

Neutralising and assisting robot SMR-100 Expert – design problematics

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Abstract. Neutralisation of the terrorist explosive devices is a risky task. Such tasks may be carried out by robots in order to protect human life. The article describes chosen design problems concerning the new neutralisation and assisting robot SMR-100 Expert. The robot was to be designed for the use in confined spaces, particularly inside the air-crafts, buses and rail cars. In order to achieve this ambitious plan, new advanced technological designing tools had to be applied. A number of interesting design issues were approached. The successful development of the prototype robot Expert in Poland resulted in the creation of the first intervention robot in the world able to perform all necessary anti-terrorist tasks inside the passenger planes.

Key words: mobile robots, service robots, teleoperation, CAD.

1. Introduction

Neutralisation of the terrorist explosive devices is a risky task. Such tasks may be carried out by robots in order to protect human life. A robot may be used to identify and neutralise a dangerous explosive. Such robots can help considerably to reduce or even eliminate time of the bomb technician presence in the danger zone. Procedures applied during neutralisation of terrorist explosive devices (IEDs – improvised explosive devices) include the following: check and identification, X-ray film, destruction of the explosive charge using various methods, collection and disposal of the explosives (e.g. at the military training ground). In order to carry out such tasks various sensors and tools have to be delivered to the danger area and a possibility to manipulate different objects must be ensured. It is worth mentioning that mere approaching a bomb may be dangerous because of the possibility of traps. Irrespective of the precaution, experience and expertise, the risk undertaken by a bomb technician is enhanced because the universal availability of different remote control (such as mobile phones) increases the chance of a sudden explosion of the bomb triggered by a terrorist from a safe distance (even from abroad by means of a mobile phone). The whole risk may be taken over by an intervention robot. When using such robot bomb technician may then concentrate on his task – this obviously improves the efficiency and safety of his operations. Even if a robot cannot draw near the bomb it may still efficiently assist the bomb technician through the inspection of access or delivery of the tools. The robot cameras may additionally be used to record the operations for future analysis. [1].

Till 1996 there were no intervention robots in Poland (except of one obsolete and abandoned machine at the

Warsaw Okęcie Airport). After a lethal accident happened during the removal of a bomb at the Warsaw petrol station, everyone became convinced that the Polish police forces had to be provided with such robots. Before the above mentioned tragic incident, PIAP (Research Industrial Institute for Automation and Measurements) started research work on the development of an intervention robot for the Polish police forces. Carried out under the KBN (Polish State Committee for Scientific Research) project, the work resulted in development of a prototype robot SR-10 INSPECTOR which was completed in 1999. The new construction was demonstrated to the media and potential users. The prototype (Fig. 1) was handed over to a number of the police units for testing.

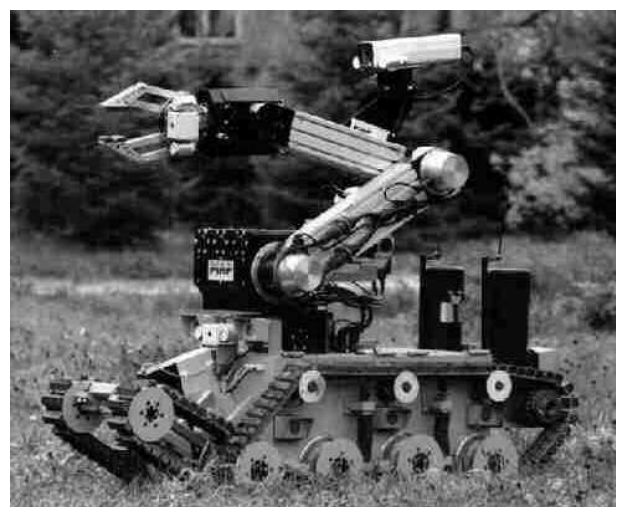


Fig. 1. Prototype robot SR-10 INSPECTOR

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In mid-2000 the police forces launched a tender for the delivery of intervention robots. The prototype robot SR-10 INSPECTOR, which already underwent the tests and was operational at that time, participated in the tender and was awarded with the contract. After the tests were carried out in the police units, it was decided to introduce amendments and improvements. In five months as many as 50 modifications were made while 5 new robots were under construction. It was a real challenge for the team of designers. Robots SR-11 INSPECTOR (Fig. 2) entered service in December 2000. Their construction has been continuously improved ever since.

