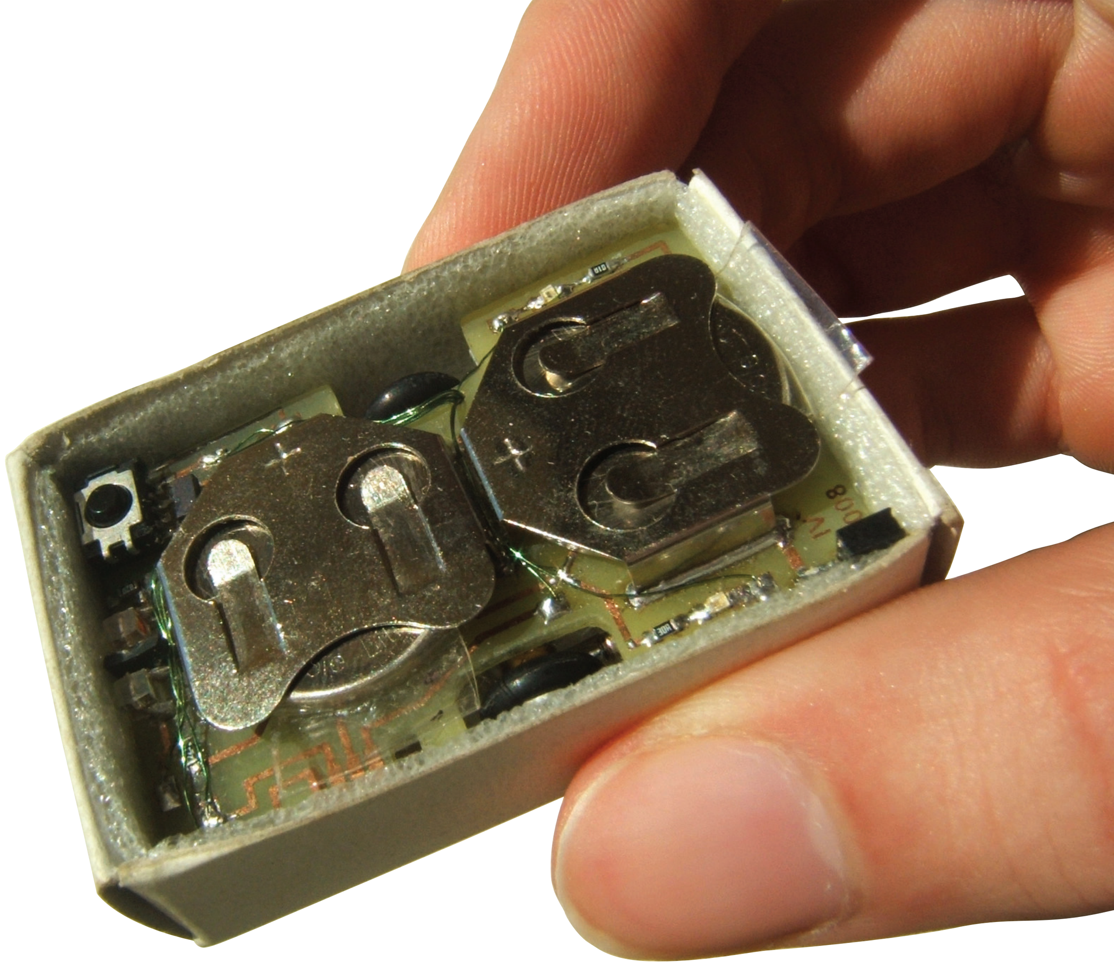
PocketBot

a matchbox-sized

line following robot



dimensions: 48 × 32 × 12 mm

weight: 19 g (body 13g, cells 6g)

speed: 0.35 ms^{-1} (line following)
0.6 ms^{-1} (max)

