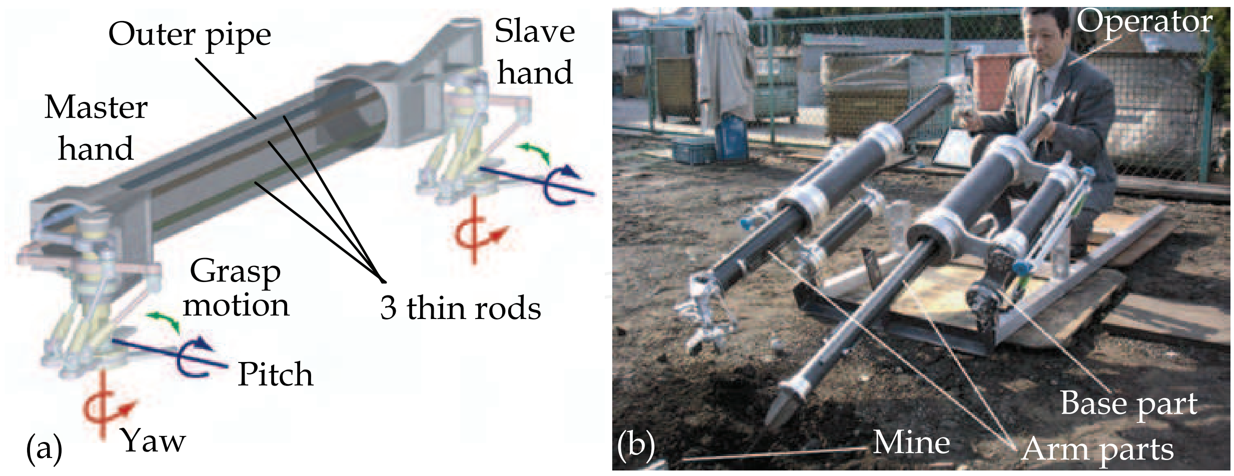


Fig. 17. Early version of *Mine Hand* : arm part (a), overview of the system (b)

Three thin rods, running inside the main pipe, transmit the wrist and grasp motions and allow for good haptic transmission. The weight compensation mechanism, integrated into the base part of *Mine Hand* (cf. Figure 17(b)), supports the arm part while giving it additional 4 degrees of freedom: two translational degrees perpendicular to the arm axis, one translational degree parallel to the arm axis and one rotational degree about the arm axis. A sophisticated weight compensation mechanism based on springs guarantees minimum manipulation effort for the operator. Motion transmission is symmetric, so *Mine Hand* is quite intuitive to use and does not require long training.

3.2 Later Developments

Once the first version of *Mine Hand* was completed, demonstrations and qualitative tests were conducted together with the directors of the *Mine Action Center for Afghanistan*. The following observations were made:

- The three degrees of freedom of the arm part are too complicated to use in severe situations. Much simpler and stronger tools are needed.
- The base part is too heavy. A lightweight and portable tool is preferred.
- The master-slave mechanism does not allow for enough force to be exerted onto the soil, which can sometimes be very hard.

By incorporating the above-mentioned design observations, *Mine Hand* was drastically simplified. As can be seen in Figure 18, its improved version consists of an arm part that goes through a spherical joint incorporated into a transparent shield made of polycarbonate, which has good fracture resistance. The motion of the arm part has four degrees of freedom (one in translation and three in rotation). A fifth degree of freedom is incorporated into the arm in form of a grasp motion. Brushes can be attached to the slave hand, and an exhaust nozzle can be used to blow sand or soil particles away. The basic motions are shown in Figure 18(a) and (b). Although the master and slave side move in opposite directions, a brief training allows overcoming this limitation.

