MSOE

A.R.C.

title

Team A.R.C. - Design Proposal

MILWAUKEE SCHOOL OF ENGINEERING

MECHANICAL ENGINEERING SENIOR DESIGN

Date

ADVISOR: DR. LUIS A. RODRIGUEZ

Team Members:

Logan Beaver

Justin Campbell

Tyler Paddock

Ronald Shipman

Executive Summary

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Project Statement

Milwaukee School of Engineering's mechanical engineering students take controls classes in their senior year. Having an automated control system would be a beneficial tool to explore controls theory. An application of Automatic Control Systems is the use and development of robotics. Development of a robot with pneumatic locomotion for the Milwaukee School of Engineering's controls classes would give students a first-hand experience with complex control systems.

The objective of this project is to design a pneumatic power driven quadruped robot, having the ability to walk with at least a creep gait. The robot should have all of its control systems onboard, as well as its electrical power supply, in the form of batteries. Aside from walking forward, the robot should also have the ability to walk backwards as to easily get out of corners and other difficult obstacles. Safety being a major concern, the robot should have at least one emergency stop button on both the robot itself and the controller, which, upon engagement, immediately causes the robot to enter a stable condition, where all legs are on the ground, and all air flow is stopped. Other necessary features of the robot include fuses to protect hardware, insulated wiring to protect against possible pinching and the robot should be joystick controlled for ease of use.

The agile quadruped robot shall be an educational tool for use at Milwaukee School of Engineering (MSOE). The product itself will be used to familiarize controls classes with the application of quadruped motion. Upper classmen students at MSOE take a controls course which looks at simpler controls systems. There is an educational benefit to having an exposure to larger and more complex control system. Students may manipulate the control parameters to change the system behavior along with viewing the PIDs and compensators executing on the robot. Aside from being used as an in-house educational tool for MSOE the robot can be displayed in community outreach programs to encourage interest in science, technology, engineering, and mathematics.

mention previous work (Kevin Lee's summer project)

Background Research /Review of Prev. work

Advantages/disadvantages of pneumatics

Advantages/disadvantages of legged mobility

Advantages/disadvantages of 4 legs

Similar robots to our specifications

- What are the diff gaits available for walking?
- Talk about stability for walking
- Pneumatic control research

Specifications

For the agile quadruped robot, a list of objectives and constraints had to be created. Objectives are criteria that the robot must meet in order to be considered complete. Constraints are seen more as guidelines to follow during the design process: if all of them are not met, the robot can still function.

Table 1: Objectives List

Objective	Success Criteria
Brown Out Conditions	Robot enters stable condition on electrical failure
Emergency stop button	Robot should be able to completely shut down with one button push
Fuses	Fuses on robot to protect components
Wires organized and secured	Wires should be insulated and protected from mechanical pinching
Robot self-collision avoidance	The robot should not be able to hit itself
Onboard Batteries	All batteries must be on the robot chassis
Number of legs	4 legs
Mechanical Power System	pneumatics
Can walk on a flat surface	Robot should be able to walk on a flat surface without problems
Easy to update controller Easy debugging of signals	Pneumatics should have an electrical panel to debug the electrical signals
Robot walks backward	The robot should be able to move backward
Controlled via joystick	Robot is controlled via joystick

Table 2: Constraints List

Constraint	Success Criteria
Load Weight	Carry at least 1.25 its own weight safely
Walking Motions	Robot should have at least a creep gait
Maximum Walking Speed	0.5 [m/s]
Weight	15 [kg]
Size	1 [m long] 0.75 [m tall] .75 [m wide] max
Battery Life Pneumatics	3 hours at least
Cost Constraint	$10000 max
System Startup Time	Starts in less than one minute
Recover from disturbances	Robot remains stable even if disturbed up to 10N
Battery Life Microcontroller	2 months at least

From the specifications determine a weighting criteria that will be used to compare the various design concepts

Feasibility

Four Legs

The implementation of four legs in the design of the agile robot is both a sound decision both financially and technically. With more than for legs, the project budget will increase to reflect the increase in components, such as air cylinders and control valves, required for additional legs. With less than for legs, maintaining the stability of the robot, while possible, will become more complex and possible require more sensors, thus increasing the budget as well. With for legs, stability is fairly easy to maintain, as long as the center of gravity of the robot falls within the support triangle formed by the three remaining legs in contact with the ground, as the robot takes a step.

