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Corvid: A Versatile Platform for Exploring Mobile Manipulation

Michael Zillich [1] and **Michael Baumann** and **Wolfgang Knefel** and **Christoph Längauer**

There is an abundance of different robot platforms used in various fields of robotics. Some are custom made, others are more or less standardised off-the-shelf products. In fields such as epigenetic robotics or swarm robotics these are typically small inexpensive platforms of limited complexity ("ton on wheels" design) such as the widely used K-Team Khepera [10], EPFL e-puck [7], Eddy [1] or Surveyor SRV-1 Blackfin [15] to name a few. These platforms are well suited to operate in specially prepared "arenas" (enclosures with various markers or obstacles, mazes etc.) and to perform experiments on navigation and obstacle avoidance. Due to their small size and simplicity however they are not so well suited to perform more complex tasks including manipulation (though the Khepera can be equipped with a 2 DOF gripper).

More complex platforms like the late Sony Aibo, or more recently humanoids like iCub [14], the Fujitsu hoap series or the Aldebaran Nao [5] offer many degrees of freedom and a sturdy design. However often only a subset of the DOFs is used in learning experiments, e. g. with a sitting humanoid where only the arms and perhaps torso are moved.

Wheeled platforms such as Stanford's STAIR [3], DLR's Justin [6] or UMass's uBot [4] offer effective mobility and good manipulation skills. Their size, complexity and also price however limit their applicability in autonomous learning: errors made by such a platform are expensive and dangerous.

A MobileRobots Pioneer 3-DX with optional 7 DOF arm seems the best choice so far, but is still on the heavy, slightly dangerous and expensive side (compared to lightweights like the Khepera). Also the rather high mounting of the small arm limits its workspace at floor level.

In summary, none of the above fulfilled our requirements for performing experiments in learning mobile manipulation:

- inexpensive to purchase and maintain
- safe to operate, to allow use in student projects
- able to carry an arm
- sufficient onboard processing power
- WLAN capabilities to enable offloading compute-intensive tasks to a PC
- possibility to connect standard peripherals like webcams via USB
- able to traverse "rough terrain" like door thresholds and cables, i. e. able to navigate on the floor in typical labs rather than in specific "arenas"

To fill this gap we present the robot platform Corvid. The name Corvid derives from the configuration of the gripper and camera (an eye in hand setup) which aims to mimic corvids (ravens, crows, jays) which are adept manipulators where similarly the eyes are in a fixed relation to the beak.

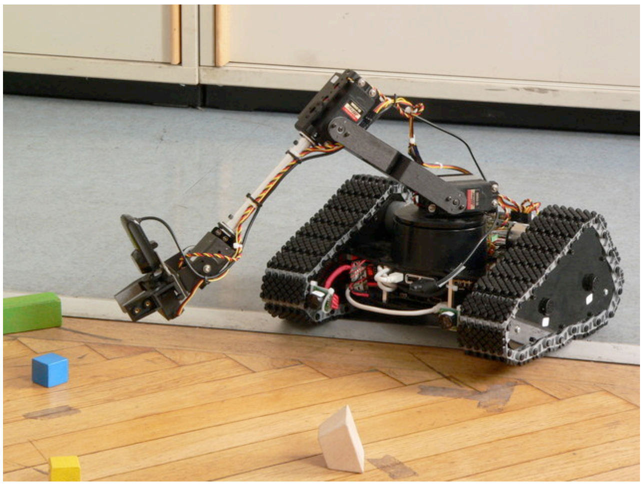

Figure 1. Corvid robot platform

Nature basically developed two concepts for manipulation. The first one involves eyes and independently moving manipulators, as in hominids (various apes and of course humans) but also sea otters or octopi. The second one involves eyes and manipulator (beak, mandibles) in a fixed relation, as in birds (of which corvids are amongst the most skilled) and various insects. Note that birds often also use their feet very adeptly, typically in conjunction with the beak. So strictly speaking they belong in both categories. It seems likely that the added complexity of independently moving manipulators fostered the development of advanced cognitive skills in such species. From that point of view our robot platform is certainly more insect-like than bird-like. But our point here is not to define strict categories (which is often more a hindrance than a help anyway) but to indicate where we place our robot design with respect to biological examples. And a bird with a flexible neck looking around and pecking and picking things seems to be the closest biological relative.

On an orthogonal axis we can distinguish manipulators composed of jointed limbs vs. highly flexible manipulators (such as the tentacles of octopi, an elephants trunk, or an ant-

[1] Vienna University of Technology, Vienna, Austria, email: zillich@acin.tuwien.ac.at

eaters tongue). The latter would seem to rely more heavily on fine-grained tactile information rather than visual feedback, and as such is very difficult to achieve with current tactile sensing technology.

