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BLUEBOT – NAVIGATION AND COMMUNICATION CAPABILITIES FOR ROBOTS IN HARSH ENVIRONMENTS

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Abstract

In safety and security applications, operators of robotic platforms have to act under severe time and mental pressure. Therefore any support of their operating activities makes the whole mission more efficient. In extreme environmental conditions, robotic platforms often have to be moved without line-of-sight control by an operator. The objective of BLUEBOT is to increase the usability and integration capabilities of robots or remotely controlled mobile manipulators in order to be used successfully in more areas of applications. Therefore BLUEBOT offers an add-on to these platforms with sophisticated communication, control, and localization capabilities. This article presents the setup and first results from the BLUEBOT prototype version.

Preface

“Harsh environments” stands for areas and conditions where nobody wants to put his nose, eyes, ears or hands into. High temperatures, radiation, toxic or explosive gases or materials among other dangerous conditions are the reason why often mobile manipulators (or robots) are more appropriate to manage tasks under such harsh environments instead of humans or animals. Very often it is not possible to let a robot do its task autonomously. In these cases an operator has to navigate the robot remotely – often without line of sight to the robot. During a police operation for example, police forces need to gain insight into an internal courtyard to inspect a suspicious object, but there is a big chance to get endangered, if someone personally would go there. Therefore a robot, equipped with a video camera, will be navigated by an officer into that area in order to have a save view of the scene and inspect the object. The problem is that the robot is very difficult to navigate without line of sight especially in an unknown area and in a stressful situation. If the operator is only supported by the robot's camera view it is very hard for him to navigate the robot carefully to any designated location and back. The operator needs an expert with an excellent three-dimensional spatial sense and a lot of costly and time consuming training of these skills. The objective of BLUEBOT is, to lower the requirements to the operator of any remotely controlled vehicle, and to make it easier for him to fulfill this navigation task. BLUEBOT is not a robot by itself, but can be used as an extension for any robot or manipulator in order to support the operator with easy-to-use navigation and communication capabilities.

1. Use cases and requirements

BLUEBOT is part of the preliminary results of a two year German research and development project (DRIEM2: Durchgängige Zuverlässigkeit im Einsatz mobiler Manipulatoren / Consistent reliability in the use of mobile manipulators) which was done by proTime together with a manufacturer of robot vehicles, the Technical University of Munich, the University of Ingolstadt and in cooperation with the EOD forces of the Bavarian police of the “Landeskriminalamt”. During this project, the requirements of seven manipulator tasks to be conducted during different safety and security scenarios were analyzed:

1. Reconnaissance missions: Bringing instruments (gas-sensor, microphone, speaker, video-camera, light, ...) into areas, which are to dangerous or not reachable for humans.
2. Radiation sensing: Due to radioactive findings at scrap dealers, accident with transport of radiation materials, illicit trafficking controls, nuclear power plant inspections, terror attacks or satellite fall scenarios, sources of radiation have to be detected inside a defined area.
3. Transportation and manipulation of suspicious dangerous goods (e.g. improvised explosive device)
4. Provision, rescue or transportation of people and goods into- or out of dangerous areas.
5. Repeater: Using mobile units (robots) to carry and distribute communication hubs in order to establish a flexible wifi communication mesh-net.
6. Manipulation assistance: Provision of additional views (e.g. from the left and right side) to the object to be manipulated by an operator.
7. Shield: Bringing physical protection between radioactive- or explosive sources and people.

From the analysis of these tasks, three areas for technical improvements for working with mobile manipulators were deducted: Positioning, control, and simulation/training. The idea of BLUEBOT was to support control and positioning of any mobile manipulator or robot by using GNSS, IMU and wireless communication technology [Lizarralde, 2003] [Borenstein, 1997] [Koch, 2005]. For our prototype setup we installed the BLUEBOT extension on a 6-wheel Forbot platform from the company Roboterwerk GmbH (Germany).

2. System overview

Based on the requirement analysis an architecture for the BLUEBOT system was developed, which consists of the three main components:

1. high precision positioning (indoor and outdoor),
   to give the operator a better orientation and understanding where he is
2. secure communication,
   to extend the area where the robot can operate
3. intuitive navigation and control,
   to reduce the training needed.

The prototype realization of these three modules will be explained in more detail in the following.

