

Variable Geometry Tracked Vehicle (VGTV) prototype : conception, capability and problems

Jean-Luc PAILLAT (jlpaillat@gmail.com), Philippe LUCIDARME
(philippe.lucidarme@istia.univ-angers.fr), and Laurent HARDOUIN
(laurent.hardouin@istia.univ-angers.fr)

Laboratoire d'Ingenierie des Systèmes Automatisés Angers, France

Abstract. This paper presents a prototype of tracked UGV (Unmanned Grounded Vehicles) called B2P2. This tele-operated robot has been designed to intervene in unstructured environments like for example battlefield or after an earthquake. This robot based on an original system of multiple articulations can be classified into the VGTV (Variable Geometry Tracked Vehicle) category. The proposed concept allows the robot to adapt its shape in order to increase its clearing capability. Unlike existing robots, the tension of the caterpillars is actively controlled and can be turned off to increase the robot/ground contact surface needed for some special kind of obstacles. After a short state of the art, the paper presents the detailed architecture of the robot. The third part introduces the data and video transmission materials tested during the conception of the robot. The behaviour of the robot over several obstacles (staircase, curb and bumper) is analysed and the necessity of releasing the tracks is discussed.

1 Introduction

The use of robots in dangerous environment like partially collapsed buildings or nuclear power station is currently a research topic of prime interest. Designing generic robots well suited to a large variety of missions and environments is still challenging : the challenge is thus to design the smallest robot as possible (able to pass into narrow openings) and with the best clearing capabilities. The prototype called B2P2 presented in this paper is a tracked vehicle based on an actuated chassis (Fig. 1). It has been designed to maximize the clearing capability to the robot size ratio. Unlike existing robots the track's tension can be controlled on our prototype. Experiments presented in the following will discuss of the interest of controlling the track's tension. This article is organized as follows. Section 2 presents an overview about a selection of existing robots. Section 3 gives the technical description of our prototype. Next section is dedicated to the data and video transmission materials tested during the conception of the robot. The last section discusses about real experiments performed with the robot over three obstacles : a curb, a staircase and a bumper. A general conclusion ends the paper and presents some perspectives.

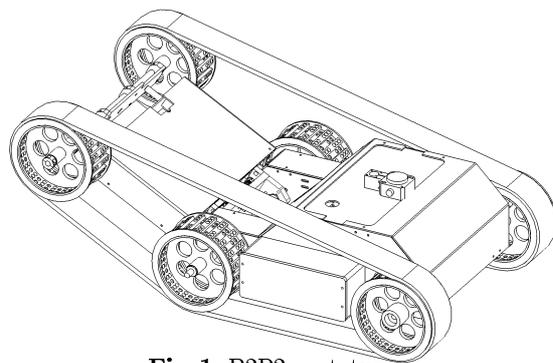


Fig. 1. B2P2 prototype

2 Existing UGVs

2.1 Wheeled and tracked vehicles with fixed shape



(a) ATRV-Jr robot.
Photo Courtesy of
AASS, Örebro Uni-
versity.



(b) Talon-Hazmat robot
(Manufacturer : Foster-
Miller)

Fig. 2. Two UGV with fixed shape models

This category gathers non variable geometry robots. Theoretically, this kind of vehicles are able to climb a maximum step twice less high than their wheel diameter. Therefore their dimensions are quite important to ensure a large clearing capability. This conception probably presents a high reliability [1] but those robots are not well suited for unstructured environments like after an earthquake [2].

Fig. 2(a) and 2(b) present two vehicles dedicated to reconnaissance and surveillance.

2.2 Variable Geometry Tracked Vehicle

A solution to ensure a large clearing capability and to reduce the dimensions consists in developing tracked vehicles which are able to modify their geometry in order to move their center of mass and climb higher obstacles than half their wheel's diameters. The Micro VGTV Fig. 3(a) is a good example of the possibility of this kind of UGVs. Indeed, with a wheel diameter of only 6.5 cm, it is able to climb a step of 25 cm. [3] provide endurance tests results for this UGV. Another solution consists in using flippers as the Packbot (Fig. 3(b)). This kind of VGTV can clear a lot of different obstacles and its control is easy, but it does not offer a gentle clearing as the caterpillars' models. For more information and a detailed survey on clearing capability of the packbot, the reader can consult [4].

Our prototype (Fig. 1) belongs to this category and can clear a maximum step of 35 cm high with a wheel diameter of 12 cm.

