Arduino Controlled Filling Yarn Presenter of Modern Rapier Loom

Soadbin Khan[a*], Md. Mohaddesh Hosen[b]

[a,b]*Department of Fabric Engineering, Bangladesh University of Textiles, Dhaka-1208, Bangladesh*

[a]*Email: khansoadbin@gmail.com*

[b]*Email: mohaddesh@butex.edu.bd*

Abstract

This paper is concerned with the application of filling yarn presenter with the help of Arduino mega controlled by various analog and digital inputs. Modern Rapier looms are more advanced in every aspect of production than conventional power looms. Quickstep mechanism is used in multicolored weft insertion. In the current project we introduce a prototype of servo-motor-controlled filling yarn presenter as well as a hypothesis has been shown in order to maximizing the number of filling yarn presenter. We took advantage of Arduino-based programmable circuit board (PCB) along with necessary components such as keypads, potentiometers, breadboards, servo motors, LCD, metal wires and plastic pipes. The integration of all these parts results in a prototype based on this redefined mechanism which is able to manually control 4 individual colored weft yarns according to their sequence that also can be inputted manually.

Keywords: arduino mega; potentiometer; servo motors; filling yarn presenter; modern loom.

1. Introduction

A rapier loom is a weaving loom in which the filling yarn is carried through the shed of warp yarns to the other side of the loom by finger-like carriers called rapiers. Rapier weaving today exists in various forms. During the last two decades the developments in rapier weaving have been carried out in a continuous way. Today's rapier weaving machine is designed with modern electronics, with automation of weaving and central microprocessor control system, also ensuring maximum reliability, user-friendliness, ease-of operation, shorter design changing time, excellent fabric quality, low energy consumption, and optimized insertion cycle for required industrial speed[1-4].

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* Corresponding author.

Rigid rapiers were invented in 1870 and perfected by O. Hal-lensleben in 1899. The main breakthrough came in 1922 when John Gabler invented principle of loop transfer in the middle of the shed [5-7]. In the period till the beginning of the World War 2 many patents were applied for, but it was only in the 50s and 60s that rapier weaving finally become commercialized and since then has made highly significant improvement in achieving the modern weft insertion rate of 1,500 m/min and over [8].Stationary packages of yarns are used to provide the weft yarns in the rapier machine. One end of a rapier, a rod or steel tape, carries the weft yarn. The other end of the rapier is connected to the control system. The rapier moves across the width of the fabric, carrying the weft yarn across and through the shed it approaches to the opposite side. The rapier will then retracted and leave the new filling in place. Ease of multicolor weft insertion is fully exploited by rapier looms and many can insert up to 12 colors in any pick-at-any desired patterning sequence, including their capability to deal with a very wide range of yarns and fabric types. The weft insertion parts and elements have been made smaller and lighter in weight [2,4,9-11].Versatility in Color Insertion by Electronic Insertion The weft color selectors of today's rapier weaving machine are microprocessor controlled, compact sized ones and can be available in 16, 12, 8, 4 or 2 colors. Picanol developed the Quick Step filling presenter, operates with independent module, each consisting of an electronically controlled stepper motor with presenter needle. The color and weave pattern are microprocessor or jacquard controlled. After the left gripper receives and takes the presented yarns, the Quick Step needle returns to an intermediary position, so the course of the filling yarn is straight and the tension of the yarn is low and remains consistent. The Quick Step filling presenter has several advantages. It is monitored by the machine with micro-processor, so the timing for the presentation of the filling yarn is perfectly synchronized with the machine speed and the weave pattern. The filling presenter also provides the perfect position for rethreading. The modules of the Quick Step are interchangeable and there are no external mechanical drives, so no maintenance or lubrication is required to operate perfectly[5,12]. Dornier offers the Electronic Color Selector (ECS) and the electronic filling tension device with integrated filling stop motion (EFC) are based on state-of-the-art stepping motor technology and are controlled by an external CAN-BUS[12,13,14].Mechatronics is a synergistic discipline that combines elements from electronics, programming, control systems and mechanics. Some of the learning approaches discussed in literature use a bottom-up [15] or a competition-based [16-19] curriculum. A web-based learning approach is described in [20, 21]. Recently microprocessor control systems have become requisite because of their high performance with economical hardware and software. In servo applications, the modern digital control can satisfy the various engineering specifications [22, 23]. Nowadays microprocessors are found in most of the industrial applications. It is expected that in the near future most incremental servo systems will contain a microprocessor as a controller [24, 25]. In this work a prototype of filling yarn presenter mechanism is created aided by mechatronics. In recent years, the low-cost Arduino has become a popular prototyping platform, especially among hobbyists and also for educational purposes [26, 27]. We took advantages of programmable circuit board (PCB) with Arduino, a human machine interface (HMI). We first designed the prototype model consisting of 4 fingers and 2 rigid rapier named Giver and Receiver. All of these 6 mechanical parts use servo motor to move according to the input. We designed the whole frame in a way that it successfully received filling yarn from 4 fingers as sequence inputted and picking of each yarn is done using Giver and Receiver rapier. We coded the Arduino Mega for each and every electronics parts present on the board. We wrote our code in a form that by using analog and digital input the degree of rotation, rotation speed, delay time after each rotation, sequence of fingers activation of 6 servo motors can be controlled

