# WORM TRACKING USING SUPERPOSITION OF MERIT FUNCTIONS

By

Linda I. Rivera

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Approved:

John T. Wen, Thesis Adviser

Rensselaer Polytechnic Institute
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## ABSTRACT

There is an increasing need for biology research scientists to perform long term observations of single cells, organisms, animals and populations simultaneously without disturbance of their natural states. Particular interest is presented toward a model organism for developmental biology called, *Caenorhabditis elegans*. Traditional solutions to track *C. elegans* lack efficiency due to computationally expensive algorithms, and field of view limitations in optical microscopes. This thesis demonstrates real time tracking of multiple *C. elegans* with a novel optical microscope design called Adaptive Scanning Optical Microscope (ASOM), developed at the Center for Automation Technologies and Systems (CATS). The experience gained during real time experimentation is used to generate an improved algorithm that allows tracking multiple worms in the presence of entanglements.

The contributions of this thesis are divided into three stages. The first stage presents an enhanced digital motion controller for the ASOM high speed scanning mirror. The augmented control system suppresses undesired vibrations, which limit the system capacity to track multiple organisms. The second phase of the research is the integration of the ASOM apparatus, the high speed motion control, and a base tracking algorithm, all which allows for rapid image acquisition to track multiple *C. elegans* in real time. The base algorithm was developed at CATS and has been proven to track a single *C. elegans* in real time. To demonstrate the efficacy of the complete system, video results of several experiments are provided. The third and ultimate contribution of the research offers an enhanced tracking algorithm that shows improved accuracy and robustness, by tracking multiple worms even when they collide with each other. Previously acquired images of the *C. elegans* are analyzed and used as the basis to generate the algorithm. Taking in account the unique ASOM design, individual segments of the worm are tracked throughout an image sequence, and a mosaic pattern covering the entire worm is subsequently created. The algorithm takes advantage of geometric and dynamic knowledge of the *C. elegans* such as size, and movement patterns. The enhanced algorithm is tested on previous failed experiments and simulated results illustrating its effectiveness are presented.