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PUMAII

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Overall Description

Project Description

The project's overall objective is getting PUMAII ready to successfully compete in the intelligent Ground vehicle competition (IGVC) June 2010. This includes software and hardware integration to implement a state of the art robot control system.

Major software blocks:
1) Motor control system
2) Obstacle avoidance/detection software
3) Image processing for line and pothole detection
4) GPS waypoint navigation

Major Hardware Blocks:
1) Custom built power regulation boards
2) Optimized integration of hardware sensory system.

Testing & Verification:
1) Real time processing of most independent blocks.
2) Robot dynamics and control simulation
3) On the field runs.

PUMA Description

PUMA is an autonomous ground vehicle that was built to meet all the requirements of the IGVC competition rules (these rules are summarized in a later section). Its power is supplied by four 12 volt batteries.

Figure 1: PUMA on work stand, Spring 2007

PUMA is a 3-wheeled robot; the 2 front wheels are the drive wheel and the rear wheel follows. It is equipped with 3 Quicksilver drive motors and 3 Quicksilver steering motors. These motors also have their own software for testing and calibration.

Figure 2: Drive Motor

Its sensor devices include ultrasonic transducers, video cameras, and a SICK laser range finder.

Figure 3: Ultrasonic transducers (blue boxes)

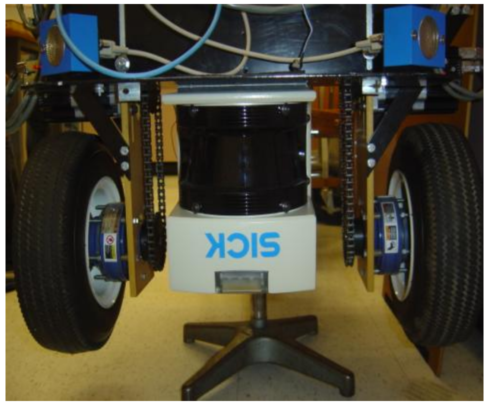

Figure 4: SICK Laser Range Finder

Project Scope

What value will we add to PUMA?

We will develop a working configuration for PUMA in the form of a master control software module. It will be the main control for PUMA's motors and sensors. Basically, the master control module will determine which processes have execution priority and determine the appropriate response to sensor input. For example, PUMA is mapping its location, saving estimated position in its map grid when the laser sensor indicates an obstacle in the path, master control will process the higher priority obstacle interrupt by suspending the mapping process and then executing obstacle avoidance and path planning software.

We will also be adding obstacle avoidance, path planning and motion control software. The most challenging software module we will develop is a simultaneous location and mapping (SLAM) component. The idea behind SLAM is that as the robot navigates through its world, it creates a map of its path and any obstacles found. When the robot traverses the same course again and encounters an obstacle, it checks its map and associated probability grid to determine its position in the world. The idea is that as the robot runs through its course multiple times and encounters the same obstacle, the probabilities in the probability grid become stable near 1, thereby letting the robot determine its location accurately. This in turn allows the robot to navigate more quickly and safely through a course.

IGVC

The Intelligent Ground Vehicle Competition will be held in June, 2010 at Oakland University in Rochester, Michigan. The competition rules for 2009 are found at http://www.igvc.org/rules.htm. There are three parts to the contest: (1) autonomous challenge, (2) design competition, and (3) navigation challenge.

The autonomous challenge objective – A fully autonomous unmanned ground robotic vehicle must negotiate around an outdoor obstacle course under a prescribed time while staying within the 5 mph speed limit, and avoiding the obstacles on the track.

The design competition is a written report and oral presentation. Design innovation is a primary objective of this competition. Two forms of innovation will be judged: technology (hardware or software) that is new to the competition and a substantial subsystem or software upgrade to a vehicle previously entered in the competition.

The navigation challenge allows the use of a GPS (global positioning system) on a different obstacle course.

Realistic Applications Constraints in Design

- **Intelligent Transportation Systems** – Collision Avoidance, Lane Departure Warning, Automated Highway Systems, Vehicle Safety Systems

- **Military Mobility** – Mine Detection, Unmanned Weapons Deployment, Surveillance Systems

- **Manufacturing** – Machine Safety, Material Handling, Unmanned Storage Systems

Process Design

Our design is based on the strategies laid out in the Hatley and Pirbahai book "Strategies for Real-Time System Specifications." This allows us to develop robust systems quickly and accurately. The design process consists of the following: context diagram, data / control flow diagram (the what and when), architecture diagram (the how), design, implementation and testing/verification.