The communication module offers secured video and data transmission via Wi-Fi, GSM/UMTS, radio or satellite link. Wi-Fi mesh-net technology allows for a flexible extension of a communication network coverage by adding several communication hubs (see “box” in figure 1) between the robot and a data sending/receiving controle/repository unit – if needed. Every sensor, which connects to the BLUEBOT-box gets a position stream including longitude, latitude, date, time and quality information in NMEA format every second. Additional compass, barometer, gyro and accelerations data may be configured and is streamed in a protocol based on NMEA standard. The IMU measures acceleration-, gyro-, compass, and barometric values, which are processed in the CPU in combination with odometric data supplied by the Forbot engine controller. In outdoor areas GNSS data are available in addition.

The figure 1 shows the conceptual setup for the communication capabilities of BLUEBOT.

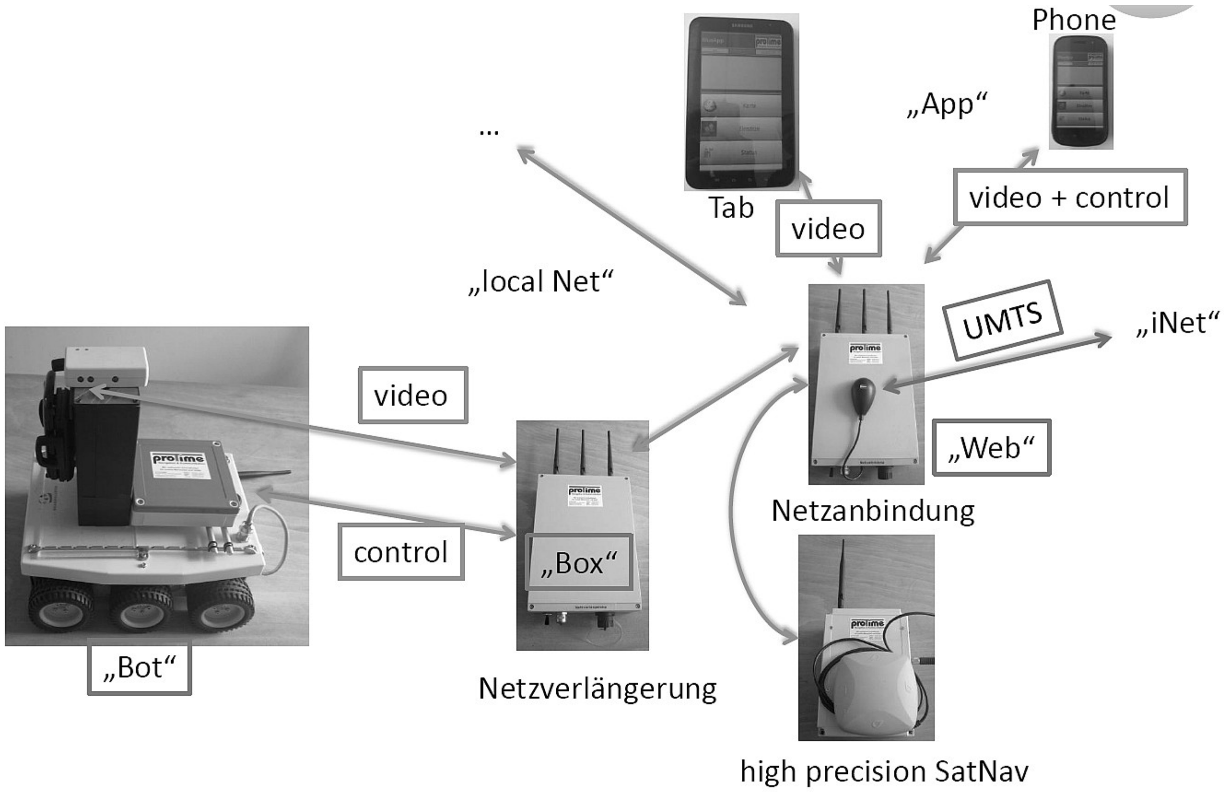

Figure 1: Conceptual communication setup of the BLUEBOT extension

The robots and some additional communication boxes for a flexible WiFi mesh-network which enables ad-hoc communication between the robots, the operator(s) and additional persons (besides the operator) which can get video or sensor data through a App. For high precision Satellite Navigation, there is also the possibility to add a HighPrecision Satellite Navigation box, which delivers locally precise correction data. The mesh-met is self configuring, that means there is no need for a change of setup if additional nodes were added or the radio connection is lost. Also, if there is only one box with a internet connection , either by GSM/UMTS or satellite link, the complete network will have these internet access.

