Gmail **Jonathan Bruce <lostinmyfro@gmail.com>**

Advancement to Candidacy Report

Gabriel Hugh Elkaim <elkaim@soe.ucsc.edu> Thu, Sep 3, 2015 at 9:17 PM
To: Jonathan Bruce <jbruce@soe.ucsc.edu>
Cc: Emily Gregg <egregg@soe.ucsc.edu>, Mircea Teodorescu <mteodore@ucsc.edu>, "Sunspiral, Vytas (ARC-TI)[Stinger Ghaffarian Technologies Inc. (SGT Inc.)]" <vytas.sunspiral@nasa.gov>, Ricardo Sanfelice <ricardo@ucsc.edu>

Hi Jonathan,

First off, congratulations on your advancement. The work you have presented is exciting, and has great potential for an ongoing area of research far beyond your PhD.

It is clear that you have spent a great deal of time down in the "nuts and bolts" of the tensigrity robots, and are becoming an adept robotics researcher. The work you have done is well beyond what we expect at this point, and look forward to seeing what you present us for the final defense.

There were a few specific points the committee wanted to make to guide you as you continue your work on the PhD:

(1) Design for control: While it is not practical for Jonathan to build multiple different versions of the robot using different designs and sensors, it would be good to have an in-depth discussion about the different design options available that enable efficient control of these tensegrity robots. Of specific interest are the many choices in sensor technology, placement, calibration, and the advantages and disadvantages of the many possible ways that one can build and maintain a good system model for use by controllers. This discussion will be grounded by experimental evidence from the current prototype.

(2) Practical Controller Comparison: A number of other control options for SUPERball like robots have been explored in simulation, while these cannot all be directly ported onto the SUPERball hardware (due to reliance on sensors that do not exist on SUPERball, for example), it would be very valuable to have a comprehensive discussion of the full spectrum of different control approaches that have been explored for tensegrity robots and a comparison of their different advantages and disadvantages. This will be grounded with results from his control work on the current prototype.

(3) Come up with a crisp set of contributions that you are going to claim as yours. These are the points on which you are going to hang your intellectual hat, so make sure they are well defined, and defensible.

(4) It was said that the model does not include forces. In addition, it doesn't look like it includes the impact dynamics. It would be useful to add those. The following reference (and those therein) on perhaps the simplest system with impacts could be useful:

https://hybrid.soe.ucsc.edu/sites/default/files/preprints/17.pdf

https://hybrid.soe.ucsc.edu/sites/default/files/preprints/79.pdf

(5) The idea of modular tensegrity robot opens up the possibility of using multi-agent systems theory, in which case every module would be its own system that is linked to its neighbors through the cables. If you add to

that the impact dynamics and the unavoidable underactuation, you would end up with a very interesting multi-agent hybrid system.

(6) I wasn't able to gather how much analysis of the dynamics of the system has been performed and how much you want to do. From a dynamical systems viewpoint, you have a nonlinear system with multiple actuators. It would be important to determine what configurations can be reached from a given initial condition, namely, determine the controllability of the system and figure out (an approximation of) the configurations that can be reached (i.e., the reachable set). I'm not saying this for the sake of doing mathematics, but rather due to this study potentially providing key information about the maneuverability, speed, etc. of the system.

(7) It wasn't clear what type of state estimation you would like to do. Actually, it wasn't clear what kind of data you would use to estimate what. I guess one comment is that whatever estimation algorithm you use would need to handle measurements that are noisy, in particular, jumps/spikes occurring at the impact times.

(8) Exploring the needed and designing multiple modes of operation of the system. Certainly, classical control techniques will not suffice and one would need to develop more advanced control algorithms that allow for logic so that the individual systems of your modular tensegrity robot moves in a coordinated fashion. Hybrid control algorithms would be capable of providing such logic, not only to model the dynamics of the system over different modes but also cope with faults, changes of terrain, etc.

(9) Indoor experiments in a motion capture system would certainly be possible. What is not clear is what you would you want to get out of the camera system.

Again, congratulations on a job well done, and we look forward to an excellent thesis from you in the near future.

--Gabriel, Chair Advancement Committee.

--
Gabriel Hugh Elkaim
Professor
Autonomous Systems Lab, Computer Engineering Department
University of California at Santa Cruz
1156 High Street--SOE3, Santa Cruz, CA 95064
831.459.3054 (Office) 831.459.4829 (Fax)
www.soe.ucsc.edu/~elkaim