

The Volksbot

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Abstract. This paper presents our VolksBot robotic system. VolksBot is a flexible and modular mobile robot construction kit based on high value components. The concept behind the VolksBot system is the Physical Rapid Prototyping of mobile service robots. The paper firstly presents the concept on the Volksbot kit and secondly the current versions and already realized robotic variants and projects.

1 Introduction

A typical observation during the past two decades at our Institute and in other robotic projects was that various robotic applications always start from scratch. That is remarkable since most of the projects deal with similar problems. The development of mobile robotic systems is a demanding task regarding its complexity, required resources and skills in multiple fields such as software development, artificial intelligence, mechanical design, electrical engineering, signal processing, sensor technology or control theory. Current mobile robot systems often are monolithic, highly integrated prototypes that took long time to develop, they are costly and hard to maintain. Also robots tend to grow old quite quickly when used frequently or used under highly physical stress or when the robots hardware simply gets outdated after a few years. Fluctuation of people combined with long training times for new team members and loss of knowledge are other difficulties we frequently experienced.

In this paper we present our methodologies to cope with such diverse difficulties by using modular, component-oriented design approaches for mobile robot prototyping. The approach should enable developers to focus on their specific domain, still being able to have a clear comprehension of the entire system by help of different levels of abstraction and well defined interfaces to hardware and software modules. Furthermore, (re-)usability should be maximized by having well documented, system components of manageable size. An implementation of such an approach will be presented with the VolksBot concept (Wisspeintner et al. 2006 [1]).

The VolksBot project has three main goals:

1. The fast and cost effective realization of robotic applications while using high value standard robotic components.
2. The development of a kit for R&D as well as industrial applications. Customer demands and extensions should be easy to realize.
3. To build a base for in-house robotic projects.

1.1 The concept

VolksBot is a flexible and modular mobile robot construction kit. The concept behind the VolksBot system is the Physical Rapid Prototyping of Mobile Service Robots. This means that the VolksBot system provides a wide variety of sensors, actuators and software modules which are fully compatible to each other. This allows the cost- and resource-efficient development of mobile service robots. All robots of the VolksBot system are based on the same components and interfaces which make it easy to adapt existing robots to changing requirements. If you start with a simple VolksBot robot platform you can easily add components over time which fit always your actual needs and your future demands. This guarantees a high security of the investment since once purchased components and obtained experiences can be used for a wide variety of applications. The component-based approach offers a plug-in architecture in electronic hardware, software and mechanics. It provides open interfaces to hardware and software modules. Combined with an effective and robust design, a wide range of domain-specific robots can be created with little effort. Furthermore, the modular concept facilitates reusability of already developed components. The VolksBot concept was successfully applied in national and international R&D projects. The construction kit is the result of long time experiences of Fraunhofer IAIS and the answer to the problems and difficulties with the construction of autonomous mobile robots hardware and software. The robot construction kit is continuously enhanced with new and special components based on our experience in current national and international R&D projects.

Currently the VolksBot system has the following characteristics:

- It is a physical rapid prototyping system for mobile robot applications.
- It has a component based architecture in hardware and software.
- Hardware components include software modules with a basic functionality.
- The availability of a basic functionality allows customers quickly building their own applications.
- The modular approach enables short development times and customized configurations.
- It is a component based approach with a plug-in architecture with open interfaces in electronic hardware, software and mechanics.

The concept has two target groups. First these are industrial groups which have to build prototypes. They have a little or no contact with robotics but they have a special application from their field which has to be solved with mobile robots. The other subgroups are researchers and developers from industry and universities. During the last years the kit has also become very popular in the education of master and PhD students due to the professional selection of industrial components for the kit. The approach leads to the following advantages:

- cost reduction
- increased reliable and robustness
- standard components
- service
- better documentation

- more robust complete systems
- safety regulations
- increased flexibility
- improved learning curves