Pneumatic Power Source

When comparing pneumatics to other driving sources, such as electrical, through servos, and hydraulic, pneumatics provide a greater force and speed per unit size than servos, while also being lighter, cheaper and easier to maintain than hydraulics. More specifically, with the correctly chosen pneumatic power source the forces required to support the weight of the robot are easily obtainable.

Electrical Components

Gait

Utilizing forward and inverse kinematics, gaits can be generated in MATLAB. With the use of a microcontroller, pneumatic cylinders can be forced to extend or retract, providing the necessary torques and forces to generate a gait for the robot. The robot will need to have at least a creep gait, where one leg moves forward at a time and there is no dragging of the remaining three legs. With the stability of four legs, if efficient control of the pneumatic system is achieved and all of the kinematic models are correct, the creep gait, being less complex compared to other gaits, is possible.

Size

When constraining the size of the robot, the idea of portability was in mind. The robot needed to be able to be moved relatively easy and it also needed to be able to fit in restricted spaces, such as vehicle trunks and perhaps storage closets. Robot sizes vary depending on application, and sometimes even budget. BigDog (Boston Dynamics), for example, is about 3 feet long and 2.5 feet tall, however it is also intended to be a pack-mule robot, carrying supplies thought precarious terrains. Cheetah-Cub (funded by AMARSI) on the other hand, being 0.5 feet tall and 0.69 feet long, was intended for natural locomotion research for implementation in robotics. The decided size limit kept in mind related quadruped robots, but was based heavily on the intent of the robot being educational and thus portable.

- Alternative Conceptual Designs
- Details of selected design

After feasibility study

Weight (Load Capacity)

In order to keep the robot portable, as the intention is for educational purposes, including community outreach, light weight yet strong materials, such as aluminum, will be used for is chassis.

[Need strengths of materials analysis to support]

Walking Speed

A walking speed of 0.5 meters per second as a minimum should be well within the capabilities of the robot when comparing to other quadruped robots.

Robot (Author Year)	m_{rob} kg	h_{hip} m	l_{rob} m	v_{max} m s^{-1}	FR	BL/s s^{-1}	Gait
Quadruped (Raibert 1990)	38	0.56	0.78	**2.2**	0.88	2.8	**trot**
	38	0.56	0.78	2.9	**1.53**	**3.7**	**bound**
Tekken1 [2] (Fukuoka et al. 2003)	3.1	0.21	0.23	**0.5**	**0.12**	**2.2**	**walk**
Tekken1 [2] (Fukuoka et al. 2009)	3.1	0.21	0.23	1	0.49	4.3	trot
Tekken1 [2] (Fukuoka et al. 2009)	3.1	0.21	0.23	1.1	0.59	4.8	bound
Aibo RES-210A [2] (Kohl et al. 2004)	1.4	0.129	0.289	0.294	0.07	1	walk
Puppy 1 [2] (Iida et al. 2004)	1.5	0.2	0.17	0.5	0.13	2.9	bound
Scout II [2] (Poulakakis et al. 2005)	20.865	0.323	0.552	1.3	0.53	2.4	bound
Puppy II [2] (Iida et al. 2005)	0.273	0.075	0.142	0.5	0.34	3.5	bound
Tekken2 [2] (Kimura et al. 2007)	4.3	0.25	0.3	0.95	0.37	3.2	trot
BigDog [2] (Raibert et al. 2008)	109	1	1.1	**3.1**	0.98	2.8	**bound**
	109	1	1.1	1.6	0.26	1.5	trot
	109	1	1.1	2	0.41	1.8	trot
KOLT [2] (Estremera et al. 2008)	80	0.7	1.75	1.1	0.18	0.6	trot
	80	0.7	1.75	**1.06**	**0.16**	0.6	**pronk**
Cheetah-2008 [2] (Rutishauser et al. 2008)	0.72	0.14	0.235	0.25	0.05	1.1	walk
	0.72	0.14	0.235	0.11	0.01	0.5	pace
Rush [2] (Zhang et al. 2009)	4.3	0.2	0.3	0.9	0.41	3	bound
PAW [2] (Smith et al. 2010)	15.7	0.212	0.494	1.2	0.69	2.4	bound
HyQ [1,2] (Semini et al. 2011)	70	0.68	1	2.0	0.6	2.0	trot
Cheetah-cub	1.1	0.158	0.205	1.42	**1.30**	**6.9**	**trot**

Sproewitz, Alexander et al. Towards Dynamic Trot Gait Locomotion: Design, Control, and Experiments with Cheetah-cub, a Compliant Quadruped Robot, International Journal of Robotics Research, Volume 32, Issue 8, July 2013, pp. 933 951.

