# Simulating Mobile Robots for Undergraduate Research

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**Abstract**

Our objective is to promote scientific research among undergraduate students at Eastern Oregon University through the development of mobile robots. Simulating mobile robots in research is not a novel technique, but using simulated robots that utilize virtual physics or "Physicomimetics" [2] as a tool to promote undergraduate research is unique. This paper addresses the undergraduate research experience of designing and implementing a simulated mobile robot environment using a physics-based control algorithm.

## 1 Introduction

The traditional teaching and learning methods focus on class room instructions and transfer of knowledge to students via assignments. In addition to the traditional methods, Eastern Oregon University (EOU), Computer Science and Multimedia (CSMM) department promotes active participation of undergraduate students in research. Our objective is to establish a learning environment that allows our students to discover knowledge through scientific research. Some of the expected benefits of this research initiative include,

- improving critical thinking and problem solving skills
- applying and understanding scientific research methodology
- learning innovative and creative research techniques
- utilizing technology in scientific research
- promoting diversity through group work
- preparing for graduate studies and/or industry.

Our research initiative is motivated by two viewpoints, 1) the multidisciplinary nature of robotic systems allow us to explore multiple fields of study, 2) our prior experience and understanding with robotics and multi-agent systems allow us to produce quality results that meet our research objectives.

The robotics and multi-agent systems have become one of the most important areas of research and development in the field of Artificial Intelligence. These systems are important because of their applicability to a number of diverse areas. Some of the current applications of robotic systems include industrial process control, military and defense, electronic commerce, data mining and knowledge discovery, and simulating biological and sociological models. There is a high demand in the industry for graduates that posses knowledge and skills in robotics systems. We focus on preparing undergraduate students for the challenges they may face in the industry and/or graduate programs by teaching them the fundamentals of robotics and agent-based systems.

The remainder of this paper discusses the organization, research methodology, students' experiences, and future work relating to the project.

## 2 Project Organization

We have organized a robotic research group that includes three undergraduate students and the first author of this paper. The initial funding for this project is provided by the Oregon engineering and technology industry council (ETIC) and the EOU CSMM department.

The research aspect of the initiative consists of two areas,

- simulating robot behavior

- develop physical robots

We believe that it is important to understand the basic scientific research methodology for a successful outcome of any research project. In our project, students learn these scientific principles by designing, implementing and evaluating a robot simulation. The simulation provides a better understanding of robot behavior before the students begin work on physical robots.

The development of physical robots allow students to gain hands on experience in applying scientific methods for simple practical real-world problems such as making a robot avoid an obstacle or multiple robots maintain a simple formation while moving towards a goal. Our research objectives are similar to the ones that are presented in [1], but we derive our research methodology based on well established research techniques.

## 3 Research Methodology

We use Physicomimetics [2] to simulate the robot behavior. "Physicomimetics" is an approach for modeling the behavior of multiple cooperative robots, a technique inspired by classical physics. This approach works well for distributed control of large collections of mobile physical robots [3] as well as theoretical foundations for analyzing robot behaviors [4].

In the physicomimetics framework, virtual physics forces drive multiple robots to a desired configuration such as a triangle with 3 robots or a hexagon with seven robots while obeying $\vec{F} = m\vec{a}$ laws. Each robot has position $\vec{p}$ and velocity $\vec{v}$. We use a discrete-time approximation to the continuous behavior of the robots, with time-step $\Delta t$. At each time step, the position of each robot undergoes a perturbation $\Delta\vec{p}$. The perturbation depends on the current velocity, i.e., $\Delta\vec{p} = \vec{v}\Delta t$. The velocity of each robot at each time step also changes by $\Delta\vec{v}$. The change in velocity is controlled by the force on the robot, i.e., $\Delta\vec{v} = \vec{F}\Delta t/m$, where $m$ is the mass of that robot and $\vec{F}$ is the force on that robot. $F$ and $v$ denote the magnitude of vectors $\vec{F}$ and $\vec{v}$. A frictional force is included for self-stabilization and modeled by decreasing the robot's velocity by a constant multiplicative factor. Figure 1 shows the perturbation of the robots $R$ and $R_4$ due to forces exerted upon them by other robots and the environment.

