ECE 4011/ECE 4012 Project Summary

Project Title	Design and Control of a Highly-Articulated Salamander-Inspired Robot for Future Search and Rescue Applications
Team Members (names and majors)	Austin Bush, ME Sunit Kulkarni, EE/ME Hariank Mistry, EE Alex Popescu, EE Jonathan Rundquist, ME Shashwat Sitesh, EE Brian Weaver, MSE Calvin Yao, EE
Advisor / Section	ECE 4011/4012 Advisor: Dr. Linda S. Milor / L7A ECE Advisor: Dr. Patricio A. Vela ME Advisor: Dr. Amit S. Jariwala MSE Advisor: Dr. Mary Lynn Realff
Semester	Spring 2017, ECE 4012, GT 4823
Project Abstract (250-300 words)	Robots have the potential to augment the work of emergency-response professionals. During the immediate response to a disaster, robots can provide valuable real-time data to help assess and monitor a situation and potentially save lives. In environments with hazardous materials or precarious structures, robots can navigate to places humans cannot. However, one challenge associated with disaster zones is the rough, uneven terrain that can characterize a disaster area. This may result from earthquakes, explosions, floods, and other disaster byproducts. Rough, uneven terrain poses a challenge for traditional tracked (uses tracks/treads) or wheeled robots to traverse. One solution may be to increase the size of the tracked wheeled robot, but this poses logistical issues. The proposed salamander robot resolves this terrain problem by virtue of its unique capabilities: 1. Mobility - 4 segmented legs, flexible spine 2. Stability - low center of gravity 3. Portability - small size and weight The current state-of-the-art salamander robot is called Pleurobot. It was developed by Biorobotics Lab at EPFL (École Polytechnique Fédérale De Lausanne) and uses a simple manual operator control mechanism. This robot can walk using an open-loop "playback" control system that plays-back recorded salamander walking data. Our completed salamander robot builds upon the EPFL's design, and adds vertical lift motors on the spine to allow higher reach for traversing larger heights than the legs will allow. The total horizontal spine motors have also been reduced to maintain optimal spinal movement with the least amount of motors. For our demonstration, we built a prototype model of the salamander disaster-response system. The prototype salamander robot demonstrated the robot's movement over rough terrain by direction of a joystick controller and human input. The robot will walk over small obstacles with different generated gaits..

Project Title	Design and Control of a Highly-Articulated Salamander-Inspired Robot for Future Search and Rescue Applications
List **codes** and **standards** that significantly affect your project. Briefly describe how they influenced your design.	● DHS-NIST-ASTM: "International Standard Test Methods for Response Robots measures robot maneuvering, mobility, manipulation, sensing, endurance, radio communication, durability, reliability, logistics, and safety for remotely operated ground vehicles, aquatic vehicles, and small unmanned aerial systems in FAA Group I under 2 kg (4.4 lbs)" [NIST, 2011]. ● USB: Universal serial bus will be used to send motor commands from the single board computer to the motor controller. USB is also used to send overhead camera data to the ROS network. ● ROS: Robotic operating system will be utilized to run and coordinate motor control and data collection tasks in a modular fashion on the single-board computer. ● C++: Object-oriented programming language used to create ROS programs or "nodes". ● TCP/IP: Transmission Control Protocol/Internet Protocol will be used to communicate in the ROS network of computers ● Asynchronous TTL Serial: Transistor-Transistor Logic Serial will be used to send position commands to the servomotors ● SCI (Serial Communication Interface): Used to communicate with an analog-digital converter from the single-board computer to read force sensor measurements.
List at least two significant **realistic design constraints** that applied to your project. Briefly describe how they affected your design.	● Degrees of freedom: The number of motors needs to be sufficient to mimic the articulation of a salamander. Too few motors will create an inaccurate model that may not move how we want it to, and too many motors will be redundant and costly. We decided upon 29 degrees of freedom, 2 more than the EPFL design. ● Accuracy of gait: Replicating the gait of an actual salamander for the control system will require recorded data from the movement of salamanders or construction of the walk cycle from scratch, which may be time-consuming and inaccurate when programming each motor. We opted for a genetic algorithm to generate original gaits for the robot, as they tended to be similar to actual salamander gaits given the right parameters. ● Motor torque limits: Each motor model has a limit on how much torque it can produce and this limits the types of gait patterns which we could use, as too quick movement would result in overtorquing and subsequent motor shutdown. The balance between torque limits and movement speed necessitated generating a gait that moved as quickly as possible within established torque limits.
Briefly explain two **significant trade-offs** considered in your design, including options considered and the solution chosen.	● Battery vs. power tether: An on-board battery would significantly increase robot size and volume, but would free the robot from the distance-limitations and excess drag force of a power tether. A power tether would be beneficial because it provides unlimited operating life and reduced on-board weight. Because of the ease of creating a tether from scratch, our team created multiple tethers sufficient for our power needs. ● On-board SLAM vs. overhead camera tracking: On-board SLAM eliminates an overhead camera, yet requires increased sensor payloads (weight) and more computational power. On the other hand, overhead camera tracking limits the environment size yet is an easy way to localize the robot. Due to the unforeseen complexity of gait generation and testing for the robot, we decided to remove any localization techniques and have the robot move in single directions.

<table>
<tr>
<td>Briefly describe the computing aspects of your projects, specifically identifying hardware-software tradeoffs, interfaces, and/or interactions.

Complete if applicable; required if team includes CmpE majors.</td>
<td>Hardware/Software Interfaces:
● ROS (Robotic Operating System)
○ Command the gait and control systems of the robot
○ Read data from onboard camera(s)
○ Receive remote commands from a human controller via joystick-based input
● HMI (Human-machine interface)
○ Analog controller utilized by operator’s hands in project demonstration
○ Converts analog control signals to digital inputs at Command Computer, which then are transmitted to robot</td>
</tr>
</table>