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Power supply

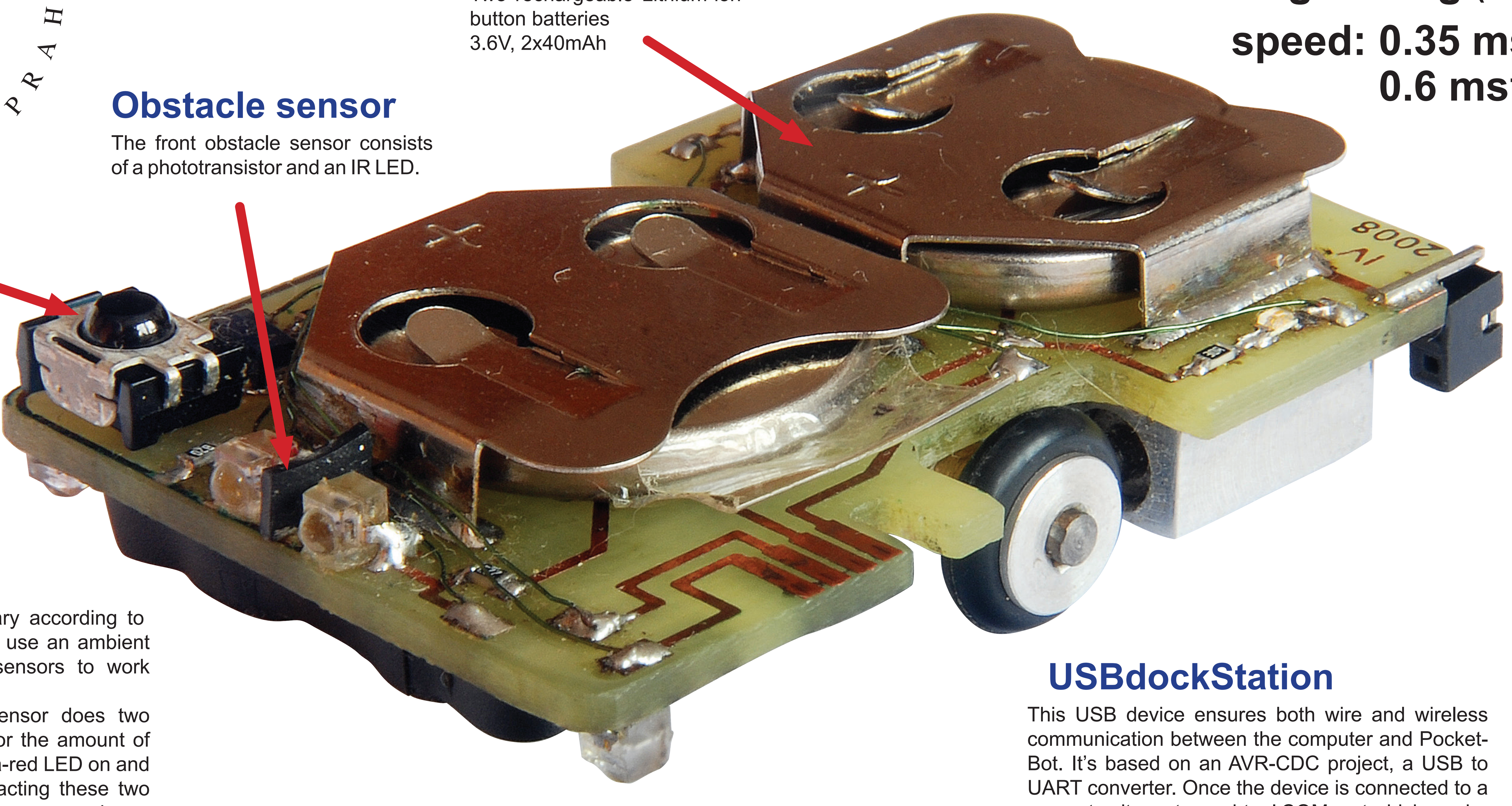
Two rechargeable Lithium-ion button batteries 3.6V, 2x40mAh

Obstacle sensor

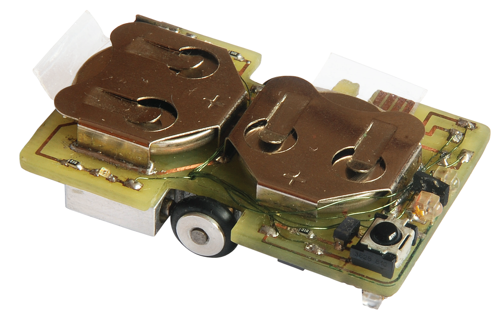
The front obstacle sensor consists of a phototransistor and an IR LED.