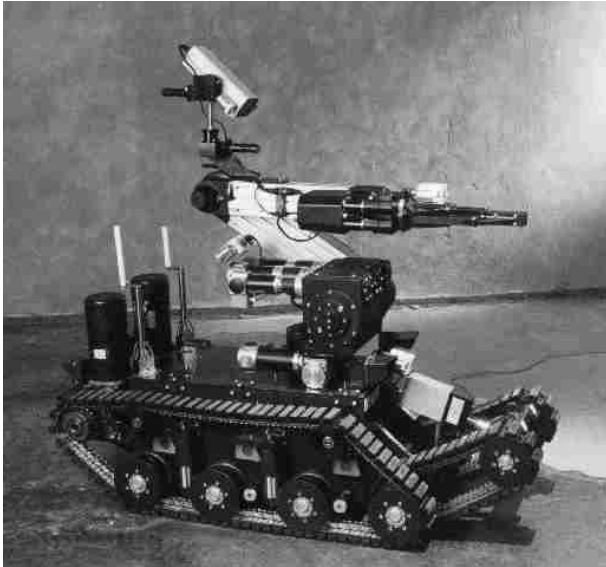


Fig. 2. Robot SR-11 INSPECTOR

The robots of the INSPECTOR type have received a lot of awards. They include NASA prize, Golden Medal at the Poznań Fairs, award of the Police Chief Commander for the best product used by the police, title of Master of Technology of NOT (Polish Federation of Engineering Associations) and recently the title "TERAZ POLSKA" ("POLAND: NOW").

Technically, INSPECTOR robot development has now two most important aspects. Firstly, new robots are ordered and manufactured. Secondly, after a new robot SMR-100 Expert has been designed, there is a feedback of new technologies towards the previously designed robots.

The brief description of the problems associated with the construction development of the new robot SMR-100 Expert is presented. We briefly describe its design and concentrate on the particularly interesting construction solutions.

2. Background of the prototype robot SMR-100 Expert development

The success of the INSPECTOR type robots encouraged PIAP designers to undertake the development and implementation of a neutralising and assisting robot referred

to as SMR-100 Expert. It was made on the basis of previous experience under the new KBN project. However, this time the research and development phases were supposed to be twice as shorter. The robot was to be especially designed for the use in confined spaces, particularly inside the air-crafts, buses and rail cars. The price of the robot was to be competitive as compared with the prices of similar foreign constructions. In order to cope with the challenge, a new designing technology was needed. For the mechanical designs of INSPECTOR, conventional methods were applied, i.e. using drawing deck plans. Electronic and software designs were also provided using simple design tools. In order to achieve this ambitious plan, new advanced technological designing tools had to be applied. As far as the electronic design was concerned, this could be solved with the purchase and application of a special CAD software. Apart from the existing apparatuses a number of advanced devices were purchased which allowed to shorten the time needed for activation of the electronic components.

In respect of IT (Information Technologies) – the advanced and specialised tools were implemented to assist the design of new software.

However, the most pronounced change was that in the design technology of the mechanical designs. Instead of a drawing deck and simple CAD software a 3-D modelling software was introduced. The mechanical design has been divided into four basic parts: mobile base, manipulator, gripping device and manipulator base rotation, operator's stand. The new software enabled all parts to be designed at the same time so that the designed components could be integrated later without any difficulty.

The development of SMR-100 Expert mechanical design will be exemplified by the robot mobile base design. This description will include dates to show how tight was timetable of the development. (Fig. 3) shows the project progress in October 2001, when analysis of the design concept was carried out.

