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# Development Of An Autonomous Anthropomorphic Mobile Agent

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## ABSTRACT

Pneuman is an autonomous anthropomorphic mobile agent. Its purpose is to provide a robust platform for robotics research. This is made possible by integrating a high performance embedded microprocessor with numerous sensors and actuators. The subsystems of Pneuman are entirely modular to allow expansion for future project goals. The platform integrates a variety of sensors and actuators to provide a human-like appearance.

## PHYSICAL SYSTEM

### Electrical Subsystem

The electrical/control system of Pneuman includes the control computers, device drivers, output devices, sensors, and power regulation hardware (Figure 1). The main computer is a ZF Microsystems 486 embedded PC/104 computer. Additionally there are three Motorola 68HC11 microcontrollers. The power system includes two 3.5 amp-hour batteries and voltage regulation circuitry.

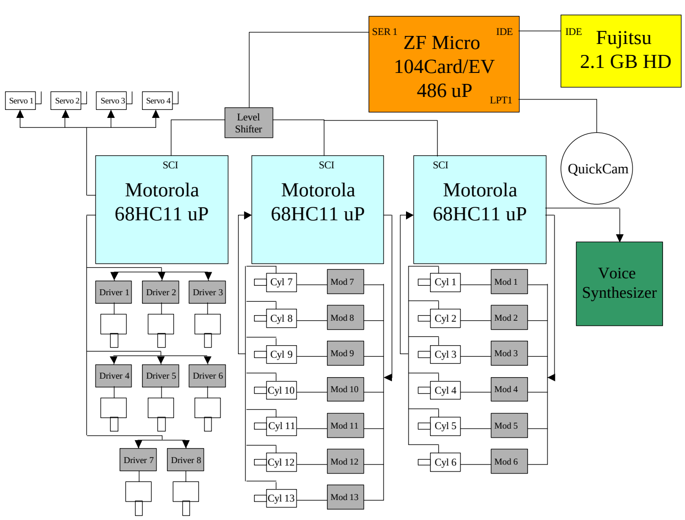


**Figure 1. Block Diagram**

An embedded 486 computer, the ZF 104Card/EV, contains all of the standard features of a desktop computer including two RS-232 ports, a parallel port, an IDE controller, a VGA port and 16 megabytes of RAM. The entire package is contained within a PC/104 form factor, making this is an ideal processor for the given application. Additionally, there is a Fujitsu 2.1 gigabyte hard drive attached to the IDE bus. An RS-232 port is connected to the 68HC11 microcontrollers and used to send the control signals. A Logitech QuickCam© is connected to the parallel port. This configuration provides the controller with all of the visual data. The embedded 486 processor operates on the Red Hat© Linux 5.2 operating system, which provides a robust multitasking environment for process control.

Three Motorola© 68HC11 microcontrollers operate on Mekatronix© TJ Pro circuit boards, each with 32k of non-volatile SRAM. Each microcontroller is contained in an individual module that brings out the connections of port E for analog-to-digital conversion, port A for pulse width modulation (PWM) and two memory mapped input/output ports. Each module shares a common SCI receive line from the RS-232 to TTL conversion circuit. The transmit line of each processor passes through a tri-state buffer, and remains connected to a high impedance line until the correct command signal is received. The processor then transmits the received command back to the 486 for error checking, disconnects the transmit line from the SCI bus to avoid a data collision and performs the requested task. Each module is capable of generating eight PWM signals, eight direction signals, and the A/D conversion of eight analog inputs. Furthermore, if additional hardware is added to the platform, another module can be designed that conforms to the SCI bus configuration, and will control the new hardware. The device drivers are needed to convert the TTL level signals from the microcontrollers to useable power signals.

There are two types of drivers present in Pneuman's control system. The motor driver has two inputs, one for direction and one for the PWM signal. There are a total of eight motor drivers used, four to control the direction of the drive wheels, and four to turn the drive wheels. The second type of driver is used to control the solenoid-operated air valves. There are two inputs, one for direction and one for PWM.

Power is provided to the computers from two 12-volt Energizer NJ1020 intelligent batteries. These batteries use the latest nickel metal hydride technology, increasing their energy density when compared to standard nickel cadmium batteries. The batteries are connected in series, thereby providing unregulated 24 volts to supply the motors and solenoid valves. Additionally, the 24 volts is fed into voltage regulation circuitry for computers and logic devices.

A VX860 speech synthesizer module from RC Systems, Inc. is used to provide Pneuman with speech. The module receives ASCII data from a memory mapped output port of a 68HC11, and, upon receiving a carriage return, outputs the text as spoken words.