Figure 2 demonstrates the BLUEBOT prototype setup of the positioning components (IMU, proTime BLUEbot box and engine-encoder of the chosen six-wheel Forbot platform.) As the BLUEBOT is independent of the used chassis, we used a small and lightwight chassis (Fig2) for our development and local testing and in a later stage the BLUEBOX was integrated into a much bigger and stronger chassis.

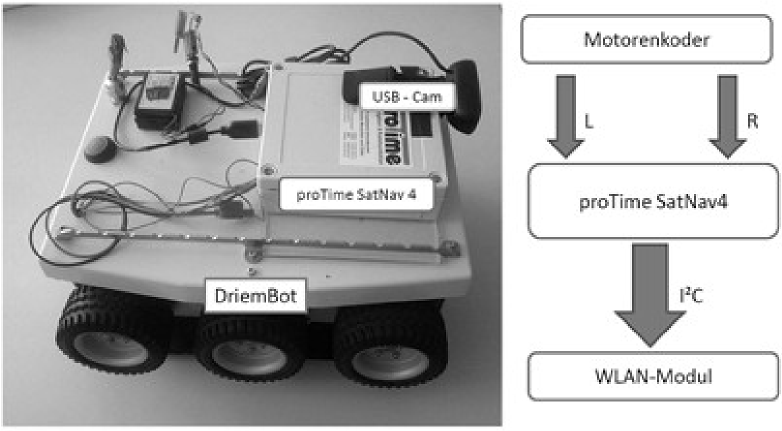

Figure 2: Prototype setup mounted on a six-wheel robot platform (left) and signal sequence (log-file consists of acceleration-, gyro-, compass, barometric-, odometric-, and GPS-values).

The navigation control module (figure 3) is a software application which runs on an Android mobile device. It allows for intuitive two-thumb touch screen navigation, real-time visualization of the trace and orientation of the robot and visualization of live camera views (in case the robot is equipped with a video sensors).

Figure 3: Intuitive GUI of the robot control tablet including video-cam live view

and real-time track of robot's relative positions.

3. Prototype implementation and first tests

In the current prototype version all electronic BLUEBOT components – except the external Wi-fi and GNSS antennas - are installed inside a small box (size, 130*130*37 mm). This BLUEBOT box can easily be attached to or into a robot.

As shown in figure 4 the BLUEBOT extension includes the following electronic components:

- IMU: 3D-Gyro/3D-Accelerometer/3D-Compass with the possibility to use a miniaturized external sensor device to reduce errors from magnetic fields of the motors to the compass sensors.
- Other Sensors (optional): Light intensity- / barometric- / temperature sensor
- GNSS receivers: combined GPS – GLONASS – EGNOS receiver, optional high precision geodätic receiver for high accurency
- Power control including charge control of batteries
- Double prozessing power: ARM Cortex M4 for realtime calculation and an additional linux based communication controller
- Local storage: SD-Card
- Communication: Wifi, two Ethernet ports (can act as router for other internal devices) and optional GSM

The positioning module can be adapted to specific application requirements. Depending on the combination of different positioning sensors (e.g. GLONASS, GPS and GALILEO, IMU, gyro, compass, and odometer) it can be used for indoor as well as for outdoor positioning and can deliver high precision geo-coordinates with an accuracy of centimeters.

For wired or wireless connection to a sensor carried by the robot [Borenstein, 1996], the BLUEBOT offers a number of interfaces.