At this stage, only general outline and dimensions of the structure were determined without details of the

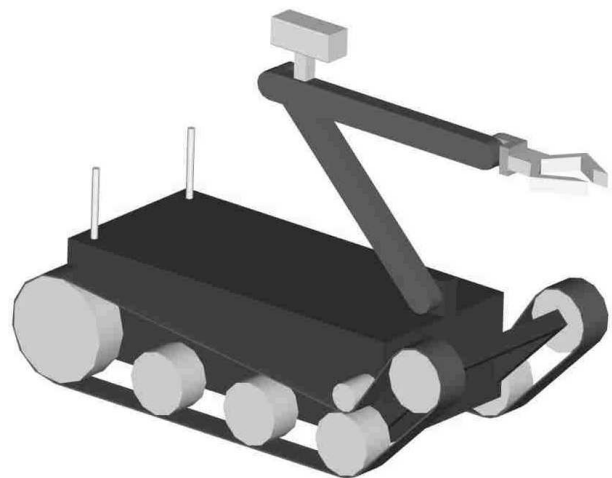


Fig. 3. October 2001, preliminary concept

structural joints. This concept may be briefly described as follows: mobile base mounted on the tracks, the adjustable approach angle front track, manipulator with at least 4 DOF (degrees of freedom), main camera mounted on the manipulator.

The next step consisted in detailed examination of dimensional limitations associated with the need of the robot operation in such places like the interior of an aircraft, bus or rail car. Different manipulator kinematics concepts were examined. At the same time the energy balance of the robot was determined in order to determine the size of the onboard batteries. Size of those batteries influenced mostly the dimensions of the mobile base. The concept drawing was supplemented also with other selected parts such as: drive gears, main motors, front track control servo.

The dimensional limitations imposed on the mobile base and the coincident requirements of the extensive range of the manipulator had lead to a paradox: short and narrow base with a large operation space of a long arm. The result was that the robot tended to overturn, particularly to the sides. To overcome the problem movable side stabilisers were proposed. However, their designing was a problem. When folded, these mechanisms should have a negligible impact on the mobile base width and should not touch the floor at their folded position, but at the same time they should block the robot between the seat rows or stabilise the device on a flat surface. Additionally in the front of robot a construction design was proposed to adjust the range of approach angle for the front track between 30° below the level and vertical position. (Fig. 4) shows the project progress in March 2002.

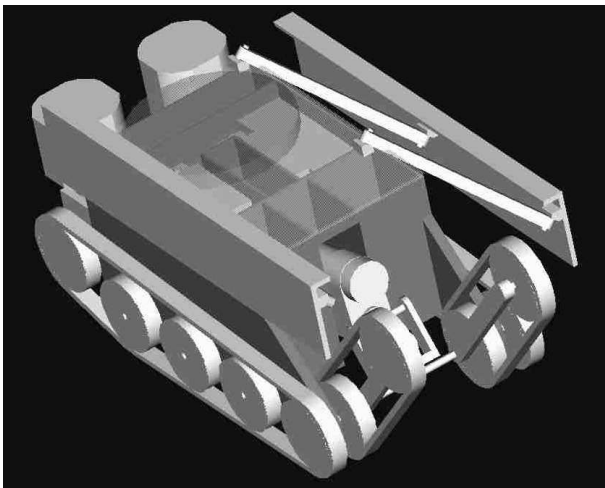


Fig. 4. March 2002, preliminary design including size limitations

In the further work (Fig. 5) the whole design was adjusted to the components available on the market such as drive motors and front track servo. Proposals for construction design of side stabilisers¹ were made. Proposed

¹Solutions presented in this paper are protected by patent claims.