manually. The main components are consisting of potentiometer, breadboard, servo motor, LCD, Keypad, metal wire and plastic pipes.

2. Construction

The prototype filling yarn presenter of modern rapier loom is constituted of Arduino mega, servo motor, bread board, Potentiometer, analog and digital input output. Arduino Mega 2560 is a microcontroller board based on Atmega2560. It comes with more memory space and I/O pins as compared to other boards available in the market. There are 54 digital I/O pins and 16 analog pins incorporated on the board that makes this device unique and stand out from others. Out of 54 digital I/O, 15 are used for PWM (pulse width modulation). A crystal oscillator of 16MHz frequency is added on the board [27]. This board comes with two voltage regulators i.e. 5V and 3.3V which provide the flexibility to regulate the voltage as per requirements as compared to Arduino Pro Mini which comes with only one voltage regulator [28]. Servomotor is also known as control motor with high torque capabilities. Unlike large scale industrial based motors, servo motors are not utilized for continuous energy conversion but only for precise speed and position control at high torques. Since this torque regulator is independent of the position controller, employing the conventional technique to design the position controller is possible [29, 30]. A servo motor is a rotary actuator which is used for applications that require a great degree of accuracy for the rotation angle [31].This is due to the presence of a feedback encoder in servo motors that measures the difference between the reference and required angle and ensures the final position is achieved to a greater accuracy. When using stepper motors, the absence of a feedback system can lead to the possibility of a lag due to inertia and an inevitable loss of accuracy in attaining the final position [32]. A potentiometer is a variable resistor. By turning a knob, the amount of resistance can be adjusted, often from no resistance at one extreme to several thousand ohms of resistance at the other extreme. As the resistance increases, the amount of current in the circuit decreases. Pulse-width modulation (PWM), or pulse-duration modulation (PDM), is a modulation technique used to encode a message into a pulsing signal. The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to the off periods, the higher the total power supplied to the load. The main advantage of PWM is that power loss in the switching devices is very low.A breadboard is a perfect device for temporary prototype with electronics and test circuit designs. Most electronic components in electronic circuits can be interconnected by inserting their leads or terminals into the holes and then making connections through wires where appropriate. The breadboard has strips of metal underneath the board and connects the holes on the top of the board. The top and bottom rows of holes are connected horizontally and split in the middle while the remaining holes are connected vertically A keypad is one of the most commonly used input devices in microprocessor applications. In a standard keypad wired as an X-Y switch matrix, normally-open switches connect a row to a column when pressed. If a keypad has 12 keys, it is wired as 3 columns by 4 rows. A 16 key pad would have 4 columns by 4 rows. Arduino IDE is the open source software that is mainly used for writing and compiling the code into the Arduino Module. It is the official Arduino software, making code compilation too easy that even a common person with no prior technical knowledge can get their feet wet with the learning process. A wide range of Arduino modules are available including Arduino Uno, Arduino Mega, Arduino Leonardo, Arduino Micro and many more. Each of them contains a microcontroller on the board that is actually programmed and accepts the information in the form of code. This environment supports both C and C++

languages. The other materials that we needed to complete building up the whole projects are –

a. Connecting Wires, b. Board cut out of Foam, c. Square Wooden Plate, d. Plastic pipe, e. Metal Wire, f. Glue Gun, g. 30 Ne Yarn

2.1. Building up connections

A massive complex coding was done to control the whole project. We used the Arduino 1.8.9 version of the software and then burnt inside to the Arduino Mega 2560 memory through cable.

