POLITEKNIK MALAYSIA
SEBERANG PERAI

MINI DIDACTIC CNC MILLING MACHINE

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SESI JUN 2017

DECLARATION FINAL REPORT SUBMISSION

DECLARATION FROM STUDENTS (GROUP LEADER)

PLEASES TICK (/)

- [✓] We have made all the necessary amendments based on comments and suggestion given by the supervisor and panel.
- [✓] Format for report writing is in accordance with the format guidelines.
- [✓] We have the approval of the report from the supervisor.
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Abstract

This project is about our final project in semester five for Polytechnic group project. We have selected this project to design and manufacture a complete 3 axis CNC machine. The whole idea is to make this fully functional CNC, as cheap as possible compared to the CNC machines in the market.

The way we have approached to manufacture this CNC machine to make it as cheap as possible by the materials that are used for daily usage such as salvaged stepper motors from printers so that anyone can replicate this design of my CNC machine using the information in this report.

I have used an open source programs and microcontrollers which helped a lot in modifying it to fit my purpose in the project which could satisfy the desired outcomes.

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CHAPTER 1: Introduction

1.0 Background

Our products is didactics tools that includes a theory of teaching in a wider sense, a theory and practical application. In demarcation from "mathetics" (the science of learning), didactics refers only to the science of teaching. This theory might be contrasted with open learning, also known as experiential learning, in which people can learn by themselves, in an unstructured manner, on topics of interest. The theory of didactic learning methods focuses on the baseline knowledge students possess and seeks to improve upon and convey this information.

CNC is stands for 'Computer Numerical Control '. The machines works with taking digitized data, a computer and CAM program is used to control, automate, and monitor the movements of a machine. Milling is the machining process of using rotary cutters to remove material from a work piece by advancing in a direction at an angle with the axis of the tool.

To makes the products is working, basically needs a software to works. We will using 'Arduino' software. Arduino is a computer hardware and software company, project, and user community that designs and manufactures microcontroller kits for building digital devices and interactive objects that can sense and control objects in the physical world. The project's products are distributed as open-source hardware and software, which are licensed under the GNU Lesser General Public License (LGPL) or the GNU General Public License (GPL), permitting the manufacture of Arduino boards and software distribution by anyone. Arduino boards are available commercially in preassembled form, or as do-it-yourself kits. The project's board designs use a variety of microprocessors and controllers. These systems provide sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards ("shields") and other circuits. The boards feature serial communications interfaces, including Universal Serial Bus (USB) on some models, for loading programs from personal computers. The microcontrollers are mainly programmed using a dialect of features from the programming languages C and C++. In addition to using traditional compiler tool chains, the Arduino project provides an integrated development environment (IDE) based on the Processing language project. The Arduino project started in 2005 as a program for students at the Interaction Design Institute Ivrea in Ivrea, Italy, aiming to provide a low-cost and easy way for novices and professionals to create devices that interact with their environment using sensors and actuators.

1.1 Problem Statement

1. Insufficient CNC milling machine for Polytechnic Seberang Perai students especially in Mechanical program.
2. The prices of CNC milling machines is too expensive.
3. The existing size of CNC milling machine is large and possible to place in laboratories classroom.

1.2 Objective

1. To trial-run didactic CNC milling machine with program code and can be used to Polytechnic students in other disciplines engineering course.
2. To build didactic CNC milling machine supported by Arduino board with low-costing budget compare in the market.
3. To design and build the didactic CNC milling machine in minimum sizes and implementation in laboratories classes.

1.3 Scope Of Research

1. **Use component that already existed**

   We can find the other component everywhere. Our components is shaft, we can find it from printer. Besides, we can easily find stepper motor at any computers or electronics shops.

2. **Use Arduino as microcontroller**

   From the research we found, the Arduino can reduce costs, especially for any mini projects. The Arduino project started in 2005 as a program for students at the Interaction Design Institute Ivrea in Ivrea, Italy, aiming to provide a low-cost and easy way for novices and professionals to create devices that interact with their environment using sensors and actuators.