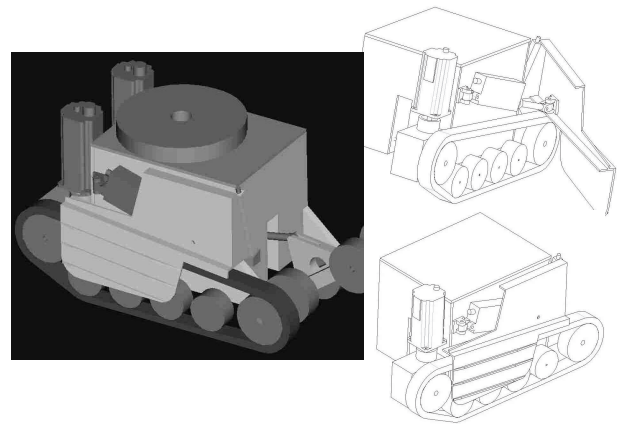


Fig. 5. September 2002, further approach to the project, side stabilisers concept

solution guaranteed no problems with initial force (when stabilisers are folded), very limited space for folded mechanism and more then doubling of a robot width in unfolded configuration. Location of the electronic equipment elements inside the main robot body was planned and, therefore, the team of electronic engineers could start working on their designs.

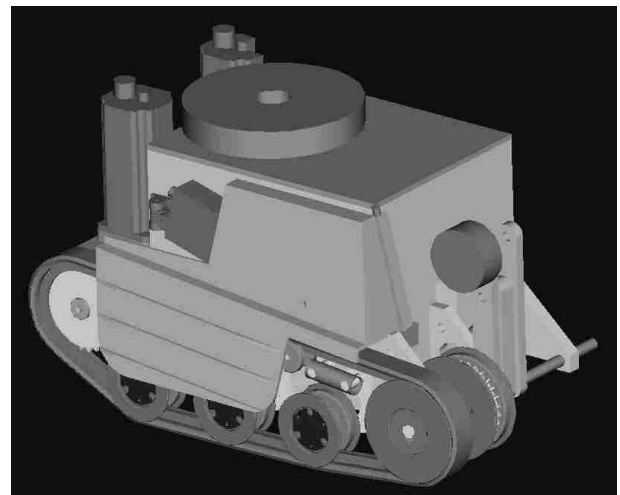


Fig. 6. January 2003, detailed design of suspension system and mobile base track

In January 2003 (Fig. 6), the detailed design of suspension system and mobile base track was ready. A number of interesting design issues were approached, such as:

- How to build small sufficiently strong ground wheels (conflict between the resulting from durability calculations relatively big sizes of bearings and required small wheel dimensions) – the solution was to design complex multi-material structure of wheels.
- How to build a narrow (due too limited space inside an aircraft) and sufficiently strong track. The solu-

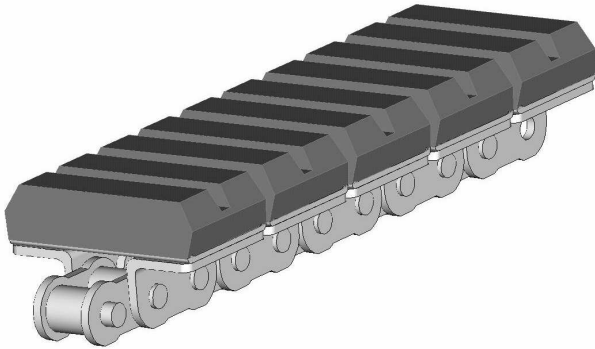


Fig. 7. Tracks made of a steel chain with rubber elements attached

tion is shown in Fig. 7 and is based on a steel chain with rubber elements attached.

- How to design the kinematics of the suspension systems for all ground wheels so as to ensure shock absorption in a very limited space,
- Variable length of a contact between tracks and a ground was proposed. This reduces power consumption on a solid ground (especially while turning).

Design of the robot suspension springs was the most difficult task. All methods suggested in the manuals and guides lead to the conclusion that such springs could not be made. Only when an advanced CAD software was used, the proper solutions could be proposed. Instead of using empirical formula, the calculations based on FEM (Finite Element Method) were carried out. A very similar situation was found in the development of an arm. The use of FEM helped very much in this case also.