1.2 A brief review

There is always a trade off between the general applicability and the performance in modular approaches. Significant work has been done in the field of rapid prototyping of robots in the past. Won et al. have shown that rapid prototyping is a viable method to create articulated structures of robotic systems [2]. Reshko et al. have illustrated methods to quickly produce prototypes of desired quality in considerably small time by using ready-made components such as servo motors, sensors, plastics parts and LEGO blocks [3]. Examples for robot construction kits mainly used for education and edutainment are LEGO Mindstorms (Ferrari et al. [4]), Fischertechnik Mobile Robots [5], Tetrixx [6] or the Cubesystem [7]. Though aspects of modularity are addressed well by these systems, they are limited in onboard computational power and focus on miniaturization and low-cost hardware. As a consequence the aspect of application-oriented rapid prototyping of fully autonomous robots is hardly provided in these approaches and on-board perception is limited. On the other side, several robot platforms with higher complexity in sensors, actuators and higher processing power are usually specialized for a certain field of application or a certain scenario (Evolution Robotics) (K-Team) [8]. Besides, many of such systems are specific in their morphology, their mechanics and hardware does not follow a construction kit approach. One exception is presented in the MoRob project with a focus on educational robotics [9].

The paper is organized as follows. Chapter 2 presents some of the basic robotic kits and chapter 3 some realized project. Links to videos which show the behavior of the systems are referenced in each section or subsection.

2 VolksBot

With the VolksBot construction kit various variants of powerful mobile robots can quickly be built and adapted for different applications such as autonomous transportation, exploration, surveillance, education, research and industrial rapid-prototyping. VolksBot offers three families of robots:

- VolksBot RT (Rough Terrain)
- VolksBot XT (eXtreme Terrain)
- VolksBot Indoor

These variants are described in the next subsections.

2.1 VolksBot Rough Terrain (RT)

The VolksBot RT family consists of three robot variants. The high agility version RT3¹, the compact version RT4 and the RT6 for high mobility and payload, each with all-

¹ National Instrument has selected the VolksBot RT3 controlled with a CompactRIO control unit for their WorldClass Seminar <http://niworldclass.eu>

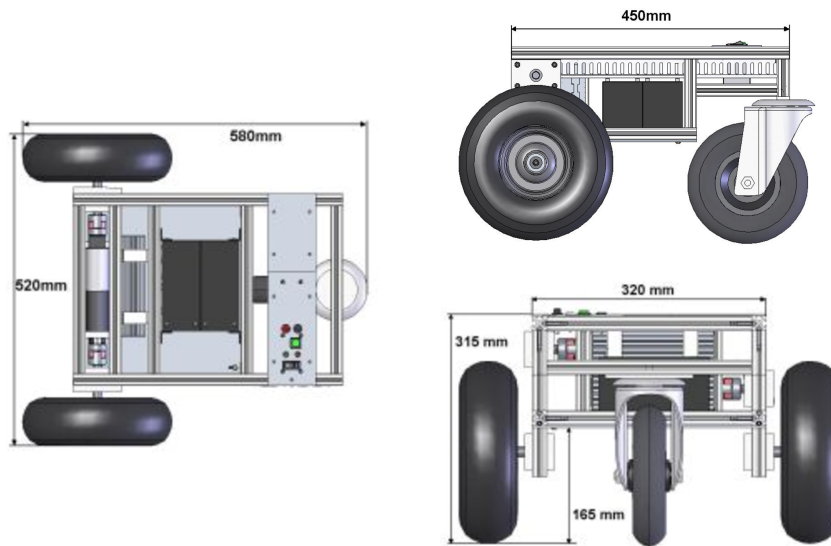


Fig. 1. Volksbot RT3 series. A video can be seen at: <http://de.youtube.com/watch?v=AJYT3QkHIaw>

wheel drive. We use a double layered main frame consisting of two parallel X-beams and a Universal Drive Unit (UDU) with chain transmission. Equipped with two 150 watt DC-Motors the variant e.g. the RT6 is able to climb a slope of 43 degrees and has a maximum speed of 1.3m/s. As the motor gears can be exchanged easily, the maximum speed can be adjusted according to the demands. With little effort different variants in size and wheel configuration of the VolksBot RT can be built.