1.4 The important of the Project

1. Using Inventor software to design the CNC machine
2. The machine performs very accurately compared to the similar size machine's in the market.
3. It would consist of a laptop attached to the side of the CNC machine for giving commands to the machine via USB.

CHAPTER 2: LITERATURE REVIEW

2.0 Concept/ Theories Related Project

A traditional CNC router can move and cut in three directions which are usually referred to at the X, Y, and Z directions. The X-axis is usually the longest of the three running front to back. The Y-axis runs from left to right while the Z-axis runs up and down. Below you can see each axis labeled respectively. These machines are very efficient in that they work in all three directions in near perfect unison, giving this machine the capability of carving complex shapes.

Figure 1: X, Y and Z axis table.

Adapted from: (Google open access, 2016)

The CNC controller and computer system work together as the brain for these machines, telling the motors and drive system which direction to move and how far. Of course the computer must be given a design. Most designs start in a digital format such as a DXF drawing or some other similar format. The user would then use a CAM software package along with the CNC controller software provided. These types of software convert a 3D or 2D digital image into a tool path code such as G-code. The computer then converts these commands into a digital signal which it relays to the CNC controller which converts the digital signal to varying voltages and currents that control the mechanical drive systems. Most of this is far more than anyone operating a CNC wood router would need to know. It is usually plug and play. The user interface varies depending on the type or manufacturer, but the overall process is the same. You begin with a digital design and then use additional software to make tool paths for the machine to follow.

Figure 2: Controller & Computer System)
Adapted from: (Google open access, 2016)

The spindle is the part of the machine doing the cutting. Think of it as the actual router, such as a standard wood router. The router spindle is classified by its power rating, horse power in English units and Watts in SI units. The spindle works by rotating a cutting tool, such as router bits, at varying speeds. A typical spindle designed to cut wood plastics and other soft materials usually have a range of 8000 to 30,000 revolutions per minute. Spindles designed to cut metals operate between 2000 and 10,000 RPMs. Most CNC wood routers are capable of cutting metals as well. However, it is usually limited to nonferrous metals such as aluminum. When cutting metals or carbon based composites at high spindle speeds, a coolant system that cools the material being cut and the tool itself is usually necessary. Some spindles are controlled via the CNC controller which regulates the RPM based on material and the feed rate of the machine. There are other options that may be installed as well, some of which include an automatic tool changer, tool sensor, and touch probe.

Figure 3: A Spindle
Adapted from: (Google open access, 2016)

The cutting bed is where all the action happens. The cutting bed may come in several different types but the function remains the same. The cutting bed is designed to support and secure the piece of material being cut. There are several different designs that do this effectively. Some of the most common cutting bed designs cutting bed designs are the T-slot, pictured above, and the vacuum table. The T-slot style table works well for most any part as it uses bolts and clamps to secure the piece to the bed. The vacuum table is found on many high end models and works well for companies cutting the same design several times a day. However, it is limited to relatively flat pieces such as wood and sheet material. The T-slot is more versatile in that is can hold virtually any piece but lacks in efficiency and speed of setup. There are many other types available, some are a hybrid mix employing both a T-slot and the vacuum design. However, these are the two primary types of cutting beds.

Each axis employs a linear drive system that moves the spindles in that axis. The CNC linear drive system includes a motor, a linear bearing system, and some sort of lead screw assembly. The motor is the link between the mechanics and the electronics of the system. The motor receives its power via the CNC controller providing rotational power when needed to the lead screw assembly. There are two types of motors found on CNC wood router machines, which are stepper motors and servo motors. Steppers motors are the cheaper alternative and offer good performance and reliability but are usually not a closed loop system. Servo motors offer a closed loop system, which means after receiving their directions from the CNC controller, they send a signal back to the controller that verifies they have completed the task. Closed loop systems are usually found on high end models. The type of controller depends on the type of motor. The controller for a stepper motor or a servo motor is not the same. The motor offers the power in the form of rotational motion which needs to be converted to linear motion. This is where the lead screw assembly takes over. Combined with a linear bearing assembly, the lead screw assembly moves the gantry or spindle along its axis. Different designs employ varying methods of converting rotational motion to linear motion and some are better than others. The most common are a lead screw and nut assembly, a ball screw and nut assembly, or a rack and pinion assembly.