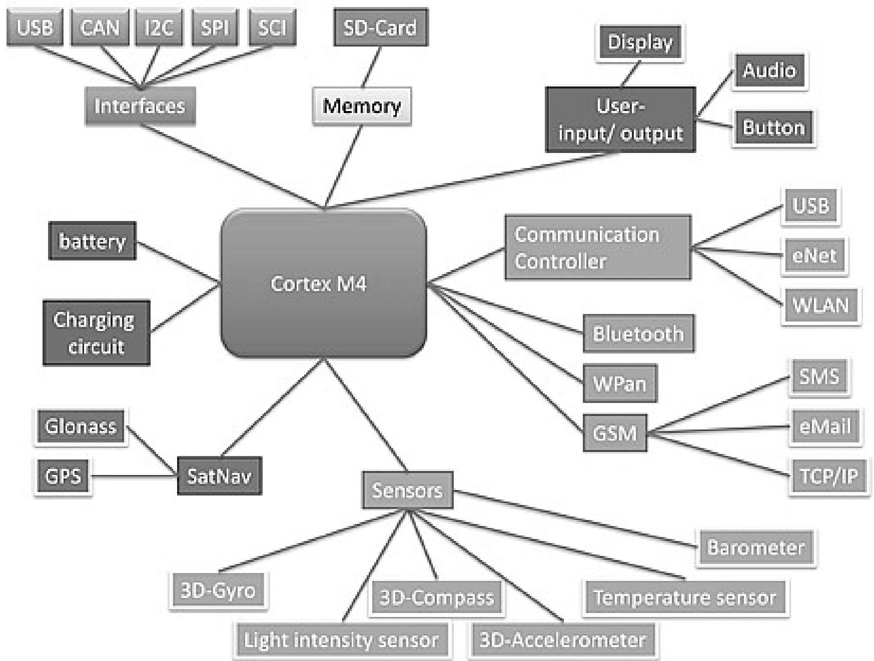

Figure 4: The BLUEBOT's internal components as a sketch

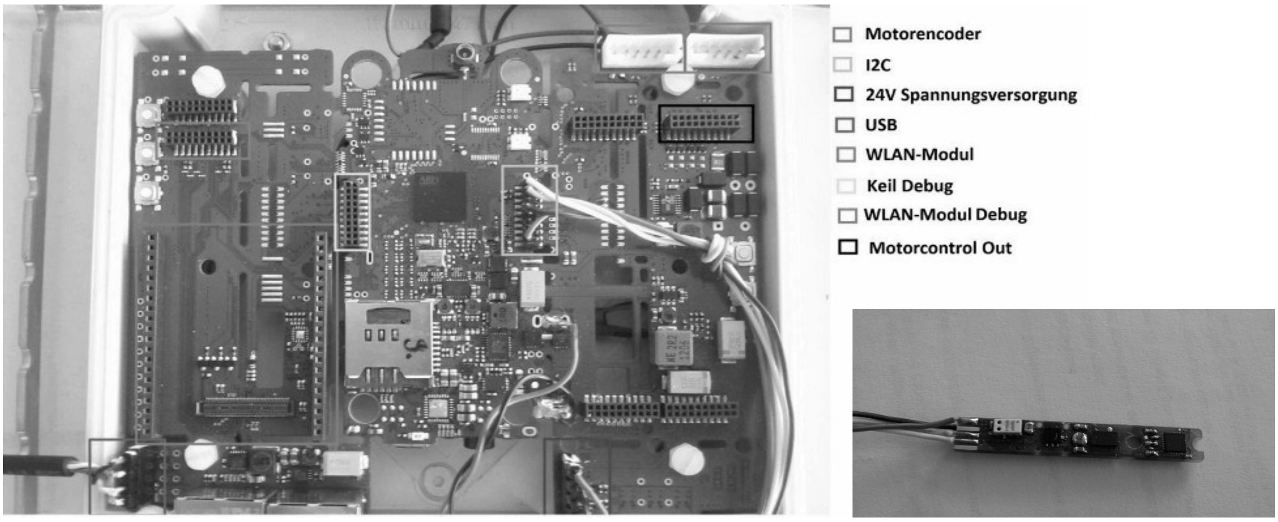

Figure 5: The BLUEBOT's components in reality

The complete electronics is integrated onto a highly integrated 110*120 mm PCB board. As we used a modular approach, only the components needed for a given application have to be used. If there is no need to communication through GSM, the GSM part of the PCB can be omitted. To reduce specially magnetic interferences to the compass sensor, the compass, gyro and acceleration IMU sensors are integrated into a small external PCB which has a size of 5mm*40mm.