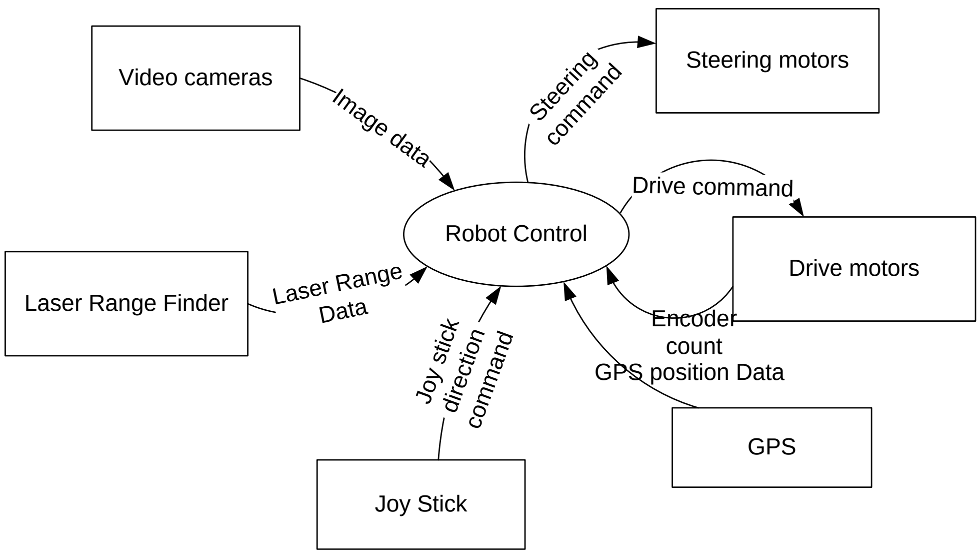

Figure 5: Top level context Diagram

Figure 6 shows the combined Data Context and Control Context diagrams for Puma's control system. The context Diagram is the highest level representation of the system, showing a single process (Control Robot) along with its data and control inputs and outputs. This allows you to get a quick the big picture of where data and control signals originate and in which direction they flow.

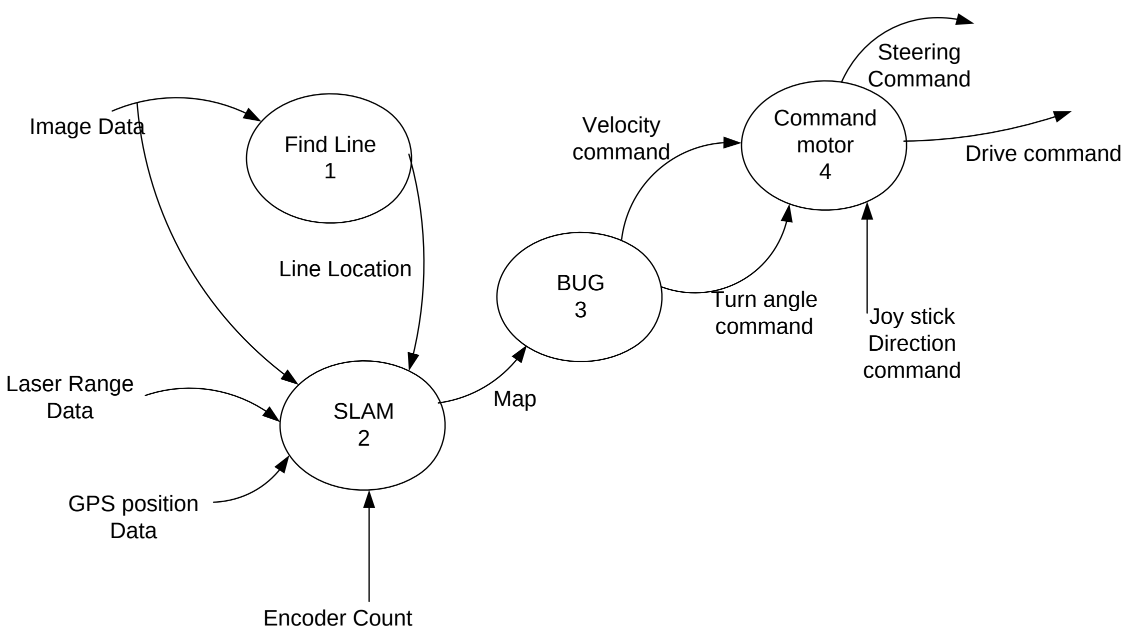

Figure 6: Level 0 CDF and DFD

Figure 7 shows the combined Data Flow and Control Flow diagrams at level 0 (directly below the context diagrams). This diagram is a drill-down into the "Control Robot" process of the context diagrams. The data flows are similar to those on the context diagram with some new data flows.

