HCL Embedded real-time system with applied machine learning

Embedded systems

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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.

Number of pages: 16.

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
NXT : Lego Mindstorms NXT 2.0
EV3 : Lego Mindstorms EV3

Contents

1 Introduction

Tracking airborne objects can be quite difficult. This difficulty has inspired different sports and hobbies, including skeet shooting. 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 a number of different features, including gravity, wind, initial force, any artificial acceleration. Furthermore, 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 vehicle, where the majority is aircrafts[1][2]. Even though 65% are estimated to cause little damage, 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 to be quite effective, while also reinforcing other methods. This both kills a singular bird, but also scares away other birds. However, it can be expensive in both 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 that 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 use more simplistic targets, to remove unpredictable parameters, and to remove the possibility of harming any living creatures.

These considerations creates the following initial problem, whereas the analysis will create a more in-depth set of requirements and a concrete problem statement.

How can a software system track a moving airborne projectile

Analysis 2

2.1 Embedded platform

The goal of the 5th semester, is to develop an embedded system. The following sections examines a few different embedded platforms.

2.1.1 Lego Mindstorms

Lego Mindstorms is a programmable computer kit, made by Lego. The platform is based around a central control computer, called the Intelligent Brick. It also includes a variety of sensors, motors and connection cables. Each generation further improves on the concept, adding more computational power and better sensors.

The Lego Mindstorm platform, comes with a graphical drag and drop interface. However, various different compilers for many different languages exist. As such the choice between different generations, does not come down to language preferences.

On the 5th semester of Software, each group is supplied with a lego kit, consisting of both a Lego Mindstorms NXT 2.0 kit and a Lego Mindstorms EV3 kit, aswell as an assortment of sensors, motors and Legos. On top of this, it is also possible to order other platforms and sensors.

Lego Mindstorms NXT 2.0

The Lego Mindstorms NXT 2.0 (NXT) is the second generation Lego Mindstorms kit. The NXT Intelligent Brick is a micro computer based on the 32-bit ARM7 microprocessor, with 256 kbytes of flash memory and 64 kbytes of RAM[6]. It includes a variety of sensors, such as touch, sound, light and ultrasonic (vision) sensors. On top of this, the consumer kit also includes servo motors and lamps.

A potential major disadvantage of the NXT 2.0, is that the platform is rather old. This means that problems could arise, especially in regards to compatability with newer platforms. This will be further elaborated on in a later section

Lego Mindstorms EV3

The Lego Mindstorms EV3 (EV3) is the third generation of the Lego Mindstorms line. The EV3 mainly improves on the specifications of the second generation, adding a significantly more powerful 300MHz ARM9 processor, running Linux, 16 MB of flash memory, which is extendable with a microSDHC card and 64MB of RAM[7]. On top of this, it also adds remote control and WiFi capabilities, as well as more recently updated compilers.

It is also fully backwards-compatible with the NXT sensors[8].

2.1.2 Single-board computers

Besides the Lego Mindstorms platform, which is the recommended platform for this semester, there is also the option of using single-board computers, such as the Raspberry Pi or the Arduino. Both of these are more general purpose computers, designed for small electronics projects. Both of the platforms include different models, with some being more powerful than others or having more ports.

Arduino

The Arduino is a single-board computer platform, designed for small electronics projects. The Arduino platform is am eco-system, comprised of different boards, that share the trait of being easily programmable in the included language, a subset of `C++`. Arduino boards typically includes a processor, some RAM and flash memory, as well as programmable GPIO pins[1].

The primary advantage of the Arduino platform is that it is easy to work with, and very modular. It is comprised of many different boards, all of which differ in power, meaning that one that matches any requirements most likely exist.

The Arduino platform is comprised of a lot of different boards, all of which are built for different purposes. They all differ in both their processing power, aswell as their connectability The Arduino Uno, is the best Arduino board to get started on, as well as the most used board in the Arduino ecosystem[9]. It has a 12 MHz ATmega328P processor and 2 kB of ram. A larger Arduino, the Arduino Due has an 84 MHz processor and 96 kB of Ram[10]. It has many more input/output pins and is meant for larger scale Arduino projects.

