HCL Embedded real-time system with applied machine learning

Embedded systems

Aalborg University

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Abstract:
In the Danish educational system, the Arduino platform is often used to introduce students to computer science. The Arduino's hardware is relatively simple and easy to grasp. However, the Arduino language can often be difficult for novices. While the Arduino language is a simplified subset of `C++`, there are still parts of the language that are difficult to comprehend for novices.
This report elaborates and explains the development of the HCL language, a programming language designed to ease the introduction to programming for students and novices, whilst also implementing high-order functionality on the Arduino. HCL does this by emphasizing a resemblance to the English language. A compiler for HCL was developed, as part of the project. The compiler is written in Kotlin, by hand, and compiles to `C++` code.

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Preface

This report is written during the fifth semester of the bachelor's degree in Software at Aalborg University. It is written for the study board of computer science at the School of Information and Communication Technology. The report is written with the guidance of one supervisor.

The topic of the semester is 'Embedded Systems'.

The system to be developed was chosen by the project group.

Terms and abbreviations used in the report:

TM : Turing Machine
NTH : Nice to Have

Contents

1 Introduction

Tracking airborne objects can be quite difficult. This difficulty has inspired different sports and hobbies, including the shooting of clay pigeons. Hitting a target requires the tracking of it, it's velocity and direction, as well as the calculation or prediction of its future trajectory. The trajectory can be impacted by number of different features, including gravity, wind, initial force, any artificial acceleration, and if the object is intelligent in anyway, the path might change procedurally.

Tracking of airborne objects has multiple different applications.

1.0.1 Airports

Estimated thirteen thousand "bird strikes" happen each year, which is the event of a bird colliding with a vehicles, where the majority is aircrafts.[1][2] Even though 65% are estimated to cause little damages, the damages are estimated to cost 1.2 billion dollars each year, world-wide. [3] The majority of these accidents happen at low altitude, during landing or takeoff.[3] Airports utilize different methods of bird control, including killing, trapping, poison and lights.[4] Shooting birds is one of the most common methods, and has been observed as been quite effective, while also reinforcing other methods. This both kills a singular bird, but also scares away other birds, however it can be quite expensive in salaries and effort.

1.0.2 Military

In a military setting hitting a moving airborne target is relevant in a defence context, for instance destroying incoming projectiles or shooting down hostile planes. Compared to the airport-case, the problem can arise at a variety of locations, both on vehicles, boats, planes and tanks, but also on stationary military installations. The American military developed the Phalanx CIWS, Close-in weapon system, which is a radar-guided 20mm Gatling-style rotary cannon, mounted on a base that moves on two axes.[5] These are mounted on ships and can shoot incoming missiles and other airborne objects deemed a threat. The Dutch also developed a similar system called the Goalkeeper CIWS. These are both autonomous.

1.0.3 Initial Problem

Tracking an airborne object has multiple different problem areas that makes it an interesting domain. This makes it interesting to research, and this report will try to look into ways of solving this problem on a smaller scale, in clinical examples, to research the different parameters. Before hitting an airborne target, it is important to estimate its trajectory, and the problem can therefore be simplified to two subproblems.

1. Calculating how many seconds it takes before a projectile can reach the target
2. Calculating where the target will be in T seconds

Combined, these two problems means finding the spot where the travel-time of the target meets the travel-time of the projectile.

This report is build on courses in both real-time systems as well as machine learning, and this problem works in the context of both. In regards to machine intelligence, the problem of tracking an airborne target has potential for intelligent analysis by an artificial agent. Likewise, it is a time-critical task to move a weapon so it aims at the target and hits the target, before the target is out of range or hits the ground.

As hitting the target with a projectile introduces a lot of unknown variables, this report will focus on tracking the target with a laser, as the travel time is near instant (based on the speed of light), and it's less affected by gravity. The report will focus on using a ball as a target, as these are more predictable, and doesn't in anyway harm living creatures.

How can a software system track a moving airborne projectile

Analysis 2

2.1 Educational single-board computers

While HCL is developed for the Arduino, other educational computer platforms are analyzed, to gain further inspiration.

Apart from the Arduino board, a lot of other single-board computers(SBCs) have been created with educational purposes in mind. To figure out why these SBCs are so popular for technical learning, some of the most popular ones were analyzed. This should help to figure out which functionality HCL should include in order to comply with the educational intend of the SBCs[6]. As such this section explores the Arduino Platform and its competitors.

2.1.1 Arduino Platform

The Arduino platform is an open-source, programmable mini-computer[?]. It is designed to be used in small electronics projects, and for teaching computer science. The Arduino eco-system is comprised of many different boards, that all share the same language, and easy programmability.