2.1.1. Wiring up Arduino

The jobs to connect three wires to Arduino:

1.   A blue wire into analog pic A0
2.   A black wire into one of the GND (ground) pins
3.   A red wire into the 5V pin
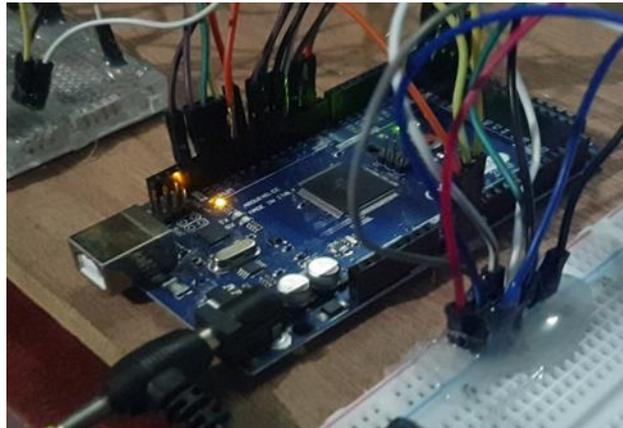
Figure 1: Connecting Arduino and breadboard along with different components

2.1.2. Connecting potentiometer

Figure 2: Connecting potentiometer

Next, we connect the wires to a dial potentiometer (here we use a 10k potentiometer, but most other types will

also work). We connect the black wire to the first pin, the blue to the second and the red to the third (as shown in the photo).

2.1.3. Connecting servo motor

Figure 3: Connecting servo motor

We used 6 servo motors and marked them as A, B, C, D, E, F For our ORB wired servo motor:

1. Orange wire connects to digital pin 11 on the Arduino
2. Brown wire connects to potentiometer GND pin
3. Red wire connects to potentiometer 5V pin

2.2. Frame building procedure

Full frame consist of 3 boards.

1. One hard wooden board
2. Two white foam board

On the top of one white foam board the wooden board is placed horizontally and another white foam board is placed on the top of those two boards vertically. Precise cutting is maintained for the vertical board so that the electrical connection can be transferred without any hassle through the entire frame.

2.2.1. On the wooden board

All the electrical setup is interconnected and joined over a hard-wooden square shaped board using glue gun and gums. Following are the components operating on the wooden board-

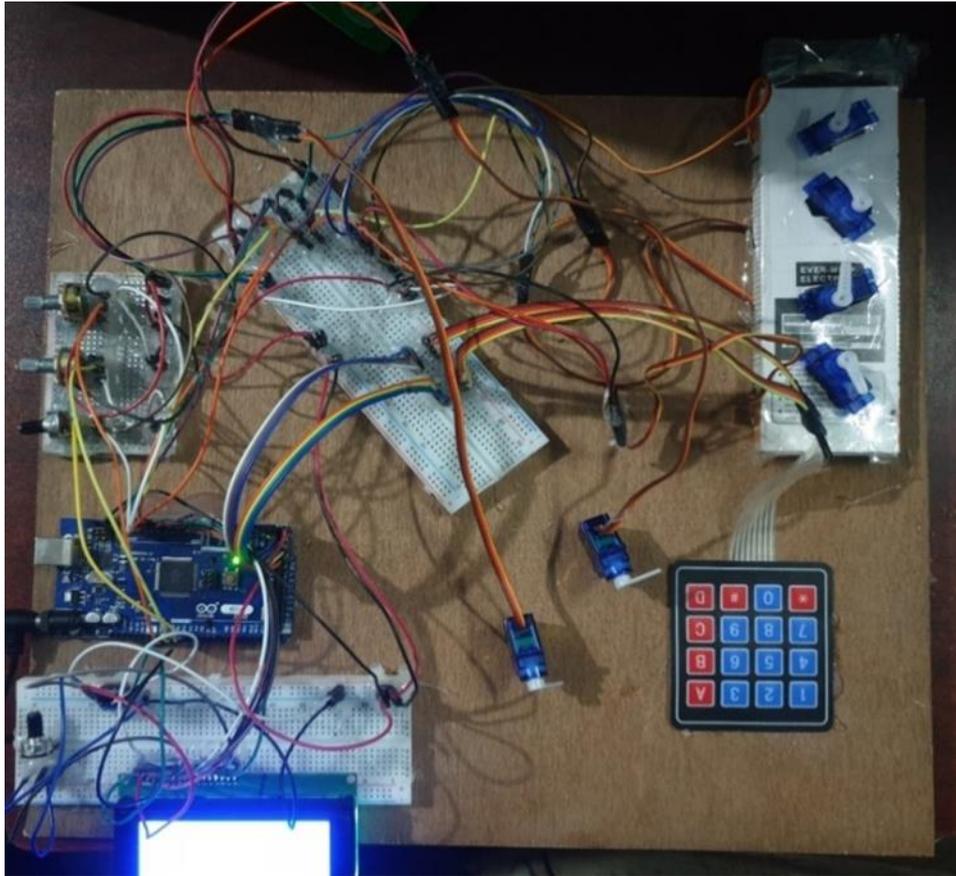1.   Arduino Mega 2560; Potentiometers; Breadboards; Keypad; Wire connections; LCD