Figure 4: Motor parts
Adapted from: (Google open access, 2016)

A shaft is a rotating machine element, usually circular in cross section, which is used to transmit power from one part to another, or from a machine which produces power to a machine which absorbs power. The various members such as pulleys and gears are mounted on it. A line shaft roller conveyor or line-shaft conveyor is, as its name suggests, powered by a shaft beneath rollers. These conveyors are suitable for light applications up to 50 kg such as cardboard boxes and tote boxes.

A single shaft runs below the rollers running the length of the conveyor. On the shaft are a series of spools, one spool for each roller. An elastic polyurethane O-Rings belt runs from a spool on the powered shaft to each roller. When the shaft is powered, the O-Rings belt acts as a chain between the spool and the roller making the roller rotate. The rotation of the rollers pushes the product along the conveyor. The shaft is usually driven by an electrical motor that is generally controlled by an electronic PLC (programmable logic controller). The PLC electronically controls how specific sections of the conveyor system interact with the products being conveyed.

Advantages of this conveyor are quiet operation, easy installation, moderate maintenance and low expense. Line-shaft conveyors are also extremely safe for people to work around because the elastic belts can stretch and not injure fingers should any get caught underneath them. Moreover, the spools will slip and allow the rollers to stop moving if clothing, hands or hair gets caught in them. In addition, since the spools are slightly loose on the shaft, they act like clutches that slip when products are required to accumulate (stop moving and bump up against each other. i.e. queue up). With the exception of soft bottomed containers like cement bags, these conveyors can be utilized for almost all applications.

A disadvantage of the roller line shaft conveyor is that it can only be used to convey products that span at least three rollers, but rollers can be as small as 17mm in diameter and as close together as 18.5mm. For items shorter than 74mm, the conveyor belt system is generally used as an alternative option.

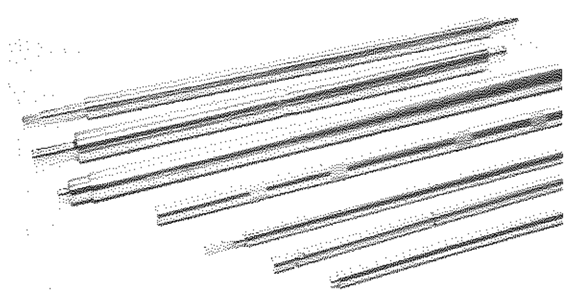


Figure 5: Line shaft roller from printer
Adapted from: (Google open access, 2016)

WHAT IS ARDUINO?

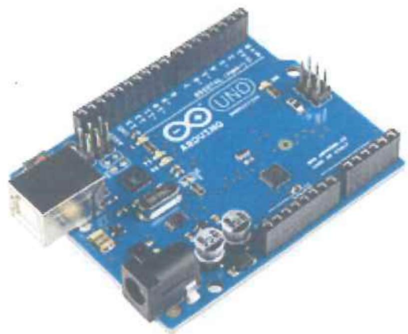


Figure 6: Arduino
Adapted from: (Google open access, 2016)

Arduino is a computer hardware and software company, project, and user community that designs and manufactures microcontroller kits for building digital devices and interactive objects that can sense and control objects in the physical world. The project's products are distributed as open-source hardware and software, which are licensed under the GNU Lesser General Public License (LGPL) or the GNU General Public License (GPL), permitting the manufacture of Arduino boards and software distribution by anyone. Arduino boards are available commercially in preassembled form, or as do-it-yourself kits.

The project's board designs use a variety of microprocessors and controllers. These systems provide sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards ("shields") and other circuits. The boards feature serial communications interfaces, including Universal Serial Bus (USB) on some models, for loading programs from personal computers. The microcontrollers are mainly programmed using a dialect of features from the programming languages C and C++. In addition to using traditional compiler toolchains, the Arduino project provides an integrated development environment (IDE) based on the Processing language project.