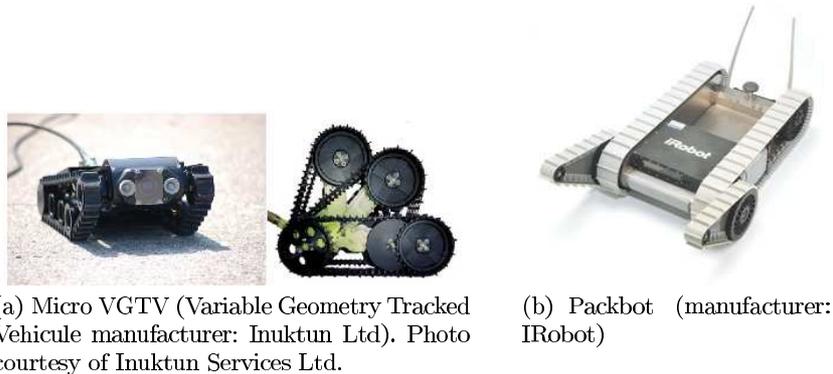


Fig. 3. Two VGTV models

3 Description of B2P2

3.1 Mechanical description

Our conception is based on a similar system than the Micro VGTV (Fig. 3(a)) previously cited. A revolute joint coupled with a translation system situated on the robot allows it to change its shape (Fig. 4) keeping the caterpillars tense.

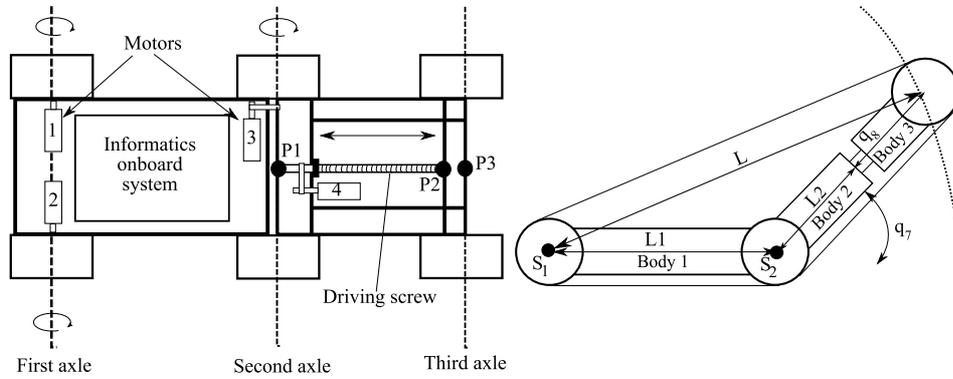


Fig. 4. Overview of the B2P2 mechanical structure.

This system, contrary to the one used on the Micro VGTV is actively controlled. Fig. 5 shows an illustration of configurations, on (a), by releasing the tracks it becomes possible to move the center of gravity (CoG), and on (b), the robot morphology is adapted to the ground.

An example which show the interest of this active system is presented on fig. 6. B2P2 is clearing a curb of 30 cm height with tense tracks. The position of the robot on Fig 6(c) can also be obtained with the Micro VGTV, but it is a non-safety position and B2P2 is close to topple over. On Fig. 6(d) the tracks have just been released. They take the shape of the curb and it can be cleared safely. This last configuration outlines the interest of using an active system instead of a passive one.

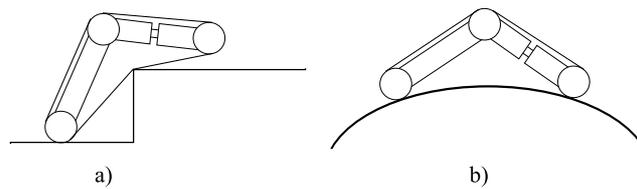


Fig. 5. Different configuration of B2P2 on obstacles. In a), the caterpillars are tense, and in b), they are not to increase the contact surface. Note that even if the system is turn on, the caterpillars are not hardly tense ; it allows soft mass transfer and clearing

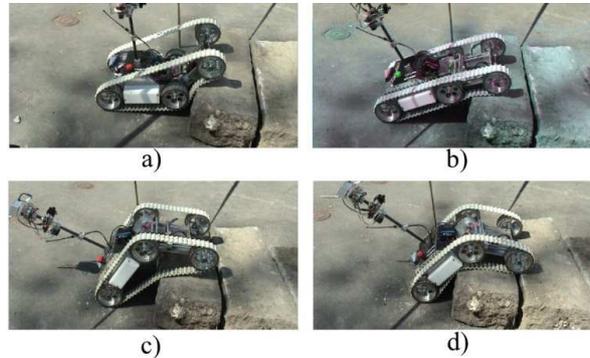


Fig. 6. B2P2 : clearing of a curb

Because of this active system, B2P2 is equipped with four motors :

- Two motors are dedicated to the rear wheels rotation (tracks actuators).
- One motor actuates the rotational joint
- One motor actuates a driving screw to control the distance between the second and the third axle (i.e. the tightness of the tracks).