Figure 4: Top view of electronics unit

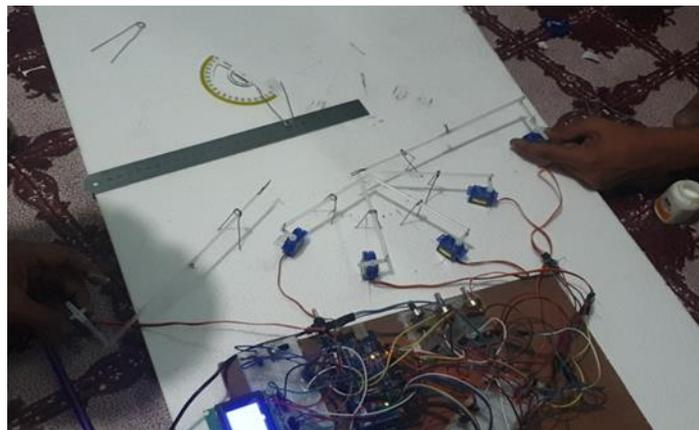### 2.2.2. On white foam board

Figure 5: Assembly of different parts in the ground frame

1. Different sizes of plastic pipes are cranked with rotating shaft of each servo motors (A-F) which acted as fingers (A-D), Giver (E) and Receiver (F)
2. A-D servo motors are then installed on vertically placed white foam board and E, F servo motors are installed on horizontal foam board at synchronized positions.
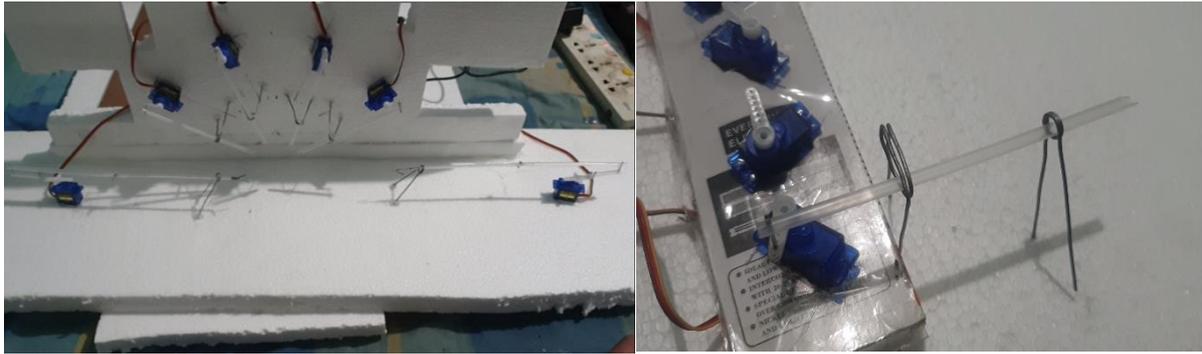
Figure 6: Assembly of different parts on the vertical frame

1.   We converted the circular motion of the servo motor rotor to traverse motion of the plastic pipe using metal wire guide and fixed to appropriate positions for synchronized motion transfer.