The sensor suite of Pneuman consists of ultrasonic rangers (sonar), a color video camera, and voice recognition. The sonar modules are used for short-term navigation and obstacle avoidance, and the video camera allows for basic object tracking and navigation. The voice recognition allows verbal commands to control Pneuman.

## Mechanical Subsystem

The mechanical subsystem of Pneuman consists of the physical structure, the actuators and the drive system. It resembles a human; has a head, two arms, and rests on a mobile base (Figure 2). There are 15 degrees of freedom (DOF). Eleven DOF are actuated by pneumatic

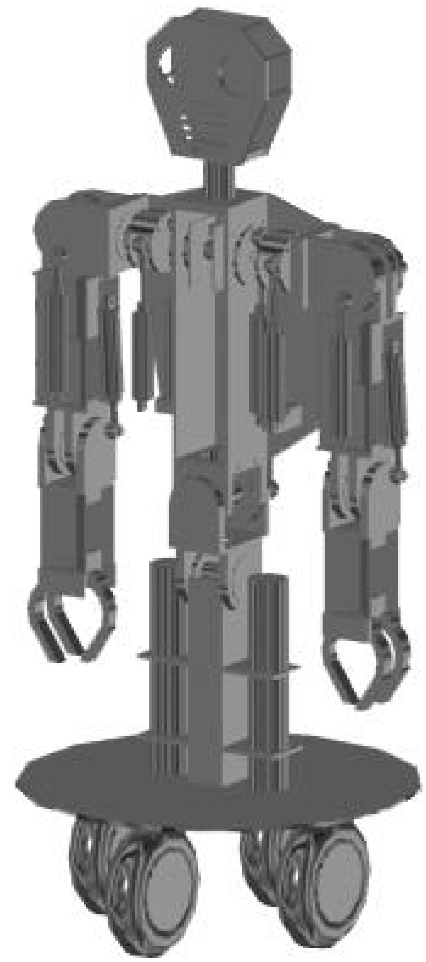

**Figure 2. Physical Structure**

cylinders, and four are actuated by motors. The DOF allow Pneuman to pan and tilt the head, abduct and adduct the arms, bend each elbow, and abduct and adduct the waist, and open and close each gripper. The combination of these movements allows Pneuman to operate in a human-like manner.

Pneuman uses two different types of actuators: double acting pneumatic cylinders and electric motors. The pneumatic cylinders are used throughout the structure, except for the drive system. Double acting pneumatic cylinders offer an increased life span over other forms of actuation, and yield a higher force per weight ratio as compared to conventional actuators.

The pneumatic cylinders on Pneuman are operated with a closed loop feedback system thereby allowing proportional control. There is a linear displacement transducer mounted on each cylinder, and the output of each sensor is input to an analog-to-digital converter. The control computer then generates the appropriate valve command signals. A 5-way valve and two 2-way valves control each cylinder (Figure 3). The 5-way valve determines the direction of travel. One of the 2-way valves controls the pressure inlet, and the other controls the cylinder exhaust. Both 2-way valves are simultaneously pulse width modulated to allow the piston to move in small increments, and stop anywhere along their travel range. All of the valves and the required driver circuitry are contained in a valve module (Figure 4).