In figure 6, you can see a complete robot electronics. To make the BLUEBOT complete to control a robot, you only have to add the power electronics for the motors you want to use. You even can directly connect the encoder signals of the motors to the BLUEBOT. But the BLUEBOT is flexible, if you want to use your given robot control device, BLUEBOT can only handle the communication task (and acts like an ethernet router) or the navigation tasks (and acts like a GPS device and IMU).

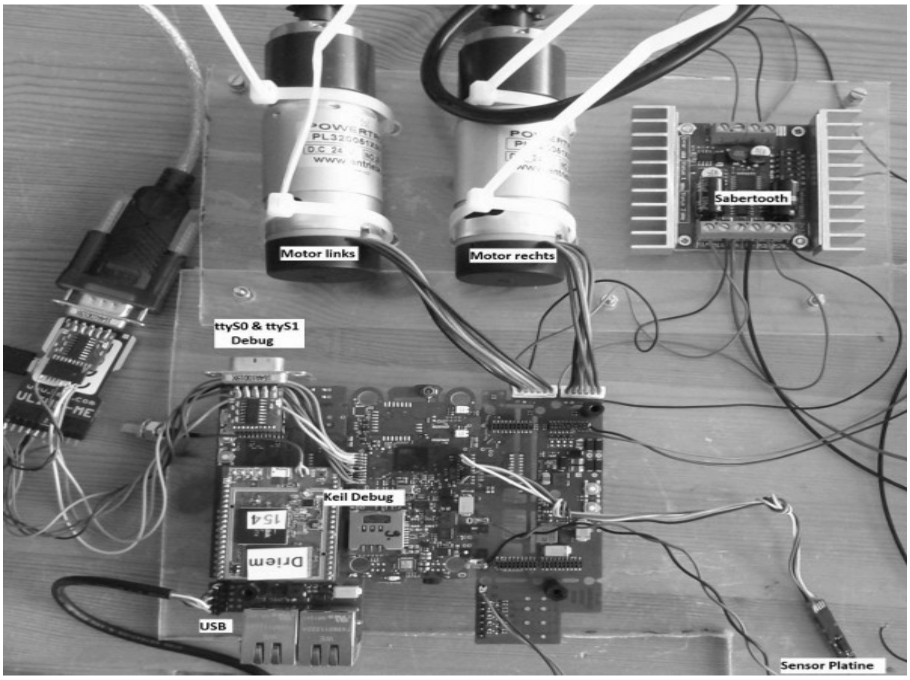

Figure 6: The BLUEBOT's components: complete electronics for a robot with navigation and communication

Figure 7 presents the results of testing the positioning inside an office building. These indoor tests, based on IMU, odometry and gyroscope measurements, resulted in a spatial deviation of less than 10 cm on a 1.5 by 8.0 m rectangular course. The accuracy error increases over time, if the positioning unit does not get a correct position fix from time to time. This could technically be solved by using RFID tags distributed inside the building, which let the robot read known positions of the tags or by receiving GNSS signals from time to time.

