Develop a Research Question

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Research Question

How do we create a bio-inspired salamander robot that can move through a granular media using foldable robotic techniques?

Tractability Discussion
Is your question tractable and achievable? Discuss your plan for scoping your problem to fit in a 15-week course

We have limited ourselves to imitating a specific reptile, a salander, moving through a specific media, sand. The plan is to create a salamander-inspired system that replicates the oscillatory and fluid-like movements of the limbs and spine using foldable robotic techniques. We have determined that we will test our system in a pre-existing granular media testbed and will test the system mobility across the top of the media as opposed to swimming underneath the surface. This reduces the complexity of the problem and limits our scope to testing the system in a very specific environment. By utilizing foldable techniques to drive our design, we limit possible approaches to the problem as well as cost.

Novelty Discussion
Is your question novel? How have you established novelty?

When we started the research some of the keywords that were used to see what has already been accomplished include: Salamander, Robot, Biomimicry, Amphibious Locomotion, Actuated Spine, Granular Media. From there we found a number of documents covering a variety of research. The following are four of the different robots and robotic elements:

The Pluerobot was built to directly mimic the structure of a salamander. The team X-rayed a salamander in motion to see every point of connection and movement in the skeletal structure of a salamander.[1] This information was translated into sections of the body with one degree of freedom to get an undulating motion while the feet provided the forward movement. This technique is great for creating a near true-to-life model of the salamander but there are a few downsides. This system requires 27 individual motors. The scale of the robot, possibly scaled due to motor constraints, is the size of a human leg.

In a Science Journal publication, “From Swimming to Walking with a Salamander Robot Driven by a Spinal Cord Model”, a team constructed a salamander inspired robot to test a numerical spinal cord model, test a simple neural circuit to control oscillatory movement in limbs and body, and test oscillatory frequencies for traversal of land to water.[2] The robot consisted of 4 independent limbs and a spine made up of six actuated hinge joints. The limbs use continuous rotations at different frequencies to simulate different gaits including the gaits for walking and swimming. The gaits were compared with real salamander movements and shown to be fairly consistent with what is seen in nature. This paper addresses the mechanisms necessary for limb coordination and axial movements and gait transitions induced by electrical stimulation (like in a brain stem). This robot is trying to effectively use biomimicry in robotics to learn about evolution of vertebrates so their system is fully actuated and controlled, using 6 actuators just for the spine base and 4 motors with motor controllers for the limbs. The goal of our project is to

achieve the same overall motion and behavior of this salamander-inspired robot, but accomplish it in as few actuators as possible, using the properties of the materials and joints we create to drive the gaited motion of our robot.

Another paper[3] introduces Salamandra Robotica II, an amphibious salamander robot that is able to walk and swim. The researchers investigate how the speed of locomotion and curvature of turning motions depend on various gait parameters such as the body–limb coordination, the type of body undulation, and the frequency. There's tons of data provided by the researchers for us to draw design and actuation parameters for our robot. The robot created by the team can be translated to a foldable mechanism based on its design, leading to cheaper production, novel models for amphibious spines and legs.

Chong et.al [4] used a robotic model based on the fire salamander animal to demonstrate that back bending assists not only the forward motion, but also the lateral and turning positions. In order to model the animals' and robots' locomotion when in contact with granular media, the Granular resistive force theory has been used. For the experiment, a 3D printed servo-driven open-loop robot having four legs and an actuated back was used and the test bed was filled with 1mm diameter poppy seeds. Through the experiments, it was found that the rotational displacement is maximized when the frequency of back bending is twice as that of the leg movement.

Overall, throughout all of these papers there are no direct foldable robotics techniques utilized , which could reduce cost, weight, size, and complexity. By using foldable techniques, we can achieve complex fluid-like motions without increasing the number of actuators therefore decreasing cost and weight.

Interesting Discussion

What makes it important to others?

These robots would be ideal for Search and Rescue operations. Low to the ground and with a wide range of motion because of its many joints, the robot would be a good choice for scoping out a collapsed building for survivors. In research, bio-imitation robots are being used increasingly as research tools to verify biological hypotheses or as models of biological sensorimotor systems. Works like this inspire mechanisms like lamprey locomotion, lobster locomotion, cricket phonotaxis, and cat locomotion.

Why is this idea important now? What prevented it from being answered 10 years ago?