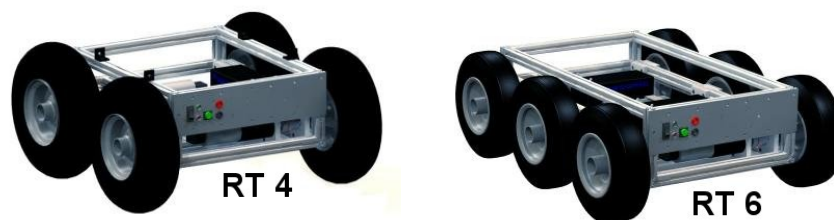


Fig. 2. VolksBot RT4 and RT6 series

2.2 VolksBot eXtreme Terrain (XT)

The all-wheel driven VolksBot XT is used in extreme terrain. The flexible mechanical construction enhances ground contact of all wheels. It can be used e.g. for climbing stairs. An increase of the mobility performance was achieved by use of a genetic algorithm which optimizes a set of the robots geometrical parameters in ODE.

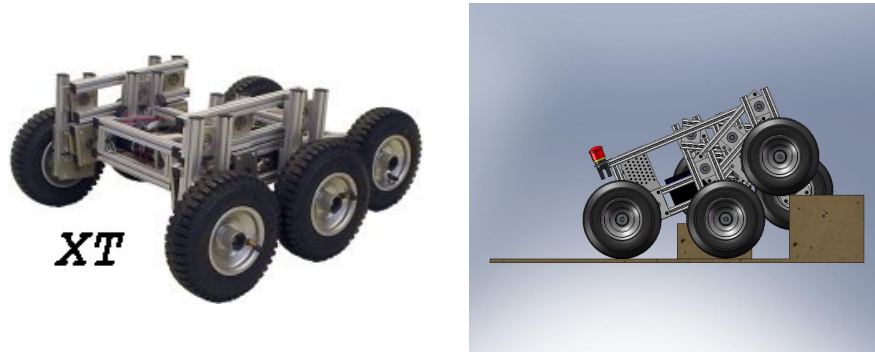


Fig. 3. VolksBot XT. A video can be seen at: http://de.youtube.com/watch?v=_7ACC8-KYQY

2.3 VolksBot Indoor

VolksBotIndoor is tailored for indoor applications and can be used as an educational platform for mechatronics in vocational training. It is powered by two 90 W motors and runs with two active and two passive wheels. Its size is 430 x 410 x 210 mm and weight 6 kg (payload 15kg).

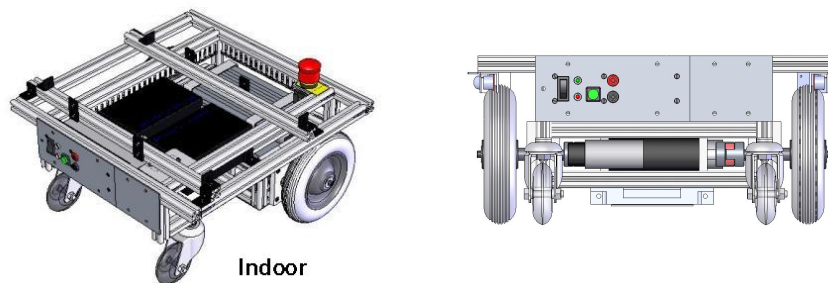


Fig. 4. VolksBot indoor version

2.4 Ackermann drive

An alternative solution to the direct actuation of both sides is the steering knuckle drive where each front wheel can turn at its own axis. (Invented 1816 from the German Lankensperger, patent from the English Rudolph Ackermann). Therefore, there is no need for a driveshaft and gauge tie bar.

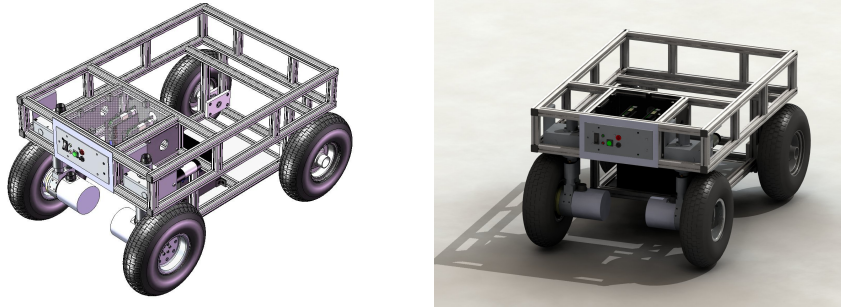


Fig.5. VolksBot with an ackerman drive. A video can be seen at: <http://de.youtube.com/watch?v=6qq1nlsxBuE>

3 Robots realized based on the VolksBot components

Based on the VolksBot construction kit we build several user specific variants of our robots. For instance ProfiBot, Marbot and BrennbBot carrying out various projects resulting in customized robotic systems.