The Arduino project started in 2005 as a program for students at the Interaction Design Institute Ivrea in Ivrea, Italy, aiming to provide a low-cost and easy way for novices and professionals to create devices that interact with their environment using sensors and actuators. Common examples of such devices intended for beginner hobbyists include simple robots, and thermostats. The origin of the Arduino project started at the Interaction Design Institute Ivrea in Ivrea, Italy.

HISTORY

At that time, the students used a BASIC Stamp microcontroller at a cost of $100, a considerable expense for many students. In 2004, Colombian student Hernando Barragán created the development platform wiring as a Master's thesis project at the Interaction Design Institute Ivrea (IDII) in Ivrea, Italy. Massimo Banzi and Casey Reas, who are known for work on the Processing language were supervisors for his thesis. The project goal was to create low cost, simple tools for non-engineers to create digital projects. The Wiring platform consisted of a hardware PCB with an ATmega168 microcontroller, an IDE based on Processing and library functions to easily program the microcontroller.

In 2005, Massimo Banzi, with David Mellis, an IDII student, and David Cuartielles, added support for the cheaper ATmega8 microcontroller to Wiring. But instead of continuing the work on Wiring, they forked (or copied) the Wiring source code and started running it as a separate project, called Arduino. The Arduino's initial core team consisted of Massimo Banzi, David Cuartielles, Tom Igoe, Gianluca Martino, and David Mellis.

The name Arduino comes from a bar in Ivrea, where some of the founders of the project used to meet. The bar was named after Arduin of Ivrea, who was the margrave of the March of Ivrea and King of Italy from 1002 to 1014.Following the completion of the Wiring platform, lighter and lower cost versions were distributed in the open-source community. Adafruit Industries, a New York City supplier of Arduino boards, parts, and assemblies, estimated in mid-2011 that over 300,000 official Arduinos had been commercially produced, and in 2013 that 700,000 official boards were in users' hands.

HARDWARE

Arduino is open-source hardware. The hardware reference designs are distributed under a Creative Commons Attribution Share-Alike 2.5 license and are available on the Arduino website. Layout and production files for some versions of the hardware are also available. The source code for the IDE is released under the GNU General Public License, version 2 .Nevertheless an official Bill of Materials of Arduino boards has never been released by the staff of Arduino.

Although the hardware and software designs are freely available under copy left licenses, the developers have requested that the name "Arduino" be exclusive to the official product and not be used for derived works without permission. The official policy document on use of the Arduino name emphasizes that the project is open to incorporating work by others into the official product. Several Arduino-compatible products commercially released have avoided the Arduino name by using -Arduino name variants.

An Arduino board consists of an Atmel 8-, 16- or 32-bit AVR microcontroller (although since 2015 other makers' microcontrollers have been used) with complementary components that facilitate programming and incorporation into other circuits. An important aspect of the Arduino is its standard connectors, which let users connect the CPU board to a variety of interchangeable add-on modules termed shields. Some shields communicate with the Arduino board directly over various pins, but many shields are individually addressable via an I^2C serial bus—so many shields can be stacked and used in parallel. Before 2015, Official Arduinos had used the Atmel mega AVR series of chips, specifically the ATmega8, ATmega168, ATmega328, ATmega1280, and ATmega2560. In 2015, units by other producers were added. A handful of other processors have also been used by Arduino compatible devices. Most boards include a 5 V linear regulator and a 16 MHz crystal oscillator (or ceramic resonator in some variants), although some designs such as the LilyPad run at 8 MHz and dispense with the onboard voltage regulator due to specific form-factor restrictions. An Arduino's microcontroller is also pre-programmed with a boot loader that simplifies uploading of programs to the on-chip flash memory, compared with other devices that typically need an external chip programmer. This makes using an Arduino more straightforward by allowing the use of an ordinary computer as the programmer. Currently, option boot loader is the default bootloader installed on Arduino UNO.