3.2 Embedded computation and sensors

The robot is equipped with multiple sensors, onboard/command systems and wireless communication systems.

- Onboard command systems :
 - PC104 equipped with a Linux system compiled specifically for the robot needs based on a LFS.
 - An home-made I2C/PC104 interface.
 - Four integrated motor command boards running with RS232 serial ports.
 - Four polymer batteries which allow more than one hour of autonomy.
- Sensors :
 - An analogical camera for tele-operation.
 - A GPS to locate the robot in outdoor environments.
 - A compass.
 - An 2-axis inclination sensor (roll and pitch).
- Wireless communication systems :
 - An analog video transmitter.
 - A bidirectional data transmitter.

4 Data communication for command and video

For three years, several transmission systems have been tested to control the VGTV and send video data to the operator.

4.1 Data communication for command

About the command transmission, we implemented a C++ software on the command computer which gets the operator commands from an USB Joystick and sends five orders per second to the robot. On the other side, we implemented on B2P2 a C real time program thanks to the Xenomai API which receives and processes data.

Several materials have been tested :

- A WiFi transmission,
- A Radiometrix 152.575 MHz transmitter on an home-made electronic board,
- An Adeunis 868 MHz RF Modem.



(a) Radiometrix 152.575 MHz transmitter (b) Adeunis 868 MHz RF Modem

Fig. 7. Data communication for command

WiFi transmission To do the tests a Netgear WiFi WPN 802 modem coupled with an USB dongle have been used. The modem was plugged on the command computer and the dongle on the robot. This modem is equipped with the Smart MIMO technology. It consists in a modem with several integrated antenna which automatically sets the optimal antennas configuration to have the optimal rate from the dongle to the modem. A standard WiFi modem with departed directional antenna has also been tested to compare both solutions.

As a result the outdoor range with this configuration (WiFi modem and USB dongle) is about 100 meters for both modems. However the indoor range is better with the seven antennas modem (about 60 meters) than the standard one (about 40 meters). Obviously, using an other modem instead of an USB dongle will increase the range.

Radiometrix 152.575 MHz modem This modem consists in a Radiometrix 152.575 MHz VHF Transceiver (Fig. 7(a)) plugged on an home made electronic

board equipped with a RS232 link. Two Radiometrix components has been tested, with two different powers (10 mW and 100 mW).

The range of both modems is quite the same. Besides they have almost the same outdoor range than the WiFi solutions presented above. About the indoor range, it is less powerful than the multi-antenna WiFi modem (about 40 meters), but RS232 link is easier to implement than network sockets.

Adeunis 868 MHz Modem This last solution consists in a half-duplex 500mW modem provided by Adeunis coupled with a RS232 UART in an IP65 case (Fig. 7(b)). About the range, it provides a tested outdoor range of about 400 meters and a tested indoor range of about 150 meters.

4.2 Data communication for video



Fig. 8. Data communication for video

The main issue about video transmission is to provide a fine picture with a good range and provide enough frame in a second to allow the tele-operation. Several configurations have been tested since the beginning of the conception :

- WiFi transmission,
- HF video transmitter,
- CMUCam3 with a ZigBee transmitter.

WiFi transmission with a WebCam A WebCam was connected to the PC104 on the robot which transmitted data by a WiFi network to the command computer. This system gives real fine pictures, but the delay between the capture and the display on the operator screen could be too long to allow a reliable tele-operation. Even if the quality of the pictures is reduced, there is always an important latency which could be really a major issue for real time tele-operation.

HF video transmitter with an analogical camera An analogical camera (Fig. 8(c)) fixed on the robot is directly plugged on a 2.4 GHz video transmitter (Fig. 8(a)). A video receiver is connected to the command PC by an USB analogical to digital converter (Fig. 8(b)). The video flow is directly read by an open source software called K!TV. It gives usable pictures (Fig. 9) with almost no latency. But the outdoor range of this system is about 50 meters. To increase this range it could be necessary to have better transmitters.

This system is the one used on B2P2 because the video flow given by the WiFi system did not seem usable.