One of the main research problems was to make proper calculations of main motors (driving the mobile base). INPSPECTOR tracks system was investigated. A few series of experiments were made on a solid and on a loose grounds. Data resulting from experiments were recorded and analysed. Preliminary model of a tracks system was created and verified. This made possible to estimate efficiency of the tracks system. In the next step model of a whole driving system was created. With the use of this model it was possible to calculate required main motors characteristics. The results were used to find such motors available on the market (only a few producers of such motors were found). Similar methods were applied in the case of motors moving the arm, front tracks and gripper.

By the end of February (Fig. 8) details of the front axle construction were ready. The problem of adjusting simultaneously the front track tension and extreme positions of the whole mechanism was solved.

In March 2003 (Fig. 9) all elements of the design were integrated, i.e. the mobile base, manipulator and gripping device. A number of simulations were made to check the components match. After a few corrections were made, the construction of a real prototype started.

Further work consisted in testing the prototype in real conditions (Fig. 10), i.e. in a bus, in the aircrafts and rail cars.

The tests carried out on the real prototype showed that it met the design concepts, however, a few corrections were needed. The most important one consisted in that the fixing point of the manipulator had to be transferred from the mobile base up cover back part to the front part. The design of the lower manipulator arm was totally changed. The changes were intended to achieve a broader range of the lower manipulator arm and to ensure better control of the robot gravity centre. The design of new version is shown in (Fig. 11).

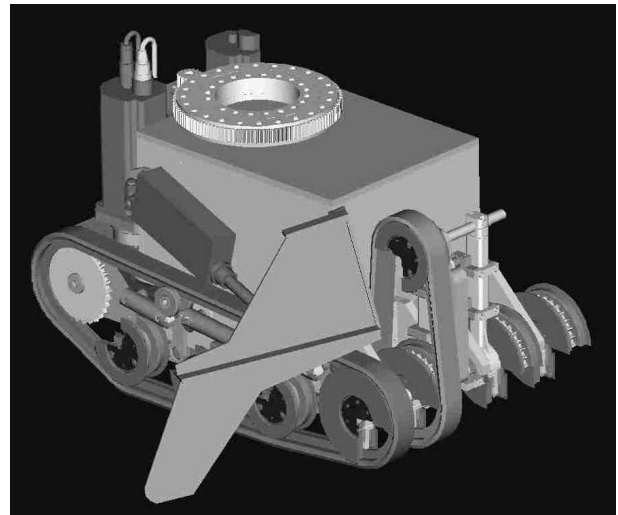


Fig. 8. February 2003, detailed design of the front axle and track

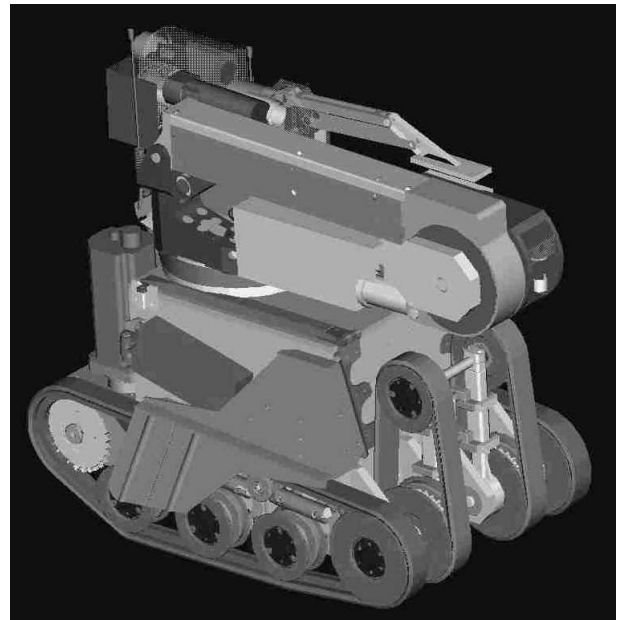


Fig. 9. March 2003, integration of all design elements

The prototype shown in (Fig. 10) already exists. It is used during various fairs and media presentations. This robot version has been generated (including the production cycle) within few months.