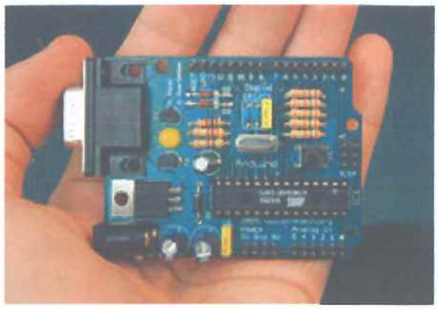


Figure 7: Arduino parts
Adapted from: (Google open access, 2016)

At a conceptual level, when using the Arduino integrated development environment, all boards are programmed over a serial connection. Its implementation varies with the hardware version. Some serial Arduino boards contain a level shifter circuit to convert between RS-232 logic levels and transistor–transistor logic (TTL) level signals. Current Arduino boards are programmed via Universal Serial Bus (USB), implemented using USB-to-serial adapter chips such as the FTDI FT232. Some boards, such as later-model Uno boards, substitute the FTDI chip with a separate AVR chip containing USB-to-serial firmware, which is reprogrammable via its own ICSP header. Other variants, such as the Arduino Mini and the unofficial Boarduino, use a detachable USB-to-serial adapter board or cable, Bluetooth or other methods, when used with traditional microcontroller tools instead of the Arduino IDE, standard AVR in-system programming (ISP) programming is used.

The Arduino board exposes most of the microcontroller's I/O pins for use by other circuits. The Diecimila, [a] Duemilanove, [b] and current Uno [c] provide 14 digital I/O pins, six of which can produce pulse-width modulated signals, and six analog inputs, which can also be used as six digital I/O pins. These pins are on the top of the board, via female 0.1-inch (2.54 mm) headers. Several plug-in application shields are also commercially available. The Arduino Nano, and Arduino-compatible Bare Bones Board [13] and Boarduino [14] boards may provide male header pins on the underside of the board that can plug into solderless breadboards.

Many Arduino-compatible and Arduino-derived boards exist. Some are functionally equivalent to an Arduino and can be used interchangeably. Many enhance the basic Arduino by adding output drivers, often for use in school-level education, to simplify making buggies and small robots.

Others are electrically equivalent but change the form factor, sometimes retaining compatibility with shields, sometimes not. Some variants use different processors, of varying compatibility.

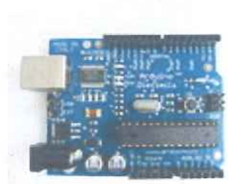
Figure 8: Arduino parts

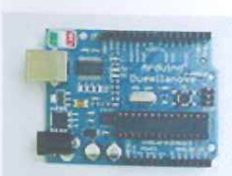
Adapted from: (Google open access, 2016)

OFFICIAL BOARDS

The original Arduino hardware was produced by the Italian company Smart Projects. Some Arduino-branded boards have been designed by the American companies Spark Fun Electronics and Adafruit Industries. As of 2016, 17 versions of the Arduino hardware have been commercially produced.


Arduino RS232 (thru-hole parts)


Arduino Diecimila


Arduino Duemilanove (rev 2009b)


Arduino Uno R2

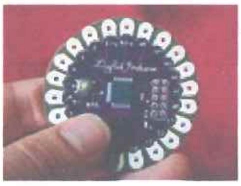

Arduino Uno SMD R3


Arduino Leonardo

Arduino Pro (No USB)

Arduino Mega

Arduino Nano (DIP-30 footprint)



Arduino LilyPad (rev 2007)

Arduino Robot

Arduino Esplora

Arduino Ethernet (AVR + W5100)

Arduino Yun (AVR + AR9331)

Arduino Due (ARM Cortex-M3 core)

Figure 9: Types of Arduino boards

Adapted from: (Google open access, 2016)

SHIELDS

Arduino and Arduino-compatible boards use printed circuit expansion boards called shields, which plug into the normally supplied Arduino pin headers. Shields can provide motor controls for 3D printing and other applications, Global Positioning System (GPS), Ethernet, liquid crystal display (LCD), or bread boarding (prototyping). Several shields can also be made do it yourself (DIY).