3. Operating methodology

3.1. Meaning of different terms

1. **RT** (rotation time) is the time needed to rotate servo motor's rotating shaft by 1 degree in millisecond. It is controlled by potentiometer for RT and then has to fix the desired numerical value from keypad.
2. **DT** (delay time) is the waiting time for each finger when it arrives at the picking insertion zone measured in millisecond. Values have to set using potentiometer for DT and fixing it requires keypad.
3. **DR** (degree of rotation) is the angle of rotation of rotating shaft from 0-180 which converts to linear direction by plastic pipes cranked with. Values controlled by potentiometer for DR and needs keypad to fix various values.
4. **Sequence** is the carrying order of different colored yarns in front of the Giver head (E) which is performed by fingers (A-D) according to the inputted combination. Here in our project it is possible to input up to 24 combinations from finger (A-D). Any sequence can be inputted by tapping keypad's A, B, C, D buttons orderly.
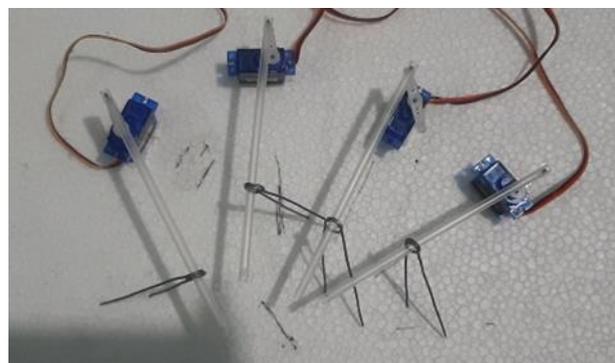

Figure 7: Randomly powering up 4 out of 6 servo motors using analog and digital input and DC power supply (ground checking phase before structured)

Figure 8: LCD showing the inputted parameters value and sequence while operating

3.2. Inputting ranges and activating operation

1. DR is controlled using potentiometer (0-180) degree. Then have to press 5 to fix.
2. DT is controlled using potentiometer (1500-3000) millisecond. Then have to press 5 to fix.
3. RT is controlled using potentiometer 3-20 millisecond. Then have to press 5 to fix.
4. After that we have to insert any sequence using A, B, C and D from keypad

After inputting all, we have to press 5 from keypad to start the whole process. At first the LCD display will show all the data inputted and then the whole picking process will start. To turn off the process we simply have to press the reset button.

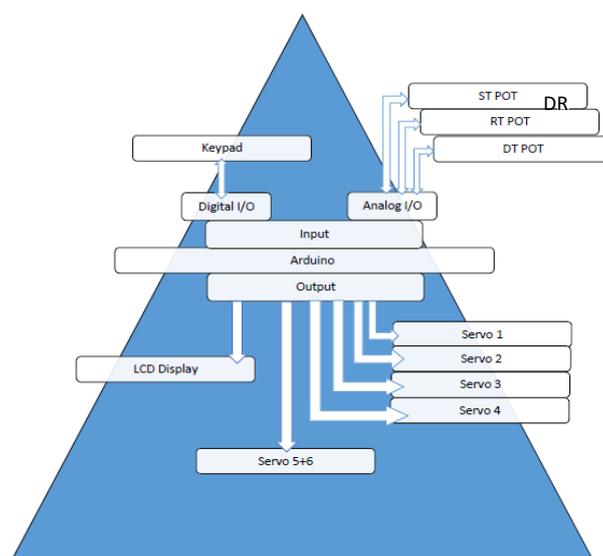### 4. Schematic illustration of different units

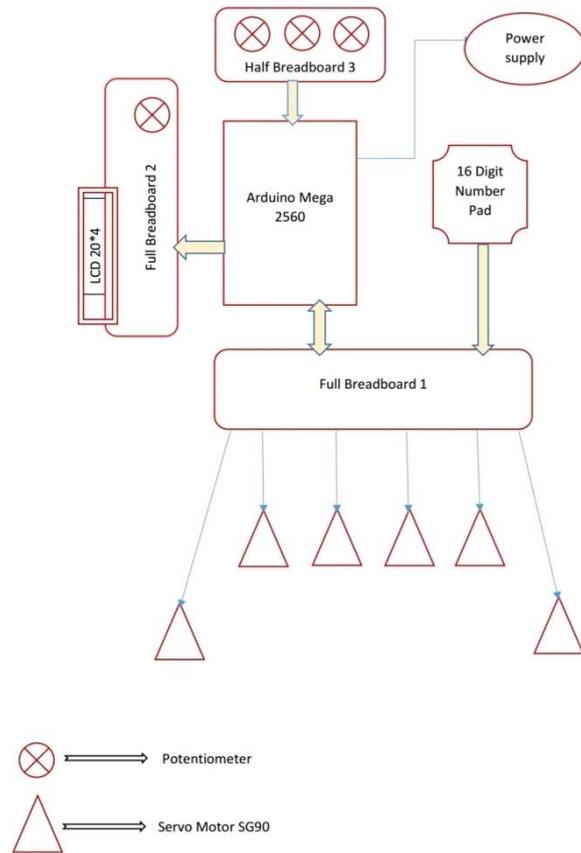**Figure 9:** All units and their relations with each other at a glance