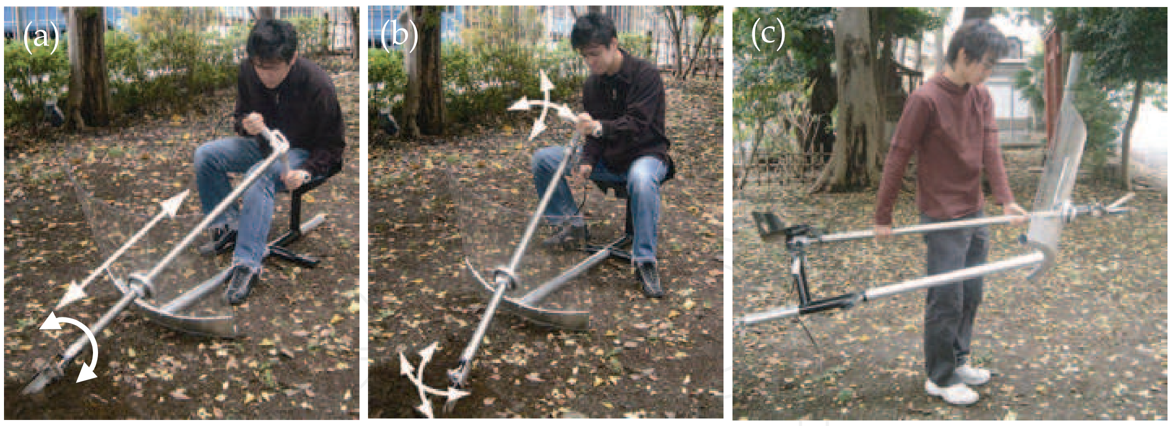


Fig. 18. Simplified *Mine Hand* : translation and roll motion (a), yaw and pitch motion (b), carrying mode (c)

Exploding experiments were conducted with several *Mine Hand*-tools to assess the device's reliability and the operator's safety. Two landmine imitations were used: MS-3 (310g of TNT) and M16A2 (601g of TNT). Although all devices were damaged, they withstood the explosion of the MS-3 landmine imitation: little damage was reported in the shield, and the operator (modelled by a 50 kg sandbag) seems to have experienced no direct effect of the blast. The M16A2 landmine imitation, on the other hand, has severely damaged the shield and the operator experienced an impact force from the *Mine Hand* arm of 2300N.

4. Conclusion

Gryphon and *Mine Hand* are complementary tools; while the former was developed to efficiently search for buried landmines, the latter one is meant to be used once a suspect spot was found to assist and protect deminers in the landmine neutralization task.
Gryphon and *Mine Hand*, more than just research prototypes, were conceived from the beginning on to be practical and well integrated systems. Minefields are no laboratories; working conditions are extremely varied and far from ideal, requiring robust systems, and based on the invaluable experience acquired during field tests, trials and discussions with deminers themselves, *Gryphon* and *Mine Hand* were continuously improved to come closer to practical and useful tools for humanitarian demining.

5. References

Hirose, S.; Kato, K. (1998). Development of Quadruped Walking Robot With the Mission of Mine Detection and Removal, *Proceedings of IEEE International Conference on Robotics and Automation*, pp. 1713-1718, Belgium, Mai 1998, IEEE, Leuven

Kato, K.; Hirose, S. (2001). Development of the Quadruped Walking Robot Titan-IX – Mechanical Design Concept and Application for the Humanitarian Demining Robot, *Advanced Robotics*, Vol. 15, No. 2, 191-204, ISSN:0169-1864

Nonami, K.; Huang, N. S. Q. J.; Komizo, D.; Uchida, H. (2000). Development of Teleoperated Six-Legged Walking Robot for Mine Detection and Mapping of Mine Field, *Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems*, pp. 775-779, Japan, October-November 2000, IEEE, Takamatsu

Rachkov, M. Y.; Marques, L.; De Almeida, A. T. (2005). Multisensor Demining Robot, *Journal of Autonomous Robots*, Vol. 18, No. 3, 275-291, ISSN:0929-5593

Shiller, Z.; Mann, M. P. (2004). Dynamic Stability of Off-Road Vehicles, *Proceedings of IEEE/RSJ International Conference on Intelligent Robots and Systems*, pp. 1849-1853, Japan, September-October 2004, IEEE, Sendai

Nicoud, J. D.; Maechler, P. (1995). Pemex-B : A Low Cost Robot for Searching Anti-Personnel Mines, *Proceedings of WAPM*, pp. 26-29, Switzerland, June-July 1995, Lausanne

Trevelyan, J. P. (1996). A Suspended Device for Humanitarian Demining, *EUREL The Detection of Abandoned Land Mines*, pp. 42-45, UK, month 1996, Edinburgh

Trevelyan, J. P. (1997). Better tools for Deminers, *Proceedings of the International Workshop on Sustainable Humanitarian Demining*, Croatia, September-October 1997, Zagreb

Fukuda, T.; Hasegawa, Y.; Kosuge, K.; Komoriya, K.; Kitagawa, F.; Ikegami, T. (2006). Environment-Adaptive Antipersonnel Mine Detection System – Advanced Mine Sweeper, *Proceedings of the International Conference on Intelligent Robots and Systems*, pp. 3618-3623, China, October 2006, IEEE, Beijing

Havlik, S. (2005). A Modular Concept of the Robotic Vehicle for Demining Operations, *Journal of Autonomous Robots*, Vol. 18, No. 3, 253-262, ISSN:0929-5593

Fukushima, E. F.; Debenest, P.; Hirose, S. (2001). Autonomous Control of an Engine-Driven Mobile Platform for Field Robotic Systems, *Proceedings of the International Conference on Intelligent Robots and Systems*, pp. 84-89, Hawaii, October-November 2001, IEEE, Maui