The different Arduino models typically consists of a microprocessor, a small amount of RAM, a small amount of persistent memory and some easily programmable I/O ports, known as GPIO pins[1]. To program these GPIO pins, the Arduino programming language, a subset of `C++`, is used. The Arduino programming language is most often written in the Arduino IDE, which also allows for uploading the compiled code to the Arduino boards. The Arduino programming language is further elaborated in section (**??**).

The Arduino Uno is the model of choice for this project. According to the Arduino website, the Uno is the best board to get started with electronics and coding, and this is evident as it is often used in education[2][7].

The Arduino Uno has 14 programmable GPIO pins, 32 KB of flash memory (31.5 KB available) for uploading code, and 2 KB of RAM. The Arduino Uno has an ATmega328P microcontroller, and operates at 5 volt. Programs are uploaded with a USB B cable.

[1] General Purpose Input Output
[2] 4 members of the group used the Arduino Uno in their electronics classes.

2.1.2 Raspberry Pi

The Raspberry Pi is one of the most widely known SBCs. It is a complete ARM-based computer, and may run anything ARM based, including both Linux and Windows based ARM operating systems. This makes it a common entry point into the GNU/Linux operating system stack, which is generally considered to be highly educational in regards to how computers work. The default Raspberry Pi distribution ships with both Scratch and Python, allowing the user to quickly get started with programming[8].

On top of this, one of the major selling points of the Raspberry Pi is the GPIO[3] pins. These allow the user to attach all kinds of devices to the board, including sensors, lights, cameras and breadboards. The Raspberry Pi allows the user to easily interact with the GPIO pins, making it an ideal device for both Internet of Things (IoT), home automation and robotics[8].

2.1.3 Lego Mindstorm

Lego Mindstorm is a robot kit from Lego. The intent is to built a robot out of Lego, with the belonging motors and sensors which can then be controlled by the "head". The head is a small computer, which can control and monitor all the attached motors and sensors. The computer can be programmed from either a tablet or a computer using a drag and drop programming environment similar to that of Scratch (**??**)[9].

2.1.4 Takeaway

Apart from being cheap, the big motivation behind these SBCs seem to be the extensibility through attachments. This allows the users to create something very concrete. For instance, it may be more rewarding for the user to get an actual lamp to blink or a car to drive, rather than just outputting something to the console. The attachments will allow the user to build something robotic, which is a common desire or goal for both new and experienced developers[10].

Since the Arduino platform also has the ability to connect various devices through its GPIO pins, it would be ideal to incorporate some easy to use GPIO handling into HCL.

[3] general purpose input output

Theory 3

Implementation 4

Bibliography

[1] Wikipedia; Various authors, “Bird strike,” https://en.wikipedia.org/wiki/Bird_strike, 2018, [Online; Accessed: 18-09-2018].

[2] US Department of Transportation, “Wildlife strike report 1990-2015,” https://wildlife.faa.gov/downloads/Wildlife-Strike-Report-1990-2015.pdf, 2015, [Online; Accessed: 18-09-2018].

[3] John R. Allan, Alex P. Orosz, “The costs of birdstrikes to commercial aviation,” http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1001&context=birdstrike2001, 2011, [Online; Accessed: 18-09-2018].

[4] Programmadirectie Ontwikkeling Nationale Luchthaven, “Bird control at airports,” http://www2.vlieghinder.nl/naslagdocs/CDrom/REGELS_SCHIPHOL/2.3_TNL/4.3.4.1_Bird_control_at_airports.pdf, 1999, [Online; Accessed: 18-09-2018].

[5] Wikipedia; Various authors, “Phalanx ciws,” https://en.wikipedia.org/wiki/Phalanx_CIWS, 1999, [Online; Accessed: 18-09-2018].

[6] ——, “Single-board computer,” https://en.wikipedia.org/wiki/Single-board_computer, 2018, [Online; Accessed: 18-02-2018].

[7] Arduino, “Arduino reference,” https://store.arduino.cc/usa/arduino-uno-rev3, 2018, [Online; Accessed: 13-05-2018].

[8] Wikipedia; Various authors, “Raspberry pi,” https://en.wikipedia.org/wiki/Raspberry_Pi, 2018, [Online; Accessed: 18-02-2018].

[9] The LEGO Group, “Lego mindstorms,” https://www.lego.com/en-us/mindstorms/products/mindstorms-ev3-31313, 2018, [Online; Accessed: 18-02-2018].

[10] Wikipedia; Various authors, “Educational robotics,” https://en.wikipedia.org/wiki/Educational_robotics, 2018, [Online; Accessed: 18-02-2018].