While independently moving manipulators allow greater flexibility, and are mimicked in humanoid robots, we opted for the fixed manipulator-eye arrangement for various reasons. The smaller number of degrees of freedom generally results in smaller (and thus hopefully more manageable) learning problems. Also from a pragmatic engineering perspective it is easier if the manipulator can not obscure the view of the camera, especially as the gripper approaches an object. Humanoid robots either have a rather limited workspace right in front of the chest with arms coming in from the sides, or would require a long, flexible neck otherwise. Moreover mounting the camera on the arm provides an active camera without the need for an extra pan/tilt unit.

Hardware The platform basically follows the ton on wheels design, where however the wheels are replaced with threads. The large contact area of the threads improves stability compared with only three contact points in case of the typical two powered wheels plus caster wheel. The threads also allow mounting low obstacles like door steps of up to about 3 cm height. This design is popular in field and rescue robotics, e. g. the Mesa Robotics Matilda [12] or iRobot PackBot [9] series. These platforms are built for extreme durability which is reflected in their steep price tag.

We chose the inexpensive Lynxmotion TriTrack chassis [11] as a basis and added a Lynxmotion AL5D arm with 4 degrees of freedom plus gripper. A fifth degree of freedom can be added via an optional wrist rotate joint. The arm has a forward reach of about 260 mm (see Figure 2) and can carry loads of up to 300 g. As can be expected from an arm powered by RC servos, due to joint backlash accuracy is rather low with maybe $\pm$ 5 mm in fully extended position. The overall dimensions of the platform are L $\times$ W $\times$ H = 270 $\times$ 280 $\times$ 560 mm (arm fully upright) with a weight of 3 kg.

A 2600 mAh Ni-MH battery provides 12 V for the drive motors and a power regulator provides additional 5 V for the RC servos of the arm and the electronics. The two 12 V DC drive motors are controlled by a Dimension Engineering Sabertooth 2x5 dual motor controller. The RC servos of the arm are controlled by a Lynxmotion SSC-32 Servo Controller.

The main robot controller is a gumstix Overo Fire board [8] with a Texas Instruments OMAP 3530 CPU (an ARM derivative) running at 600 MHz, carrying 256 MB RAM, 256 onboard flash and an additional 2 GB of microSD flash memory. It also offers a DSP and 3D graphics acceleration. The board furthermore provides USB 2.0, WLAN and bluetooth, HDMI video output, Audio I/O, I2C, A/D and PWM lines. A powered 4-Port USB hub allows connection of additional peripherals, like a webcam.

Regarding sensors, the robot is equipped with 8 Devantech SRF-02 ultrasonic range sensors for measuring distances from 15 cm up to 6 m, connected via I2C bus. A Logitech QuickCam Pro USB webcam with a high quality auto focus Zeiss lens is mounted on the gripper and provides images of up to 1600 $\times$ 1200 Pixel at frame rates of up to 30 Hz.

Software The gumstix board runs Linux (kernel 2.6.29) and thus supports almost any peripherals You can think of.

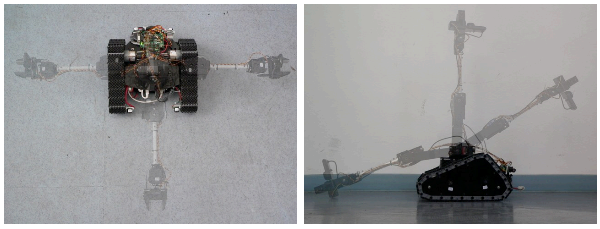

Figure 2. Manipulator workspace

Development is based on the OpenEmbedded [13] development environment.

Corvid offers a driver for the Player project [2] that implements the position2d (moving about in 2D), sonar, camera, actarray (actuator array - the arm) and gripper interfaces. Support for the limb interface (inverse kinematic control of the arm) is planned. The player server running on the platform can be accessed via WLAN.

Conclusion The platform we presented is an inexpensive option to start exploring mobile manipulation. The complete platform costs around 1500 EUR (excluding tax and shipping), which is mainly composed of 250 EUR for the chassis, 500 EUR for the arm, 350 EUR for the controller board and the rest for batteries, sensors and electronics.

The emphasis lies on maintainability and safety, to allow longer term unattended experiments and also operation by students without the worry of dangerous and expensive accidents. And if things do go wrong, single servos or DC motors can be replaced for 30 to 40 EUR.

The robot controller provides sufficient processing power to run software of medium complexity including image processing onboard. Its rich connectivity offers the possibility to add own sensors (for example IR distance sensors via I2C or even a Hokuyo laser range finder via USB) or further actuators like RC servos.

We will provide a webpage which summarises all parts and instructions at `www.acin.tuwien.ac.at/1/research/v4r`.

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