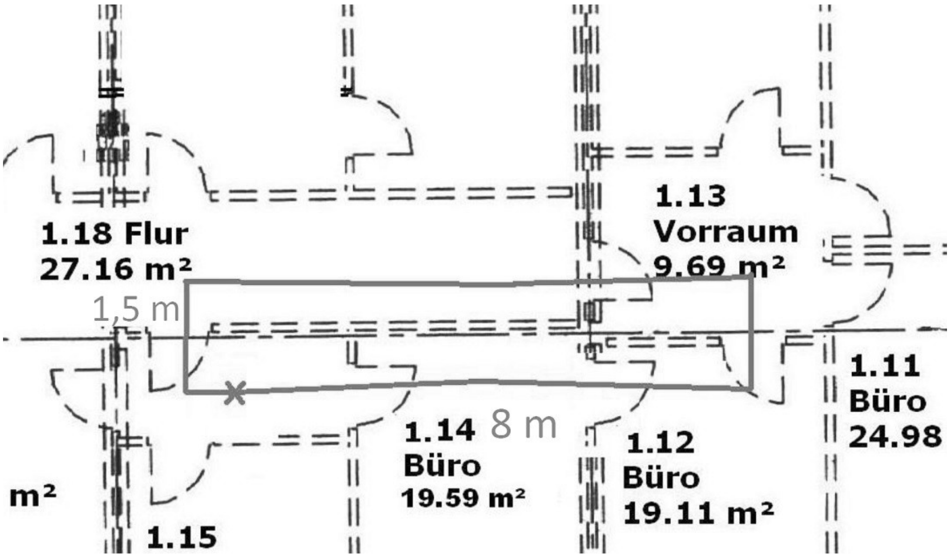

Figure 7: Indoor track based on IMU positioning

At Fig. 8 you can see a picture of our outdoor test, which is located in front of our office building. We used a 5m by 5m course on a lawn. After one roundtrip, we got an error of more than 5 m by using plain GPS signals. This is insufficient to have any advantage for control of the robot. By using the position calculated by different sensor signals and using GPS-GLONASS satellite signals, we came down to an error as low as 10 cm after one roundtrip (Fig 9). This enables the operator to get an exact position of the robot for a better understanding about the position and orientation of the robot. It even makes it possible to use this navigation signals to operate the robot in an (at least semi-) autonomous way.

Figure 8: Outdoor test setup for the comparison and combination of IMU- and GNSS-based positioning

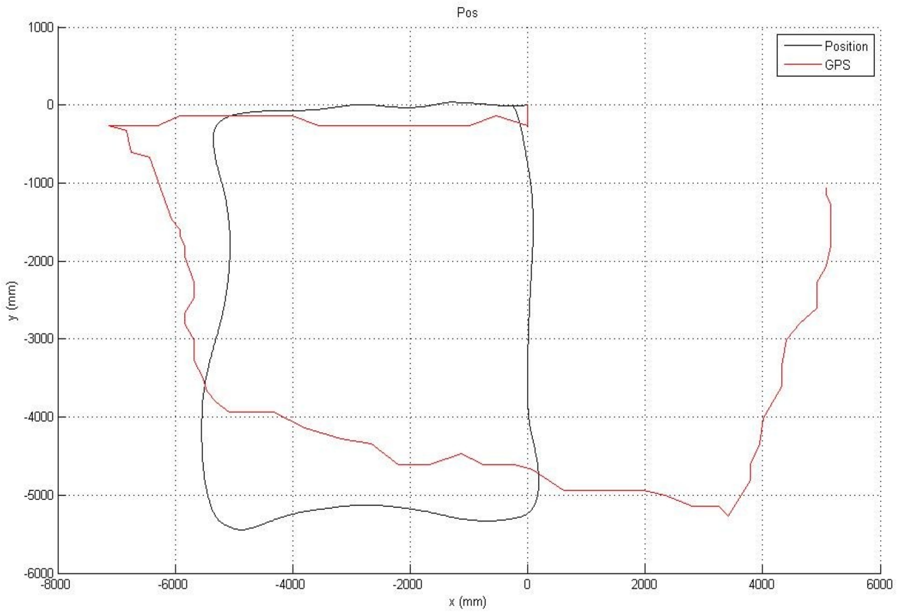

Figure 9: plain GPS (red) and BLUEBOT (black rectangular) position track of the robot.

4. Results and outlook

Currently the BLUEBOT technology is under further development for humanitarian demining applications (EC FP7 TIRAMISU 2012-2016). The objective is to enable mobile demining sensor platforms for high accuracy positioning and reliable communication.

In the TIRAMISU project BLUEBOT will act as a gateway for the demining sensors. Sensors without own communication or positioning modules can be connected through the three interfaces USB, digital inputs and Ethernet. The sensors can store files on an internal FTP server over ethernet, send serial data to the USB or generate an alarm input on one of the four digital inputs. The system will add to every information a position and time stamp and sends the data to a server, where it is stored. Furthermore, the integration of modules for nanotechnology based gas-sensors (project MATRIOSCHKA with the Russian OAO RSS), mesh-net based server components and a data repository service for the location based fusion of data from different sources will make BLUEBOT a comprehensive information management extension for every robotic platform.

Summary

The BLUEBOT is a flexible and modular approach to add communication and navigation technology to any robot chassis. By giving an exact track and orientation to the operator, the requirements for training the operator will be lowered significantly, because there is no need anymore to obtain this information himself out of some video signals. This makes the task of control a robot under extreme conditions, where often is a heavy mental load, more safe and efficient than without BLUEBOT.

Acknowledgements

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