3.1 The ProfiBot

The ProfiBot project was created for vocational training in the field of Mechatronics. The project

- develops a modular mechatronics construction system
- includes didactical teaching materials for teachers and learners
- offers courses for teaching staff

The robot construction system has been designed and realized as a prototype, and tested in practice by several application partners. The results are used for further development and for optimizing the construction system. Trainees will get the basic components to build up the base system by themselves, which later on - depending on the emphasis of education - may be extended by sensors, actuators and other technical parts. ProfiBot² docking to its charging station can be seen at: http://de.youtube.com/watch?v=lI_f7v4meBU, <http://de.youtube.com/watch?v=91X18fpDE0s>

² Profibot construction kits (incl. teaching material) can be get from Christiani(Konstanz, Germany)

3.2 MarBot

Based on VolksBot components, Fraunhofer IAIS together with the Alfred Wegener Institute for Polar and Marine Research (AWI) developed an Autonomous Underwater Vehicle (AUV) for sea bed analysis in shallow water. Instead of providing a complete housing for the robot, only the robot's sensitive hardware parts like the motor, the motor controller, the batteries or the control PC had to be shielded from the surrounding salt water. Besides the underwater environments the robot was designed for, various other demands had to be met regarding the design of the MarBot. Payload and size of the platform had to be increased to allow the installation of additional sensors and actuators like a mass spectrometer for advanced soil analysis which is mounted on a three-axis manipulator. Therefore an exchangeable center frame was designed carrying the additional hardware. Also the ground clearance had to be increased to 400mm to minimize the dispersion of sediments while driving. The resulting platform has six actuated wheels of 400mm diameter, a total size of 1200x700x650mm, a maximum speed of 1m/s and it weighs 30kg. The construction followed the design principles of the VolksBot RT series using the UDU with chain transmission. Only a few drive unit parts like the bearing blocks and bearings had to be replaced by plastic parts to avoid corrosion. A Nano ITX barebone PC is used for the control of the robot. It can communicate to a base station via WLAN and UDP connection in shallow water allowing remote control and monitoring of the sensor data. Future development will include autonomous operation by use of multiple sensors like GPS, IMU, compass and vision allowing the robot to go from shallow water into depths of up to 30m.

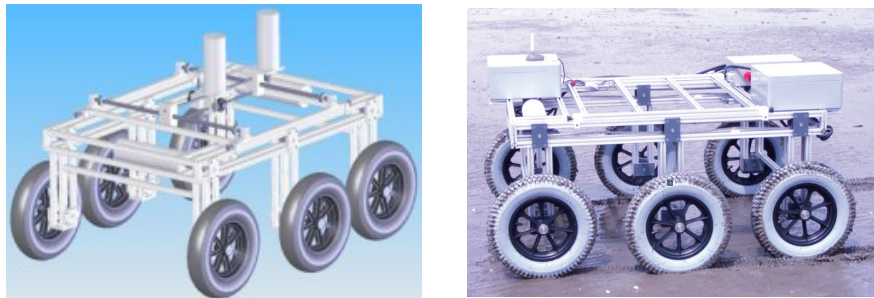


Fig. 6. The *Marbot*. A video can be seen at: <http://de.youtube.com/watch?v=6qq1n1sxBuE>

3.3 BrennBot

Based on VolksBot RT3 Fraunhofer IAIS in collaboration with Fraunhofer ISE developed a fuel-cell powered autonomous mobile robot allowing for long operation times as required in service robotic applications. Mobile robots can guard industrial installations, with conventional batteries the period of application is very limited. Therefore this is an

ideal terrain for the use of fuel cells. Depending on the mode of operation and the size of the metal hydride tanks filled with hydrogen it allows up to 24h of continuous operation. Economically fuel cells are suitable for all applications, representing more than one day continuous operation. The fuel cell provides up to 400W power at 24 VDC. In addition to the fuel cell the robot was equipped with a SICK laser scanner, an industrial PC and a TFT display. It was presented at the Hannover fair 2007 in Germany.