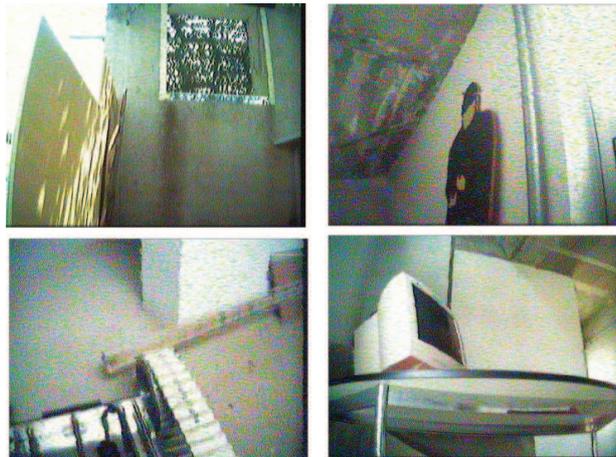


Fig. 9. Pictures received by the 2.4 GHz video receiver

CMUCam3 with a ZigBee transmitter CMUcam3 (Fig. 8(d)) is a low-cost, open-source, embedded computer vision platform [5] composed of a CMOS camera, a frame buffer and a micro controller. It is provided with a software environment which includes libraries as JPEG compression, frame differencing, colour tracking etc... The system presented here links this camera to a ZigBee

transmitter provided by MaxStream. This ZigBee transmitter has not a high range, so it can not be used for tele-operation, but the CMUcam3 is able to process picture (compression, segmentation...) before to send it. As a result, CMUcam3 could be used as a second camera on the robot to get further information about the environment of the robot. It is also possible to plug the camera on an other little robot. It will transmit information to B2P2 by the ZigBee transmission.

5 Experiments

In this section, several approaches of different obstacles will be illustrated by explaining pictures derived from a trial day and an experiment made in our laboratory.

5.1 Curb

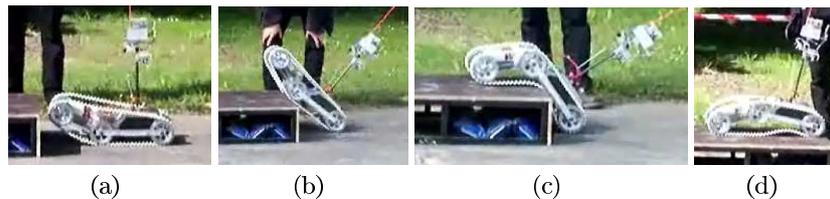


Fig. 10. The clearing of the curb

During a trial day organized by the French army in 2006, our prototype had to pass through a curb of 35 cm riser ; it is closed to its maximum obstacle height. It was tele-operated. The visual feedback was provided to the tele-operator thanks to a video transmitter fixed on the top of the turret visible on Fig. 10. This clearing can be divided into two stages :

- The approach of the curb (Fig. 10(a) and 10(b)).
- The clearing of the curb (Fig. 10(c) and 10(d)).

The approach of the curb Fig. 10 describes the different steps of this approach. First, the robot is approaching while moving up the front part. Then, when the curb is reached the robot's pitch is rising up until the second axle reaches the curb. At this moment (Fig 10(b)), the stability limit is reached, indeed, if the pitch increases a little more, B2P2 is going to fall. Keep clearing without falling is the goal of the second step of the clearing.

The clearing of the curb In order to increase the contact surface, the caterpillars was released by turning off the translation system. This "trick" increases the clearing capability but the caterpillars can slide out of the wheels, so the piloting has to be very accurate. Fig. 10(c) illustrates this step : the robot is going forward slowly while moving down the front part. The difficulty increases with the curb's height. This is a delicate step because the prototype is in a stability limit configuration and the pilot ability makes the clearing possible. However, the knowledge of the position of the CoG and the ground shape could be used to compute an assistance steering for this kind of obstacles.

5.2 Bumper

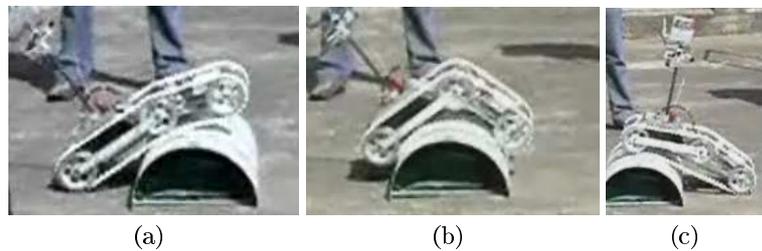


Fig. 11. Clearing of a bumper : pictures

Fig. 11 describes the clearing of a bumper of 25 cm height done in 2006 during a robotic trial day. First, the robot approaches the bumper as it was done with the previous obstacles. Once again, it is a critical step (Fig. 11(a)), because the prototype can fall if the bumper is too high.