In the first stage of this research, students experimented with developing a JAVA simulation tool. JAVA was selected as a programming tool based on the students' prior knowledge and experience. Figure 2 shows the Graphical User Interface (GUI) of the simulation tool designed and developed by the students. During project development, the students decided that they needed an efficient version control system. This was accomplished by creating an online file repository using Git (not an acronym) [5].

The simulation design is user friendly and flexible. This flexibility allows the user to define the number of robots (three circles in Fig 2 ) and the number of goals in the environment. The user can change the robot parameters by clicking on the robot and opening the configuration window (see the second open window on top of the simulation environment in the Figure 2). The slider provided at the bottom of the simulation window allows the user to change the speed of the simulation. The speed of the simulation is not the same as the robot velocity. The simulation speed is a graphical component and does not affect the robot velocity. The simulation also allows the user to start, stop or reset the robot movement, and load different simulation environments in Extensible Markup Language(XML) format. Storing the environment in XML allows the use of different configurations and makes the future modifications to the simulation less complicated. The work on our robot simulation is ongoing and we intend to complete this work by the end of March 2008.

## 4 Student Experience

It is always important to know what the students think about their learning experience while involved in a research project. Some of the expectations and experiences of the three students working on this research project are presented in this section in their own words.

> This was the first opportunity I have had as a student computer scientist to participate in research. Working in a team to develop this system has been an incredible experience for me. Designing, planning, and developing this multi-robot simulation been a priceless experience, allowing me to work side by side with fellow friends and classmates under Dr. Hettiarachchi. Not only is team work a learning experience but it gave me a chance to associate with other students who have similar interests.

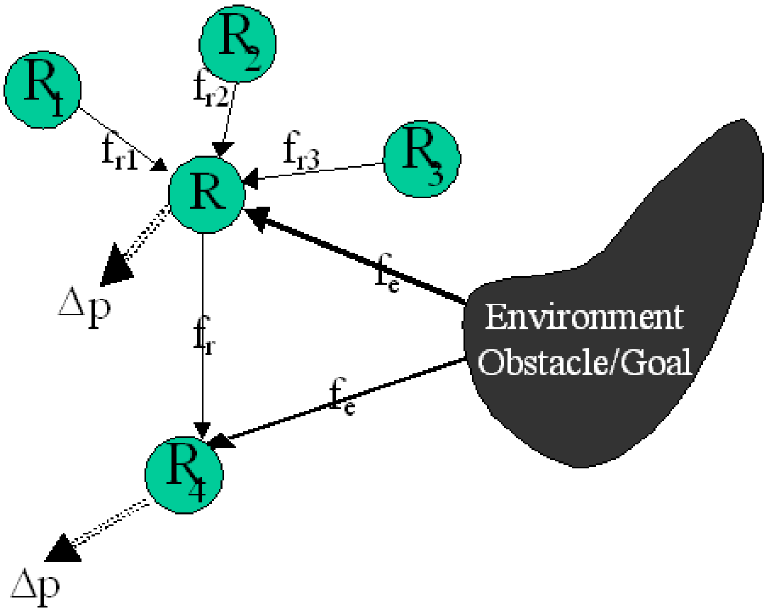


Figure 1: Robots $R$ and $R_4$ undergo a perturbation to their positions due to forces from the other robots and the environment. Robot $R_4$ does not sense forces from robots $R_1$ through $R_3$ due to sensor proximity.