Preliminary Design

Project Management

Timeline

Phase I: Design Synthesis, Fall 2014

1. Research existing walking robot designs
2. Generate constraints and objectives for the robot
3. Determine feasibility of project with a feasibility study of existing robots
4. Create initial models of components to confirm project feasibility
5. Synthesize initial design solutions
6. Formulate decision matrix for final design selection
7. Compile design report detailing the constraints, criteria, feasibility study, and final design

Phase II: Design Analysis, Winter 2014-15

1. Create advanced models of components to optimize the design
2. Perform a system response analysis on critical components
3. Develop base software architecture
4. Configure electrical wiring diagram for the robot
5. Develop communication architecture from HMI to controller
6. Determine final sizes and configuration of components
7. Use final models to develop idealized control algorithms
8. Present final design

Phase III: Development and Testing:, Spring 2015

1. Construct robotic leg components
2. Modify leg gains to optimize control algorithm
3. Construct robotic chassis
4. Mount components on chassis
5. Mount legs on chassis
6. Construct robot tether
7. Test and finalize control algorithms

Agile Quadruped Project

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
List of Constraints Due	1	4	1	4	100%
Project Plan Due	3	3	3	3	100%
Codes and Standards Homework	9	1			0%
Research Existing Designs	1	7	2		80%
Leg Model	5	1	5	1	100%
Feasibility Study	4	2	4		25%
Enumerate Initial Design Proposals	7	2			0%
Create Decision Matrix for Designs	6	1	6		0%
Design Report	6	4	6		20%
Create Advanced Electro-mechanical Model	17	5			0%
Develop Base Software Architecture	13	4			0%
System Response of a Pneumatic	15	1			0%
Electrical Wiring Diagram Completed	17	2			0%
Build Single Leg	15	4			0%
Design Communications System	17	3			0%
Design Single Pneumatic Leg	13	2			0%
Design Controls Algorithm from Models	22	2			0%
Presentation of Design	24	1			0%
Construct Other Leg Components	26	2			0%
Modify Leg Gains and Optimize Control	26	3			0%
Construct Robotic Chassis	28	3			0%
Mount Components	30	3			0%
Mount Legs on Chassis	32	2			0%
Construct Robot Tether	28	1			0%
Full System Tests	26	11			0%
Final Project Demonstration	36	1			0%

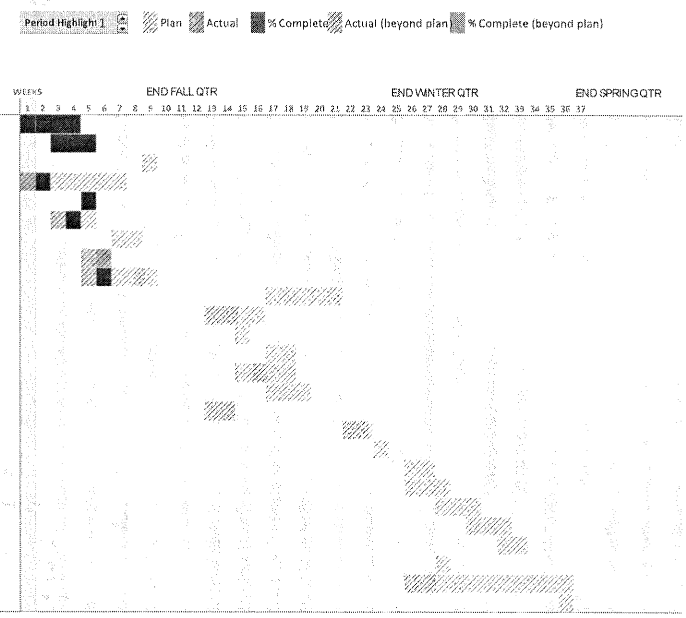

Figure #:

Preliminary Budget

The initial budget of the project is $9380. A breakdown of the project costs is shown in the table below:

Table 5: The initial project budget

Item	Cost
Proportional directional control valves (8)	$4400
Double acting piston feedback cylinders (8)	$3600
Air Compressor	$150
Single solenoid valve	$100
Reservoir cartridge	$30
Rechargeable batteries	$200
Microcontroller	$100
Aluminum for frame/chassis	$500
Miscellaneous hardware/electronic components	$300
Total Cost:	**$9380**

References

Resumes