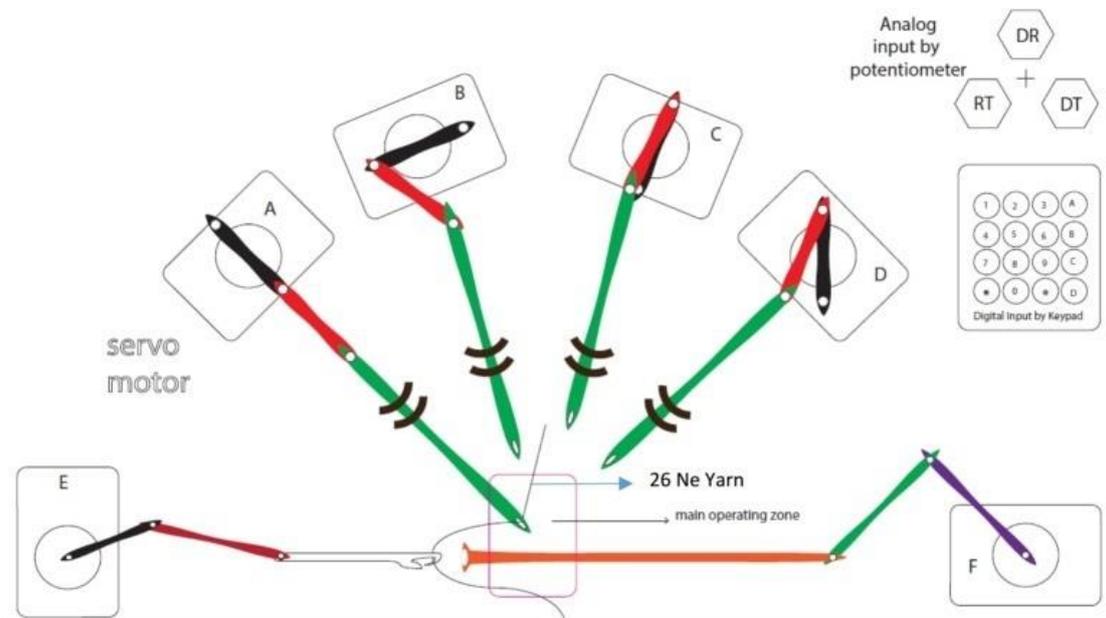**Figure 10:** Electronics unit

Figure 11: Mechanical unit

A,B,C,D will work at Y to X-X` axis and E,F will work at X-X` axis

5. Result and discussion

In our project we had shown 4 fingers performing as filling yarn presenter by connecting plastic pipes to each servo motor (A-D).We also used servo E and F as Giver and Receiver successively. Following are in details

5.1. Actions of different servo motors

Servo motor A, B, C and D is cranked with 4 inches of plastic pipe each acting as 1st, 2nd, 3rd and 4th finger successively. Servo motor E and F is cranked with 6 inches of plastic pipe each acting as Giver and Receiver successively.

5.2. Sizes of fingers and rotating shafts

1. All the rotating shafts in A, B, C, D is measured 1 inch and in E, F is 1.5 inch
2. Finger's accumulated size in servo A = pipe length+ shaft length = (4 + 1) = 5 inches As well as in servo motor B, C and D
3. Finger's accumulated size in servo E = pipe length+ shaft length = (6 + 1.5) = 7.5 inches As well as in servo motor F
4. Highest linear moving distance of finger head's in servo A vertically = 2 inches (as 1 inch rotating shaft rotates from 0-180 with cranked pipe) As well as in servo motor B, C and D
5. Highest linear moving distance of finger head's in servo E horizontally = 3 inches (as 1.5 inch rotating shaft rotates from 0-180 with cranked pipe) As well as in servo motor F
6. Total linear distance covered by finger heads of E and F horizontally is 3+3 = 6 inches

5.3. Process discussion

6 inches is the pick insertion width of our project and Giver E's giving end is situated at the vertical downside of the A/B/C/D finger's functional end. Any (A-D) finger head carrying filling yarn moves at a time vertically downwards in front of Giver E's giving end. Giver E's giving end then moves 3 inch forward carrying the any (A-D)'s presented different colored 26 Ne filling yarn (used in our project) and Receiver's receiving end comes 3 inch towards E to receive the filling yarn at the same time. After repositioning of the filling yarn presenter (A/B/C/D) the Receiver F goes back to its initial position carrying the filling yarn and thus one cycle of picking is done.