Remote control

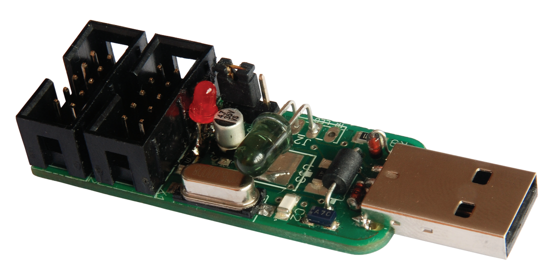
Robot is equipped with infra-red remote control receiver. It can be controlled with a standard remote control or from a PC. Communication uses the NEC remote control protocol.



IR NEC protocol



IR **UART**



USB

Ambient light suppression

Because light conditions often vary according to time and place, it is necessary to use an ambient light suppression algorithm for sensors to work properly.

The method is simple: Every sensor does two measurements. At first, it scans for the amount of ambient light. Then, it turns its infra-red LED on and measures the value again. Subtracting these two values, the bias of ambient light is suppressed.

USBdockStation

This USB device ensures both wire and wireless communication between the computer and PocketBot. It's based on an AVR-CDC project, a USB to UART converter. Once the device is connected to a computer, it creates a virtual COM port which can be accessed from a computer application. PocketBot, USBdockStation, and the PC application communicate with each other through this UART interface, using a particular protocol that was designed for this purpose.

To control PocketBot remotely, I added some extra functionality to the original AVR-CDC firmware: the USBdockStation emulates an infra-red remote control. It has a power infra-red LED and it is capable of sending IR remote control packets as an ordinary remote control.

Sensor calibration

There might be slight differences in characteristics of individual optical components; therefore the sensor module should be calibrated. The calibration is done manually in two steps:

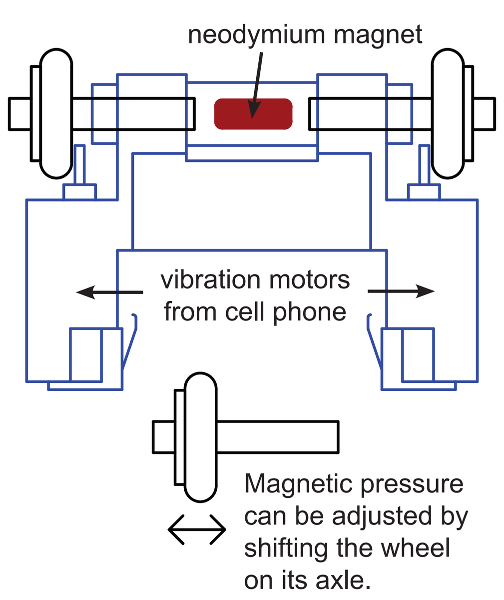
1. Offset calibration

All sensors are placed above the black guiding line. Once the calibration command is received, all sensors measure the surface reflexivity and measured values are stored in memory. Those are the offset calibration values. From now on, all measured values are automatically corrected with this offset. (Each time a measurement is made, the offset is simply subtracted from the actual value). As a result, all sensors will return equal value when they are located above the black line.

2. Gain calibration

During the gain calibration all sensors are placed above a white surface. Some sensors might be more sensitive than others, so the measured values differ from each other. But because the surface reflexivity under the sensor module is supposed to be equal, the gain coefficients for each sensor can be easily calculated. For future measurements, every measured value will be corrected (multiplicated) with its gain coefficient; so that all calibrated sensors will have similar characteristics.

Consequently, the calibrated sensor module will output normalized values.