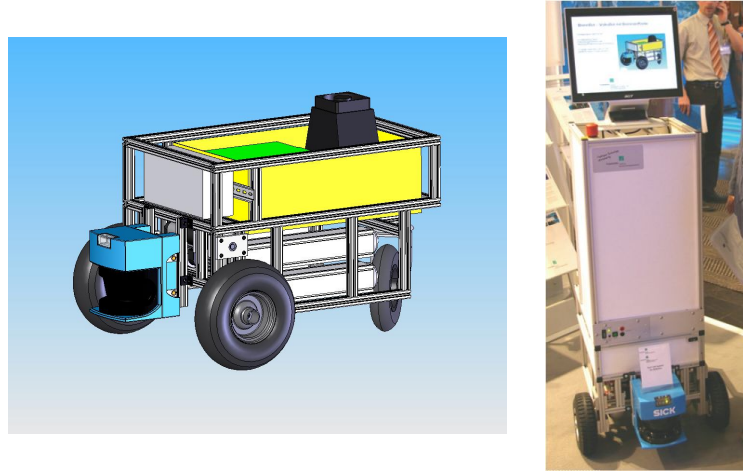


Fig. 7. The *Brennbot*. Left: CAD images. Right at the Hannover Fair 2007.

3.4 AtHomeBot

Based on VolksBot components Fraunhofer IAIS built a service robot for the University of Applied Science Bonn-Rhein-Sieg. The robot has an Neuronics Katena robot arm, a SICK laser scanner and a stereo camera and two 150W motors. Johnny won the second price at the german open 2008 (RoboCup@Home) in Hannover, Germany and also the second price at the world champion chip 2008, Suzhou, China. [10, 11].

3.5 DataBot

The DataBot (see Fig. 9) consists of an UGV and UAV. The UGV is based on a modular mobile platform RT3.³. The three-wheeled differential drive version *VolksBot RT3* is chosen out of the several variants of the *VolksBot* [12] to gather comparatively good values from the odometric wheel encoders (see Fig. 1). It has a size of $700 \times 550 \times 1300$ mm (L×W×H) and a weight of approx. 25 kg. The two wheels are driven by the two 150W

³ <http://de.youtube.com/watch?v=-7ACC8-KYQY>,
<http://de.youtube.com/watch?v=1I.f7v4meBU>

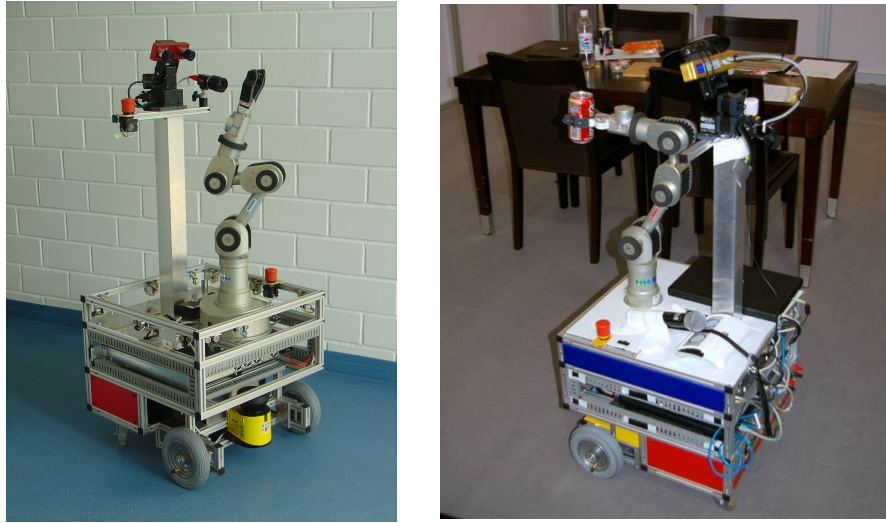


Fig. 8. The *AtHomebot*. A video where the Bot named Johnny introduce itself can be seen at: <http://de.youtube.com/watch?v=A0ZDNmpdUAg>