Fig. 10. Prototype testing (airplane, train, bus)

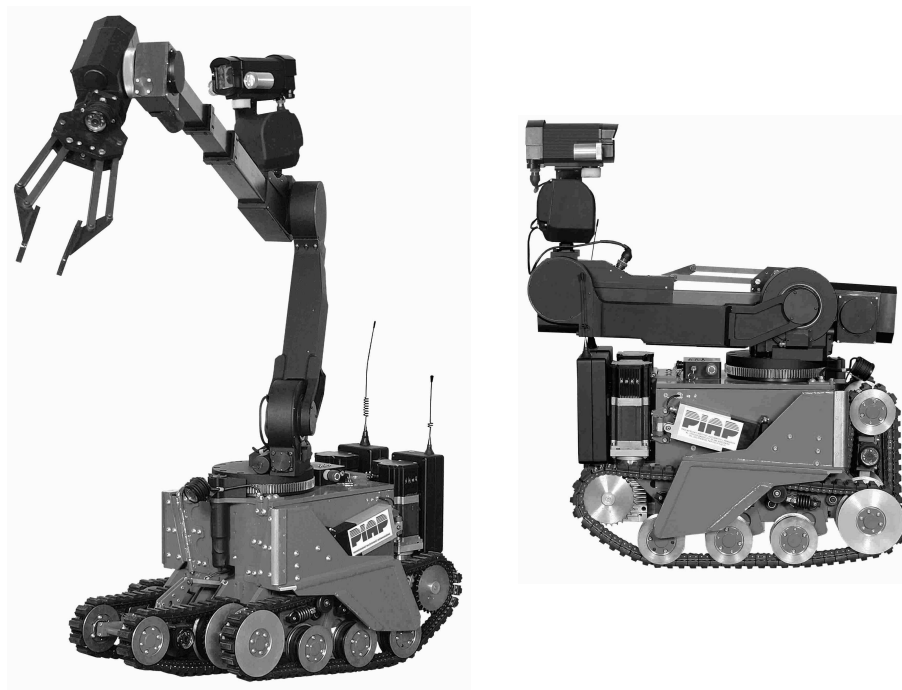


Fig. 11. New prototype design

3. Summary

This paper may seem void of scientific elements. However, this is a misleading impression. A commercial success of the INSPECTOR class robot, design of the new Expert robot over a short period of time and a considerable technological leap (new technologies not mentioned in this paper, such as the use of the CAN network, designing of own-design computers, application of the distributed software and control, application of new assembly techniques and new materials ...) would not be

possible without support and scientific experience of the designers.

In addition – what Author is intending to show in this brief article – modern technologies can not be applied without science. Also – what is very important – one of science main aims is to support engineers in their real live applications.

The team of designers of the both robots may show their scientific achievements. The team participated in

many research and development domestic and international projects associated with the mobile robotics such as [2–5]. During the implementation of these projects an important difference between the advanced mobile robots used in the laboratories and service robots was distinguished. There is a possibility of an extensive transfer of technologies. This transfer is now hampered mainly by the economical factors. In some cases new technologies are not “mature” yet – they work in the laboratory controlled conditions, but are not fit to be used in real conditions. This is where the team of designers of both robots see their mission. We want to transfer the laboratory technology to the products which are used in real life.

The present research work on the designing of an assisting robot for the intervention robots is an example of such activity. Its task would consist in providing a stereoscopic picture of the operation site from the selected points with the minimum involvement of the operator. To some extent the assisting robot is to move independently, and in the moments selected by the operator it is to be remotely operated. The intelligent controller of assisting robot will be designed using new methods developed by the team of designers and based on the algorithms of distributed controllers. [6,7].

Finally, as far as the robot Expert is concerned: on the basis of experience acquired during designing of its mobile base, the Author maintains that without advanced designing tools and developed technologies it would not be possible to design and implement such a construction, which is reaching the edges of a currently used technologies. As the designers maintain, the successful construction of the prototype robot Expert in Poland resulted in the creation of the first intervention robot in the world able to perform all necessary operational tasks inside the passenger planes [8].

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