Undercarriage

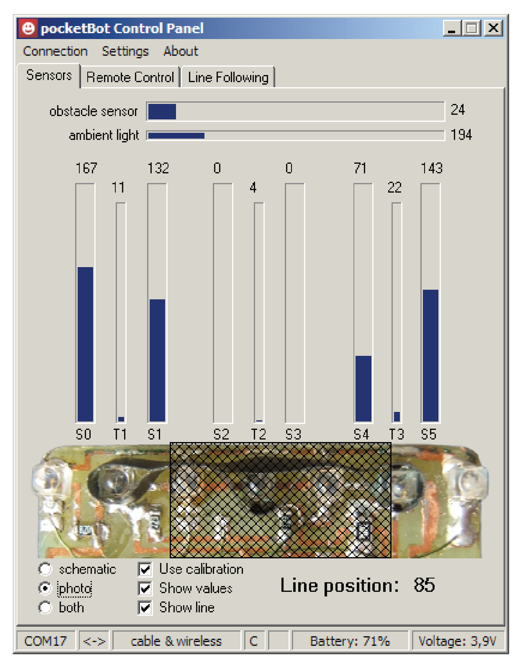
Two separately driven wheels (8mm diameter) provide differential steering.

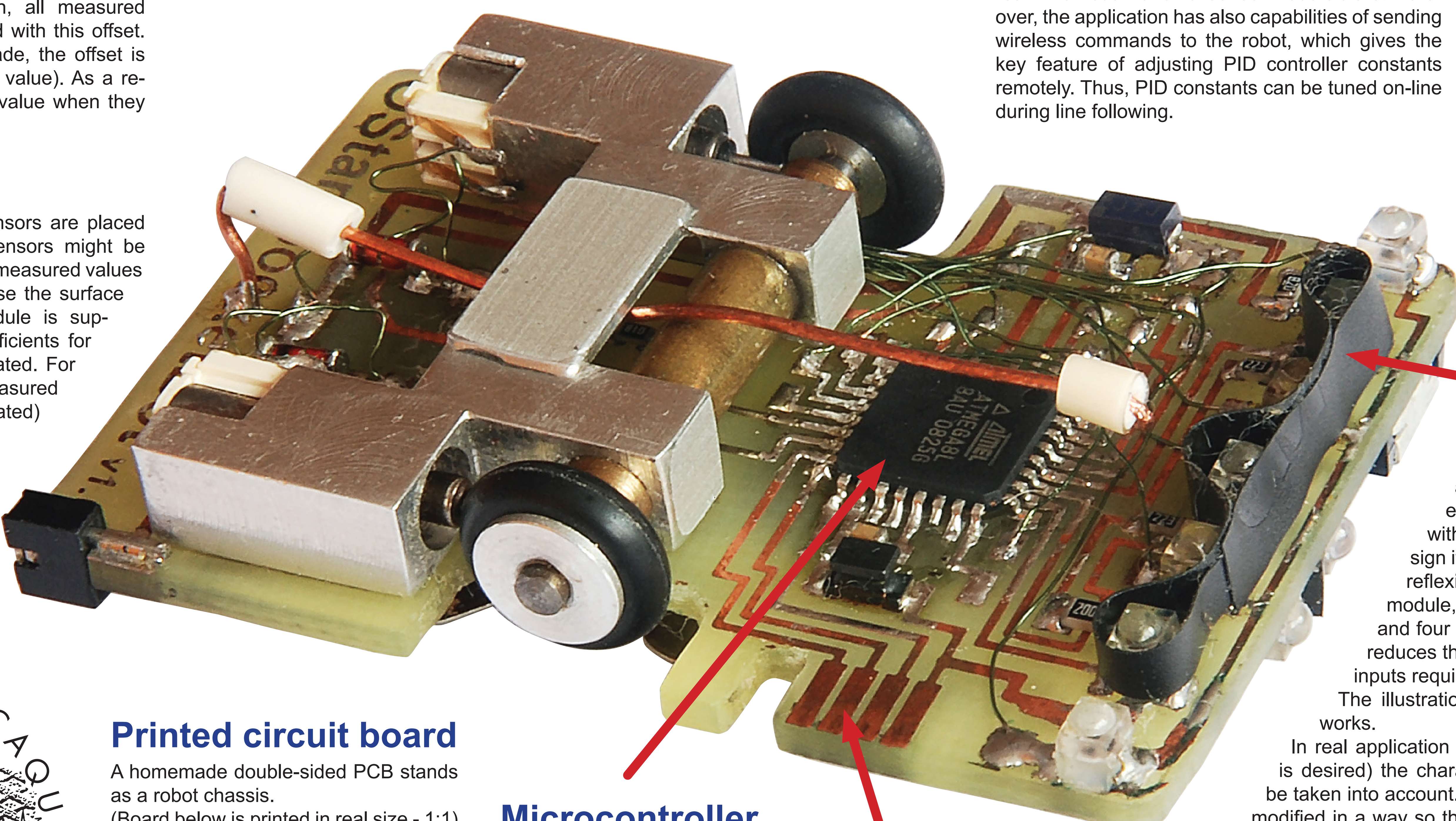
The dimensions of the gear mechanism were crucial due to considerable space constraints. Fortunately, I met Josef Vandělík who designed and manufactured the wheelframe for my robot.