Debenest, P.; Fukushima, E. F.; Tojo, Y.; Hirose, S. (2005). A New Approach to Humanitarian Demining, Part 2: Development and Analysis of Pantographic Manipulator, *Journal of Autonomous Robots*, Vol. 18, No. 3, 323-336, ISSN:0929-5593

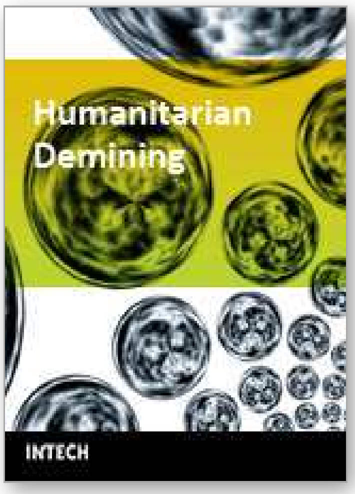
Freese, M.; Singh, S. P. N.; Fukushima, E. F.; Hirose, S. (2006). Bias-Tolerant Terrain Following Method for a Field Deployed Manipulator, *Proceedings of IEEE International Conference on Robotics and Automation*, pp. 175-180, FL, Mai 2006, IEEE, Orlando

Freese, M.; Fukushima, E. F.; Hirose, S.; Singhose, W. (2007). Endpoint Vibration Control of a Mobile Mine-Detecting Robotic Manipulator, *Proceedings of the American Control Conference*, pp. 7-12, NY, July 2007, IEEE, New York City

Furihata, N.; Hirose, S. (2005). Development of Mine Hands: Extended Prodder for Protected Demining Operation, *Journal of Autonomous Robots*, Vol . 18, No. 3, 337-350, ISSN:0929-5593

Ishikawa, J.; Kiyota, M.; Furuta, K. (2005). Evaluation of Test Results of GPR-based Anti-personnel Landmine Detection Systems Mounted on Robotic Vehicles, *Proceedings of the IARP International Workshop on Robotics and Mechanical Assistance in Humanitarian Demining*, pp. 39-44, Japan, June 2005, Tokyo

Ishikawa, J.; Kiyota, M.; Pavkovic, N.; Furuta, K. (2006). Test and Evaluation of Japanese GPR-EMI Dual Sensor Systems at Benkovac Test Site in Croatia, technical report JST-TECH-MINE06-002, Japan Science and Technology Agency



Humanitarian Demining
Edited by Maki K. Habib

ISBN 978-3-902613-11-0
Hard cover, 392 pages
Publisher I-Tech Education and Publishing
Published online 01, February, 2008
Published in print edition February, 2008

United Nation Department of Human Affairs (UNDHA) assesses that there are more than 100 million mines that are scattered across the world and pose significant hazards in more than 68 countries. The international Committee of the Red Cross (ICRC) estimates that the casualty rate from landmines currently exceeds 26,000 persons every year. It is estimated that more than 800 persons are killed and 1,200 maimed each month by landmines around the world. Humanitarian demining demands that all the landmines (especially AP mines) and ERW affecting the places where ordinary people live must be cleared, and their safety in areas that have been cleared must be guaranteed. Innovative solutions and technologies are required and hence this book is coming out to address and deal with the problems, difficulties, priorities, development of sensing and demining technologies and the technological and research challenges. This book reports on the state of the art research and development findings and results. The content of the book has been structured into three technical research sections with total of 16 chapters written by well recognized researchers in the field worldwide. The main topics of these three technical research sections are: Humanitarian Demining: the Technology and the Research Challenges (Chapters 1 and 2), Sensors and Detection Techniques for Humanitarian Demining (Chapters 3 to 8), and Robotics and Flexible Mechanisms for Humanitarian Demining respectively (Chapters 9 to 16).

How to reference
In order to correctly reference this scholarly work, feel free to copy and paste the following:

Marc Freese, Paulo Debenest, Edwardo F. Fukushima and Shigeo Hirose (2008). Development of Deminer-Assisting Robotic Tools at Tokyo Institute of Technology, Humanitarian Demining, Maki K. Habib (Ed.), ISBN: 978-3-902613-11-0, InTech, Available from:
http://www.intechopen.com/books/humanitarian_demining/development_of_deminer-assisting_robotic_tools_at_tokyo_institute_of_technology

INTECH
open science | open minds

InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820

www.intechopen.com

Fax: +385 (51) 686 166
www.intechopen.com

Fax: +86-21-62489821

IntechOpen

IntechOpen

© 2008 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike-3.0 License, which permits use, distribution and reproduction for non-commercial purposes, provided the original is properly cited and derivative works building on this content are distributed under the same license.