Process and control Specification:

Inputs data flow:

1. Laser range Data.
2. Image Data.
3. GPS position Data.
4. Encoder count
5. Joystick direction command.

Output data flow:

1. Steering command
2. Drive command

Data Dictionary:

-Laser Range Data: The LMS system operates by measuring the time of flight of laser light pulses: a pulsed laser beam is emitted and reflected if it meets an object. The reflection is registered by the scanner's receiver. The time between transmission and reception of the impulse is directly proportional to the distance between the scanner and the object (time of flight).

-Image Data: Color Images 320 X 240 Pixels.

-GPS Data: Includes UTC Time, Latitude, N/S Indicator, Longitude, E/W Indicator, GPS quality Indicator, Satellites Used, Horizontal dilution of precision, Altitude, and Differential reference station

-Joystick direction command: The input direction that is given via a joy stick by the operator

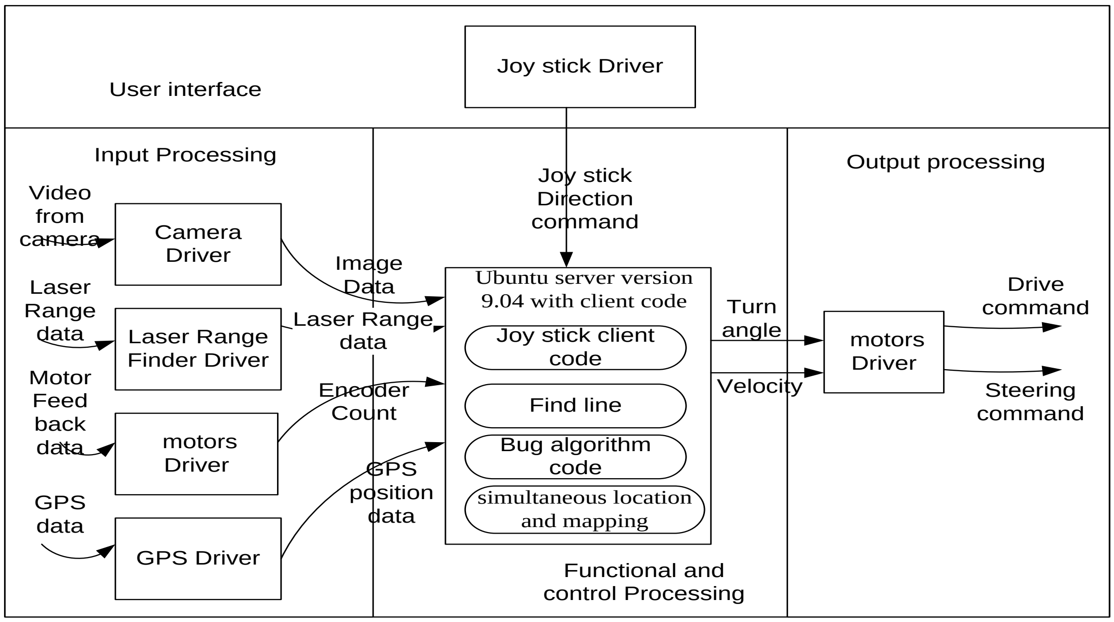

Figure 7: Software Architecture Context Diagram

Combined, the Data and Control diagrams described above make up the requirements model. Alongside the requirements model—and often developed simultaneously—is the architecture context diagram which is shown in Figure 7. This model describes the Software systems used in the system and how they interconnect. This model is much more detailed. The diagram defines the channels and software components on which the information flows and shows how the system will interact with the different type of data and how they are processed.

Requirements Model component	Architecture Model component	Joy stick driver	Camera driver	Laser range finder driver	GPS driver	Motors Driver	SLAM	Bug algo.	Find line	Joy stick client code
Find Line			X						X	
SLAM			X	X	X		X			
BUG								X		
Command motor						X				
Joy stick direction command		X								X

Figure5: Process Allocation table

Figure5 The Process Allocation table shows how every component in the requirement model is allocated to the architecture context module.

Cost Estimate

We have spent approximately 900 man hours on the construction testing and programming of Puma.

Subsystem Cost

Embedded Computer	$400
Power Distribution	$600
GPS Unit	$300
Support Equipment	$600
Cameras	$1050
Motor	$800
Total System cost	$3750

Table 2: Cost Estimate

Conclusion

PUMA will be ready to meet the challenges at the IGVC this summer, and the team is looking forward to a successful run. This project would not be possible without the help of CU-Denver Electrical Engineering instructors and faculty and the ongoing support of our sponsor The Security attaché office at the embassy of Qatar.