The wheelframe employs a friction gear system with magnetic pressure. A neodymium magnet in the central tube attracts wheel axles, pressing each wheel to the motor shaft.

PocketBot Control Panel

The PC application offers sensor diagnostic; it shows real-time visualization of sensor module state. Moreover, the application has also capabilities of sending wireless commands to the robot, which gives the key feature of adjusting PID controller constants remotely. Thus, PID constants can be tuned on-line during line following.





Sensor module

The sensor module consists of 3 phototransistors and 4 infra-red LEDs. The emitters and detectors are placed in a row alternately so that each phototransistor is surrounded with two IR LEDs. Thanks to this design it is possible to measure the surface reflexivity on six spots under the sensor module, using only three phototransistors and four IR LEDs. Generally, this approach reduces the number of components and ADC inputs required for a line sensor module.

The illustration bellow shows how this method works.

In real application (especially when high refresh rate is desired) the characteristics of IR components must be taken into account. The scanning sequence has to be modified in a way so that the sensors do not interact with each other due to reaction delays.

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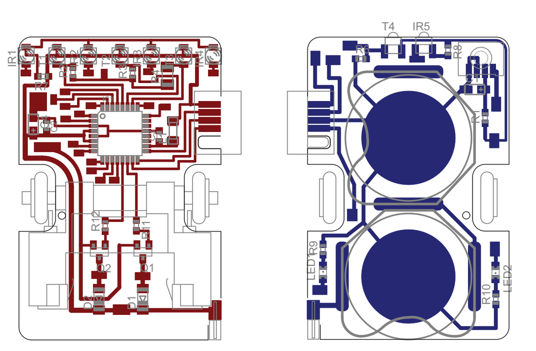
Printed circuit board

A homemade double-sided PCB stands as a robot chassis.
(Board below is printed in real size - 1:1)



Microcontroller

Atmel ATmega8
8-bit AVR, 8MHz internal oscillator,
8KB FLASH, 1KB SRAM
programmed in C

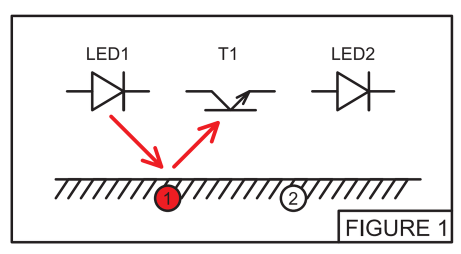
Connector

An 8-pin connector offers ISP and UART interface for programming and debugging.

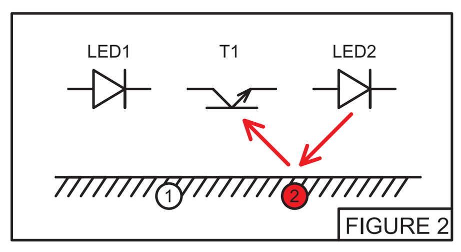
Line following

The position of the line is evaluated 30 times per second. The PID controller adjusts the motors' speed according to the actual line deflection and previous states.

LED1 is emitting infrared light that reflects to the phototransistor T1, hence the light reflexivity at point 1 is measured.



Then, LED1 is turned off and LED2 starts emitting IR light. The phototransistor T1 measures the light reflexivity at point 2.



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