motors. The robot has a maximum velocity of 1.4 m/s and a maximum additional payload of approx. 25 kg. One of the panoramic vision systems is mounted on the *VolksBot* (see Fig 9), furthermore a continuous rotating 3D laser scanner [13] and a GPS receiver are installed to compare the results for localization (see Fig. 9). A scaleable number of Mac minis (from one to four, CPU 2GHz, Memory 2GB) serve as a computational unit for processing sensor data and controlling the UAV. The UAV is a four-rotors aerial platform, a so-called *quadrotor* [14], that is capable of Vertical Take-Off and Landing (VTOL). Its flight control board is equipped with an inertial measurement unit consisting of 3-axes gyroscopes, 3-axes inertial sensors, 3-axes digital compass and a GPS module. For altitude control a pressure sensor is employed. Fusion of these sensors as well as the control of the four motors is done by means of an on-board 20 MHz-microcontroller (Atmel ATMEGA644P) and four brushless motor control boards. The on-board microcontroller communicates with the four brushless controllers via I²C bus. The quadrotor has a size of 650 × 650 × 220mm (L×W×H) and a weight of 590 g. With an extra antenna the height increases to 550 mm and the weight increases to 620 g. With fully loaded batteries (2100 mAh) it can operate approx. 20 min. Its maximum payload is 350 g. The quadrotor is controlled either by the UGV or a human operator via WiFi, Bluetooth or an analog remote control unit.

4 Conclusion

We have presented the Volksbot our flexible and modular mobile robot construction kit, some variants and reference implementations based on the kit e.g. the RT series, the MarBot, BrennBot, ProfiBot, AtHomeBot and DataBot.

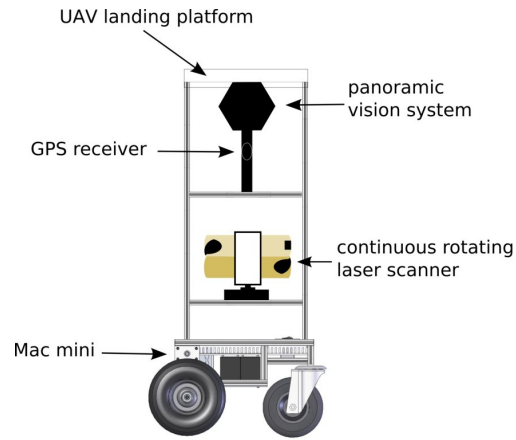


Fig. 9. Schematic survey of the evaluation platform *DataBot*. It is equipped with a panoramic vision system (sphere cube with 11 cameras), a continuous rotating 3D laser scanner, a GPS receiver, a landing platform for the quadrotor, batteries and control computers. A video can be seen at: <http://de.youtube.com/watch?v=48WVz9cEir8>

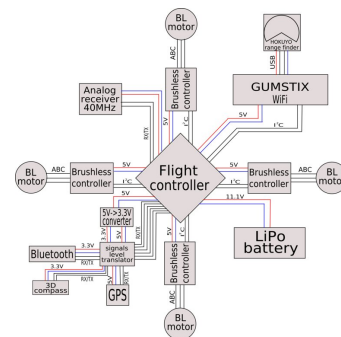
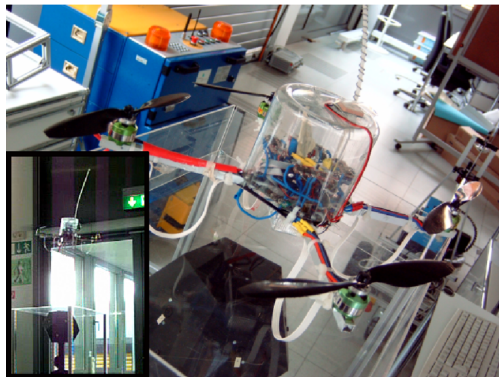


Fig. 10. Prototype of the quadrotor. On the left figure the copter is tested for landing at the RT3 platform. A video can be seen at: <http://de.youtube.com/watch?v=g6xoz4Aw7E8>

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