Raspberry Pi

The Raspberry Pi, the same as the Arduino platform, is a single-board computer ecosystem. Like the Arduino, a Raspberry Pi, typically consists of a processor, RAM, flash memory and GPIO pins. It differs from the Arduino, as the Raspberry's are typically more powerful, than their Arduino counterparts. In fact, Raspberry Pi's are, for all intents and purposes, just weaker desktop computers.

[1] General Purpose Input Output

Raspberry Pi's also typically include some form of network connectivity, whether it is a WiFi chip or a LAN port. It also includes USB ports, which means it can use a USB camera, which could be required for the object tracking.

The Raspberry Pi's differ in power. The Raspberry PI 3 B+, which is for all intents and purposes the flagship model, features a 1.4 GHz quad core CPU, with 1 GB of ram. The smaller Raspberry Pi Zero, trades performance, having only a 1 GHz single core CPU, for a smaller footprint and being less power hungry.

2.1.3 Takeaways

There are a lot of different platforms, on which to build an embedded system. The Lego Mindstorms ecosystem offers ease of use, and easy interfacability to a variety of different sensors. Both the NXT 2.0 and the EV3 are excellent robotics platform, and the choice between the two generations, will primarily be dependent on the limits that the project group imposes on itself. The more traditional platforms, the Raspberry Pi and the Arduino platform are also excellent choices, with the Raspberry Pi being more akin to a traditional desktop computer, and the Arduino being focused on small systems.

2.2 Sensors and motors for Lego NXT

The Lego NXT series offers a large variety of sensors and motors available for use, ranging from light and sound sensors to dual range, triple zone infrared obstacle detectors. Due to the amount of available components, it is pertinent to further investigate the advantages and disadvantages of each component to find the best applicable ones for the project.
In this section, the focus will be held on the basic functionality of the available components.

2.2.1 Ultrasonic Sensor

The primary purpose of an ultrasonic sensor is to determine distance from the origin to one or more objects using ultrasonic waves. To do this, the sensor head sends out an ultrasonic wave and receives the wave reflected back after hitting the surface of the target object. Using the time interval elapsed between sending and receiving the wave, the distance can be calculated.
The NXT Ultrasonic Sensor has an effective range of 1 to 250 centimeters with an accuracy of +/- 1 centimeter.

2.2.2 Touch sensor

As implied in the name, this type of sensor allows detection of touch. This allows for a variety of functionality such as enabling the machine detect if it collides with other objects.

2.2.3 Light sensor

The light sensor allows measuring the light levels by using an LED and a photo resistor. The sensor is capable of both measuring ambient light, such as the light levels of a room, and reflected light by using the built-in LED.

2.2.4 Dual range, triple zone infrared obstacle detector

The dual range, triple zone infrared obstacle detector, also known as NXTSumoEyes, is an obstacle sensor with an effective range of up to 20 centimeters using infrared beams. The major usability difference between the NXTSumoEyes and the ultrasonic sensor is that the NXTSumoEyes works with three individual detection zones of 20 degrees each, allowing for a more detailed response on the location of the detected object.

2.2.5 IRRD-T sensor

The infrared relative distance sensor, IRRD, measures the distance to an object with an effective range of up to 60 centimeters by measuring reflected infrared light, in a similar faction to the ultrasonic sensor.

2.2.6 HPMR Infrared Distance Sensor

The high precision medium range infrared distance sensor work in the same way as the IRRD-T sensor previously described.
However, this sensor allows detection of objects with a range of 10 to 80 centimeters, by using a Sharp GP20A02YK sensor, which is slightly more powerful than the sensor used in the IRRD-T sensor.

2.2.7 Motors

The NXT series offers a variety of motors in two categories: DC motors and servo motors. The DC motors are regular powered motors that can simply be turned on and off, while the servo motors have the functionality of controlling the rotation by a given degree.
The servo motors have a speed of 160-170 RPM, and a rotation precision of 1 degree. In comparison, the DC motor has a maximum speed of 380 RPM, making it faster but allowing less control of the rotation.

2.2.8 Angle sensor

The angle sensor measures axle rotation position and rotation speed. It allows measuring both the absolute angle, meaning the rotation of an axle from 0 to 359

degrees with an accuracy of 1 degree.
Likewise, it can measure an accumulated angle, which is the accumulated multiple rotation angle measured since it was last reset. Finally the angle sensor can calculate the current RPM with a rotation rate from 1 to 1000 RPM, with an accuracy of 1 RPM.

Theory 3

Implementation 4

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