When the mechanism runs, it maintains some parameters that were inputted manually. These are –

1. **DR (degree of rotation)** = in our project we fixed it to 177 degree but it can be manually adjustable using potentiometer in our Project.
2. **RT (rotation time)** = It can be ranged from 3-20 millisecond using potentiometer
3. **DT (delay time)** = It can be adjustable from 1500-3000 millisecond or 1.5-3 second using potentiometer

The possible all speed and moving calculation is given below. Here we provide some random RT value inputted by potentiometer

Table 1: List of total time requirement based on various RT value and fixed DR value

RT (in millisecond)	DR (degree)	Total time required (millisecond)/pick; excluding DT
3	177	3×177 = 531
5	177	5×177 = 885
10	177	10×177 = 1770
15	177	15×177 = 2655
20	177	20×177 = 3540

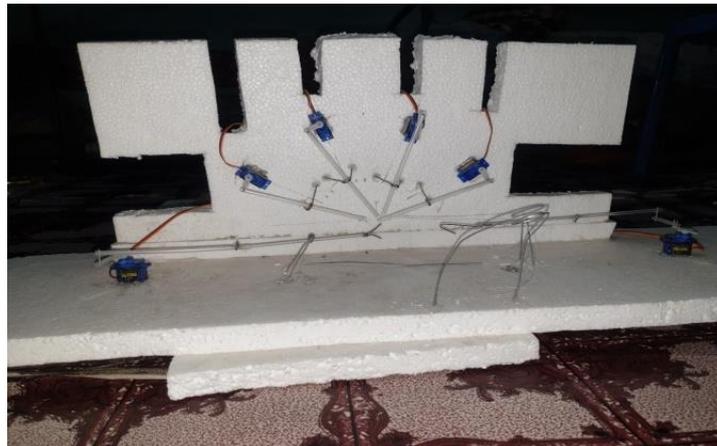## 6. Actual prototype

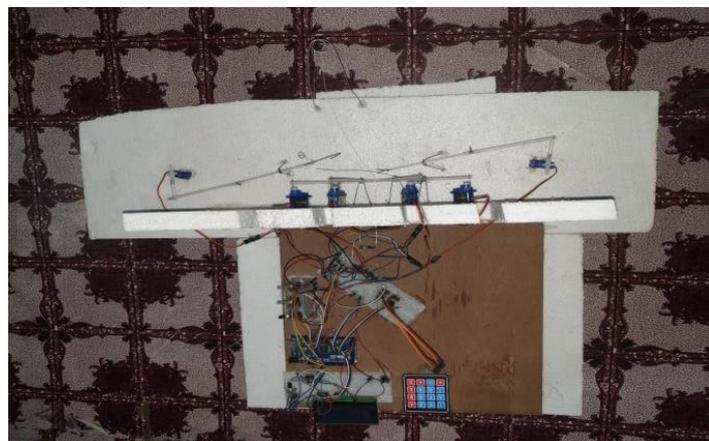**Figure 12:** Actual prototype front view
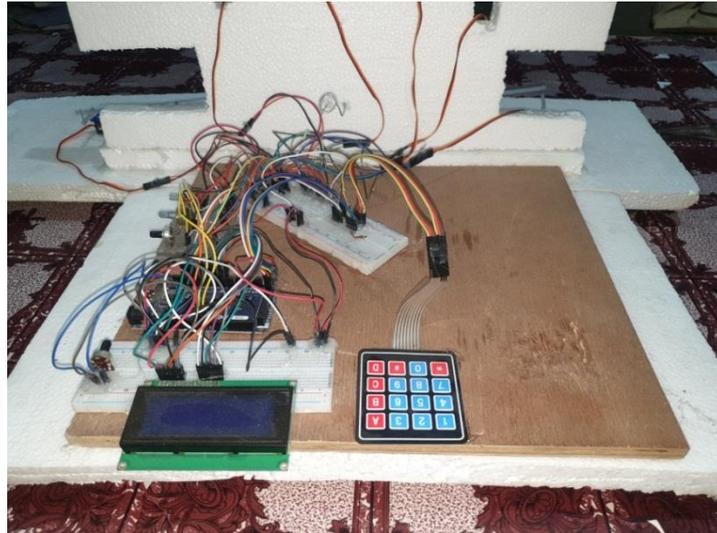

Figure 13: Actual Prototype Top view

Figure 14: Actual prototype back view

7. Future prospects

As per latest proceedings, modern rapier loom limits the number of colored weft yarns that can be inserted to 16. However, the proposed mechanism in the current work can potentially increase this capacity up to 32. Table 2 presents 6 different designs with varying capacity using our mechanism. Design A refers to the prototype discussed in this project. Design F is the proposed design where 32 colored yarns can be accommodated which is further explained in the later subsections.