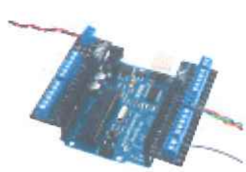
1.

Multiple shields can be stacked. In this example the top shield contains a solderless breadboard.

2.

Dragino Lora Shield allows the user to send data and reach extremely long ranges at low data-rates.

3.



Screw-terminal breakout shield in a wing-type format

4.

Adafruit Motor Shield with screw terminals for connection to motors

5.

Adafruit Datalogging Shield with a Secure Digital (SD) card slot and real-time clock (RTC) chip

Figure 10: Types of Arduino Shields
Adapted from: (Google open access, 2016)

SOFTWARE DEVELOPMENT

Arduino programs may be written in any programming language with a compiler that produces binary machine code. Atmel provides a development environment for their microcontrollers, AVR Studio and the newer Atmel Studio, which can be used for programming Arduino.

The Arduino project provides the Arduino integrated development environment (IDE), which is a cross-platform application written in the programming language Java. It originated from the IDE for the languages Processing and Wiring. It was created for people with no profound knowledge of electronics. It includes a code editor with features such as syntax highlighting, brace matching, cutting-pasting and searching-replacing text, and automatic indenting, and provides simple one-click mechanism to compile and upload programs to an Arduino board. It also contains a message area, a text console, a toolbar with buttons for common functions and a series of menus. A program written with the IDE for Arduino is called a "sketch". Sketches are saved on the development computer as files with the file extension. Arduino Software (IDE) pre-1.0 saved sketches with the extension.

The Arduino IDE supports the languages C and C++ using special rules to organize code. The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. User-written code only requires two functions, for starting the sketch and the main programs loop, that are compiled and linked with a program stub main() into an executable cyclic executive program with the GNU toolchain, also included with the IDE distribution. The Arduino IDE employs the program avrdude to convert the executable code into a text file in hexadecimal coding that is loaded into the Arduino board by a loader program in the board's firmware.

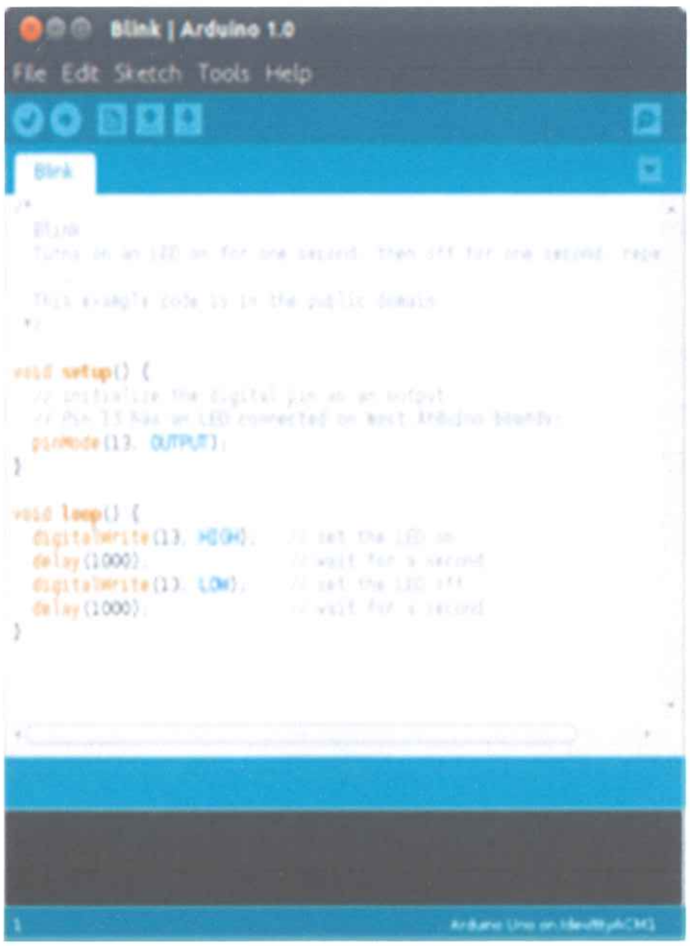


Figure 11: Example of coding

Adapted from: (Google open access, 2016)