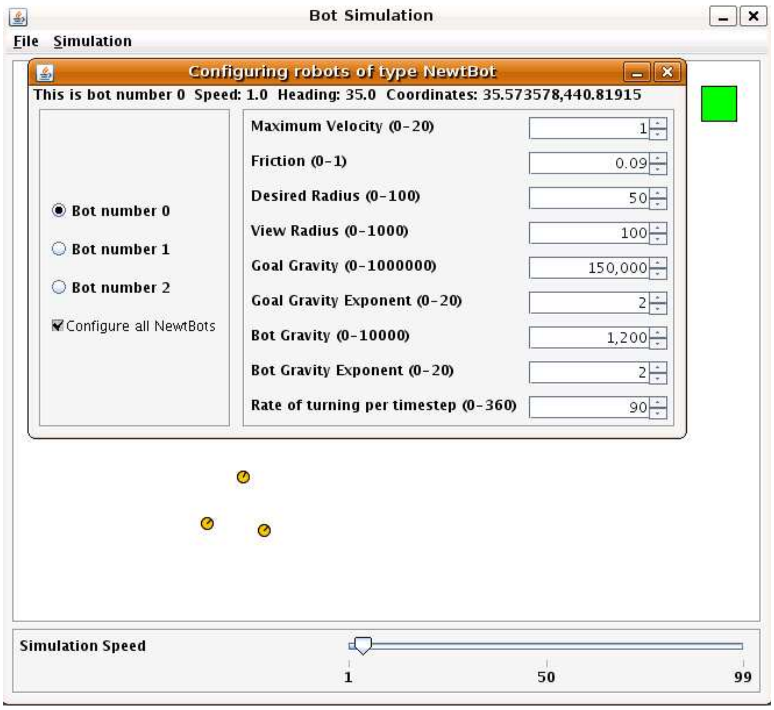


Figure 2: Three robots moving towards a goal while maintaining their triangular formation. The small window allows the user to change the robot parameters.

Brainstorming and talking about the research between the three of us generated many great ideas, ones that I would not have come up with by myself. Listening to and throwing out new ideas is really interesting, especially when they eventually lead to an elegant solution.

This research has allowed us to combine our knowledge of science, mathematics, and problem solving and use it to create a a system that goes beyond command line and number crunching. One of the biggest hurdles we overcame was learning to synchronizing our work using Git. - Nathan Schmidt

This physics is hard to get working within the constraints of the system we wrote, which is a Java program. The robots often seem to just do their own thing, and make us feel somewhat baffled by whatever variable we mislabeled or used in the wrong place. One of the things that I learned a lot about (not too unsurprisingly) was programming graphics in Java.

I feel that I am learning a lot even when I go off on a tangent or run into a problem that is not relevant to the research itself. -Eli Cohen

I have been a JAVA programmer for 3 years, but until I got involved in this project I had not done much programming in developing GUI. The simulation we are developing uses the JAVA graphical tool kits such as Swing and AWT. The most challenging part of the development has been learning how to program the movement of the simulated robots using the graphic tool kits.

In addition to developing the simulation, we have been examining the hardware components available for physical robots. Also, addressing different types of control algorithms have been a challenge for me, because there are so many different techniques we could use to model the simulated robot behavior. -Timothy Willey

It is clear that the students have different opinions of the work done and they form their own research experiences. These diverse experiences are some of the interesting outcomes of the project so far. We believe that these experiences will benefit us in understanding the future needs of this research initiative.

## 5 Future Work and Conclusion

In the near future, we intend to expand the simulation work by introducing structured obstacles in to the simulated environment. These structured environments will allow us to model and derive varying scenarios of robot behaviors. The robots will be provided with a suite of sensors for obstacle avoidance, data collection and communication. These combined simulated robotic tasks will allow us to better understand the real physical robot behaviors.

We will begin assembling our first physical robot using off the shelf hardware components. The robot platform is an MMP5, made by The Machine Lab [1]. The robot's main processor is a stackable embedded PC104 [2] module. We will install several infra red (IR) beacons on the robot for range finding, and light sensors for goal tracking. Our intention is to build at least three physical robots to demonstrate the robot swarm capabilities and importance of multi-robot cooperation.

In this paper we presented our approach to establishing a learning environment that allows our students to discover knowledge through scientific research by designing and implementing a mobile robot simulation. This work is at early stages and ongoing, but the students comments clearly show the benefits of the project. We continuously evaluate the progress of the project and the outcomes to identify the research directions that may or may not meet our objectives.

## References

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