Actuated spines in the locomotion of robotics is a relatively recent field/focus of research to increase the locomotion of bio-inspired/biomimicry robotics. Two of the recent robotic designs trying to mimic the movement of salamanders, Salamandra robotica II and Pluerobot, used X-ray recordings of the salamander's motion to see the skeletal structure in motion. While this theoretically could have been done 10 years ago the research into the internals of how the salamander's locomotion tied to it's skeletal structure was not completed.

Within what contexts could other people use your results?

For this project, achieving the spine actuation and body-limb coordination that is seen in amphibious animals such as salamanders, crocodiles etc could be useful to people who are trying to achieve the same. Application of modeling techniques used for locomotion on granular media (such as sand, poppy seeds etc) such as Hunt Crossley Model or Granular Force resistive theory would also be useful to researchers. Finally, achieving low-cost foldable robotic solutions for locomotion on granular media would be another thrust area that people could be interested in.

What are the potential broader impacts on society?
Trying to duplicate the mobility of a salamander is a worthwhile endeavor because of how effective this mobility method works in different media. In nature, salamanders can go from hard compact ground, to granular media (sand), to cohesive granular media (mud), to swimming in water. Multi-environment mobility can have a big impact on society as this technology can be used for mapping out an unknown environment, search and rescue, and helping us to understand the evolution of how vertebrates evolved from aquatic to land-based locomotion.

Open-endedness Discussion
Is your question open-ended? Could it leave room for a deeper look if given more time and resources? Discuss how you have structured your research question to permit further, deeper investigation.?

Our research question is open ended while remaining focused enough for the requirements of this class. By having a bio-inspired instead of a direct biomimicry design, we allow for different variations of movement to be taken into account and modeled. For the granular media there are a wide variety of media that could be used to model movement, each one giving different characteristics and responses to the movements of the robot. Because this is not a simple yes or no research question there are multiple ways to approach the question and different solutions can still answer the question.

Modularity Discussion
Is your question modular? How does it fit with other complementary research thrusts?

There are many avenues that this research question can lead to. The modeling techniques for salamanders can be applied to other undulating creatures, whether they are legged or not such as eels or other reptiles. Our research question will allow us to research and analyze gaits seen in nature and its application in robotics. Achieving specific gaits for optimal mobility is a hot research topic so further analysis on types/frequency of gaits can lead to interesting research. In addition, the granular media that we are using for our research question can be applied to other media such as mud, water, etc.

Team Fit Discussion
How does answering this question leverage your interests and abilities?

Teresa McBryan has prior experience working in granular media and is knowledgeable about the difficulties involved with designing and testing for this environment (i.e. sand in electronics, clogging, etc.) She has access to multiple granular media test beds such as sand, glass beads, and BP-1, a type of lunar simulant. Though her experience has been limited to traditional robotics, she has experience designing, prototyping, building and testing systems in granular media. Her expertise is granular media and hardware/programming which can be leveraged for this project.

Aaryan Bhardwaj has prior experience working with modeling and development of novel robot elements. Through current research at RISE Lab, he has access to and understanding of many modeling tools and techniques. Previous opportunities have given Aaryan experience in designing circuits, embedded programming and API development that will all help make the development process a smoother sailing.

Andrew has experience with embedded systems and specing hardware components as well as modeling different control elements in software such as MATLAB. I also have a desire to work with robotics that use novel transportation characteristics. While driving robots work on a number of solid surfaces there are situations where they won't work where putting a person in the situations is not feasible or ill-advised such as disaster sites

Rohith has good experience with designing mechanisms using CAD tools, prototyping and implementing control strategies using microcontrollers. Modeling kinematics and dynamics has always intrigued Rohith, because he hasn't used it for any practical purposes yet. So, simulating the interaction of the robot with granular media and achieving body-limb coordination is a challenge he wishes to take on during the course of this semester.

Topic Fit Discussion

How does the question use foldable robotics techniques to answer it?

Foldable techniques will be used to create the driving movements that enable mobility for the system. Salamanders are composed of 2 main sections: the main body (with a spine like movement) and the limbs. Foldable robotics techniques allow input motion to be transformed into a more complex fluid motion with less traditional hardware allowing us to create a bio-inspired oscillatory motion in the limbs similar to sand salamanders with fewer actuators. In addition, foldable techniques can be utilized to create the oscillatory spine-like motion of the main body.

References

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