SOFTWARE

Figure 12: Arduino software

Adapted from: (Google open access, 2016)

Power LED (red) and integrated LED on Line 13 (green) on Arduino compatible board, made in China .A minimal Arduino C/C++ sketch, as seen by the Arduino IDE programmer, consist of only two functions:

Setup (): This function is called once when a sketch starts after power-up or reset. It is used to initialize variables, input and output pin modes, and other libraries needed in the sketch.

Loop (): After setup () is called, this function is called repeatedly by a program loop in the main program. It controls the board until it is powered off or is reset.

Most Arduino boards contain a light-emitting diode (LED) and a load resistor connected between pin 13 and ground, which is a convenient feature for many tests and program functions. A typical program for a beginning Arduino programmer blinks an LED repeatedly. This program is usually loaded in the Arduino by the manufacturer. In the Arduino environment, a user might write such a program as shown:

```
#define LED_PIN 13                   // Pin number attached to LED.
void setup() {
    pinMode(LED_PIN, OUTPUT);        // Configure pin 13 to be a digital output.
}
void loop() {
    digitalWrite(LED_PIN, HIGH);     // Turn on the LED.
    delay(1000);                     // Wait 1 second (1000 milliseconds).
    digitalWrite(LED_PIN, LOW);      // Turn off the LED.
    delay(1000);                     // Wait 1 second.
}
```

Figure 13: Arduino code

Adapted from: (Google open access, 2016)

This program uses the functions pin Mode (), digital Write (), and delay (), which are provided by the internal libraries included in the IDE environment.

2.1 Previous Research Project

MILLING

Milling is the machining process of using rotary cutters to remove material from a workpiece by advancing (or feeding) in a direction at an angle with the axis of the tool. It covers a wide variety of different operations and machines, on scales from small individual parts to large, heavy-duty gang milling operations. It is one of the most commonly used processes in industry and machine shops today for machining parts to precise sizes and shapes.

Milling can be done with a wide range of machine tools. The original class of machine tools for milling was the milling machine (often called a mill). After the advent of computer numerical control (CNC), milling machines evolved into machining centers (milling machines with automatic tool changers, tool magazines or carousels, CNC control, coolant systems, and enclosures), generally classified as vertical machining centers (VMCs) and horizontal machining centers (HMCs). The integration of milling into turning environments and of turning into milling environments, begun with live tooling for lathes and the occasional use of mills for turning operations, led to a new class of machine tools, multitasking machines (MTMs), which are purpose-built to provide for a default machining strategy of using any combination of milling and turning within the same work envelope.

Figure 14: CNC Milling
Adapted from: (Google open access, 2016)

Milling is a cutting process that uses a milling cutter to remove material from the surface of a workpiece. The milling cutter is a rotary cutting tool, often with multiple cutting points. As opposed to drilling, where the tool is advanced along its rotation axis, the cutter in milling is usually moved perpendicular to its axis so that cutting occurs on the circumference of the cutter. As the milling cutter enters the workpiece, the cutting edges (flutes or teeth) of the tool repeatedly cut into and exit from the material, shaving off chips from the work piece with each pass. The cutting action is shear deformation; material is pushed off the workpiece in tiny clumps that hang together to a greater or lesser extent (depending on the material) to form chips. This makes metal cutting somewhat different (in its mechanics) from slicing softer materials with a blade.

The milling process removes material by performing many separate, small cuts. This is accomplished by using a cutter with many teeth, spinning the cutter at high speed, or advancing the material through the cutter slowly; most often it is some combination of these three approaches. The speeds and feeds used are varied to suit a combination of variables. The speed at which the piece advances through the cutter is called feed rate, or just feed; it is most often measured in length of material per full revolution of the cutter.