Then, once the front part rose down there is no risk of falling anymore, and moving forward slowly makes the robot climb the bumper (Fig. 11(b)). Note that the caterpillars are not tense, so the robot really takes on the obstacle shape in order to have the maximum adhesion. Thanks to this particularity, the clearing is easy and softly.

Finally, if the bumper is not too high, going forward makes the UGV clear. However the final step which corresponds to the reception on the ground could be dangerous for the mechanical structure of the robot if the pilot does not decrease the elevation angle before going forward as it is shown on Fig. 11(c).

5.3 Staircase

The pictures presented here are derived from an experiment performed in our laboratory. The prototype had to pass through a staircase sets of 15 cm risers and 28 cm runs. It can be decomposed into three parts :

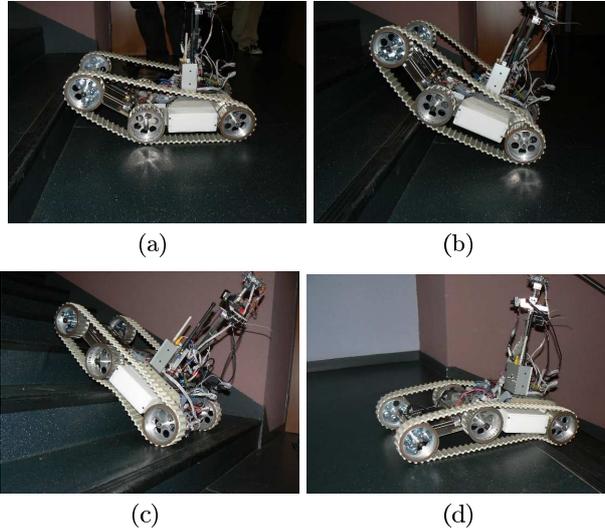


Fig. 12. Clearing of a staircase : pictures

- The clearing of the first step (Fig. 12(a) and 12(b)).
- The clearing of the middle steps (Fig. 12(c)).
- The clearing of the final step (Fig. 12(d)).

Note that the clearing of the first and the final steps are done respectively as the first and second steps of the clearing of the curb.

After clearing the first step the robot is in the position noticed on Fig. 12(b) and then it climbs naturally the stairs by moving forward (Fig. 12(c)). At each step, it is gently swaying when the CoG is passing over the step. This oscillation is dependant on the ratio between the size of the robot and the size of the steps. Of course, if the distance between two steps is longer than the robot length, the staircase is cleared like a succession of curbs.

6 Conclusion

In this paper, an original prototype was described and validated by experiments. We detailed its behaviour during the clearing of several obstacles. During all obstacle clearings, there is a critical step where the fall risk is important. Then, releasing the caterpillars before or during the clearing of an obstacle increases the risk of the tracks coming off but allows a soft and easy clearing of some obstacles. We can discuss about the purpose of that, because a bigger VGTV equipped with flippers could reach same obstacles with the same facility and without a risk. However, the goal of our VGTV prototype was to develop a robot with reduced dimensions and important clearing capability while testing

some materials which are described on the paper. The video transmission is still a major issue, which should be improved.

References

1. J. Carlson and R. R. Murphy. Reliability analysis of mobile robots. *International Conference on Robotics and Automation*, 2003.
2. J. Casper and R. R. Murphy. Human-robot interactions during the robot-assisted urban search and rescue response at the world trade center. *IEEE Transactions on systems, man, and cybernetics*, 33(3):367–384, June 2003.
3. J. A. Kramer and R. R. Murphy. Endurance testing for safety, security, and rescue robots. *Performance Metrics for Intelligent Systems*, August 2006.
4. Scott Pratt Tom Frost, Christopher Norman and Brian Yamauchi. Derived performance metrics and measurements compared to field experience for the packbot. *Proceedings of the 2002 PerMIS Workshop*, 2002.
5. D. Goel A. Rowe, A. Goode and I. Nourbakhsh. Cmucam3 : An open programmable embedded vision sensor. Technical report, Robotics Institute Carnegie Mellon University, Pittsburgh, 2007.