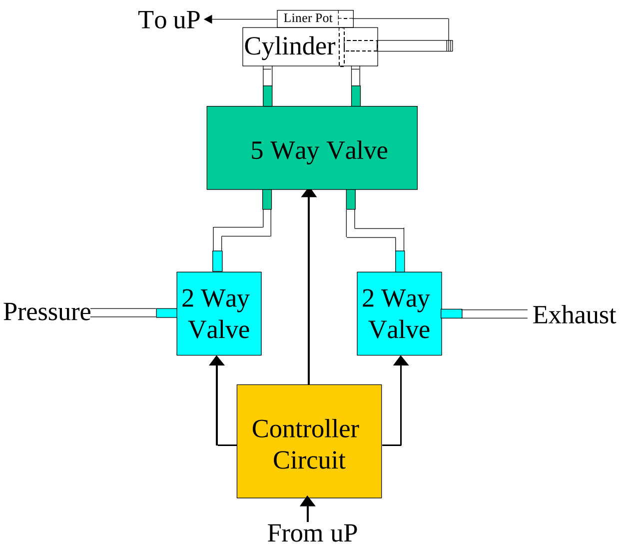


**Figure 3. Cylinder Control Structure**

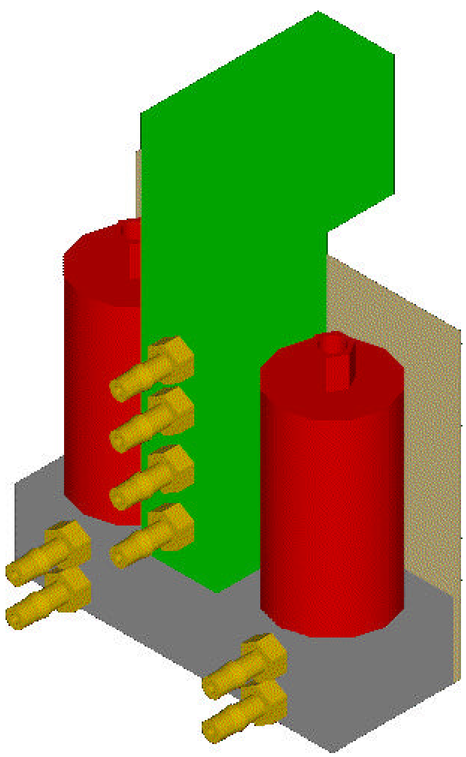

**Figure 4. Valve Module**

Although the pneumatic cylinders offer some advantages over motors, conventional motors are still used in the drive system. Four of the motors are used to drive the wheels, and the other four are used to steer the wheels. This configuration is called a “synchro” drive system. It offers improved mobility over other arrangements. This will allow Pneuman to move in any direction and rotate about a center pivot point.

## SOFTWARE SUBSYSTEM

The software subsystem is comprised of two main components, the code for the low-level control system and the code for the embedded 486 computer. The code for the low-level control is being designed using the Image Craft C Compiler for execution on the 68HC11. The code enables the 68HC11 to generate a variety of PWM signals using only three or four timers. The timer interrupts are multiplexed and used to control up to six pins, however, up to ten pins can be accommodated. Linear displacement transducers are used in a feedback loop to determine the position and speed of the pistons. Adjustments are made to the duty cycle of the PWM signals based on the feedback from the transducers.

The code contains all the routines necessary to control the sub-systems of the platform. The embedded 486 computer gives a specific address to each 68HC11 based on its primary function. Commands sent to every microcontroller contain a specific address indicating which system to actuate. The microcontroller located at that address would respond to the command while the others remain idle. This design allows other systems to be added on to the platform by assigning them a new control addresses. When the 68HC11s are powered up, the software initializes all systems into a wait state until control commands are received from the high-level processing system. A string set, terminating with a carriage return, instructs the low-level microcontrollers to perform a desired operation.

The code on the embedded 486 computer is being developed in the C programming language for the Red Hat© Linux 5.2 operating system. The code consists of six modules, all of which are individual processes (Figure 5). The main executable is a process manager that initializes memory space for the other processes and executes the requested

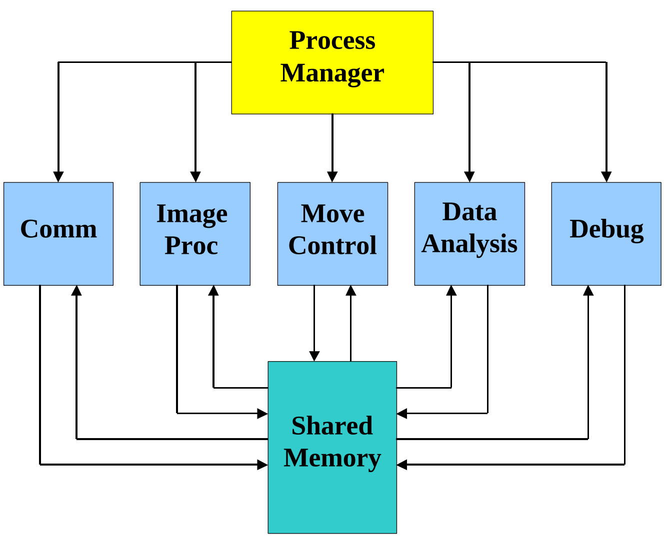


**Figure 5. Software Block Diagram**

modules. The communication module is necessary for control of the serial port. It sends command strings to the 68HC11s, and repeatedly checks a send queue to determine if there are any commands waiting to be distributed. All returned strings are stored in a receive queue for processing. The image processing module requests frames from the color camera and processes the data according to a predetermined algorithm. The results from the processes are then sent to the other modules via a shared memory space. The movement control module keeps precise records of the current states of all the actuators. This data is used to determine what control is necessary to move to a desired position. The data analysis module will contain the primary functions for all of the data processing. This module enables autonomous control of the entire system. All the other modules contain the data input and output functions to provide the data analysis module with all the necessary parameters. A debug module is included in the design, enabling human intervention into the control of the platform. The debug module provides a screen image of all the data gathered by the system, and allows an override of any control parameters.

## CONCLUSION

Pneuman is a robust platform for robotics research. The modular control structure of the platform enables the achievement various project goals. A variety of sensors allow Pneuman to behave autonomously. The anthropomorphic mechanical design provides human-like motion and control.