Table 2: Capacity of multicolored weft based on space consumption

Design ID	Servo to servo distance (degree)	Space considered (degree)	Capacity
A	60	180	**4**
B	30	180	7
C	60	360	6
D	30	360	12
E	20	360	18
F	11.25	360	**32**

If we consider the full mechanism in a conical frame then the diameter of the frame will be the operating width and the area will be the operating space. When we place 32 servos at fixed interval of distance along the circumference then the distance will be calculated by following formulas. Servo to servo angular distance θ is calculated as
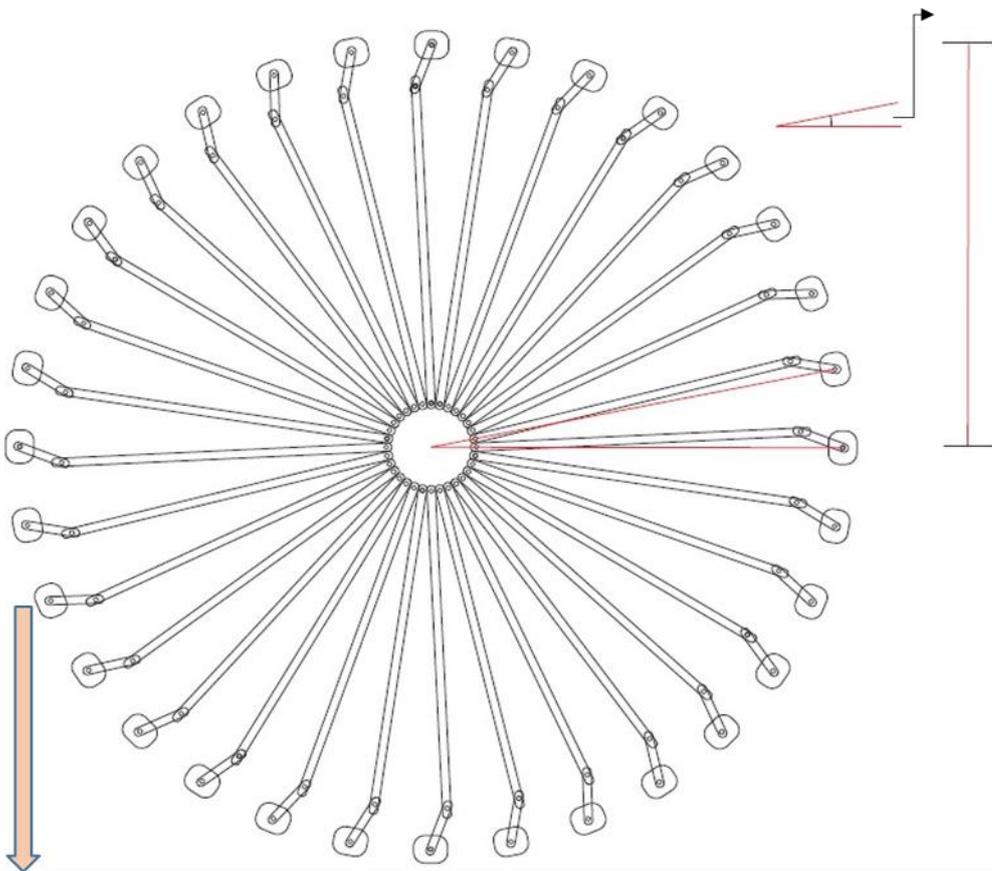
$$\theta = \frac{360}{32} = 11.25°$$

Arc length over θ is L which is expressed as follows

$$s = 11.25 \times \frac{\pi}{180} = \frac{L}{r}$$

Or, $L = r \times 11.25 \times \frac{\pi}{180} = 2.3562$

Here, r is the radius of the top of the conic which measures 12 inch. This is to be noted that the above calculations are optimal only based on the proposed design that allows the servo motors to move freely.
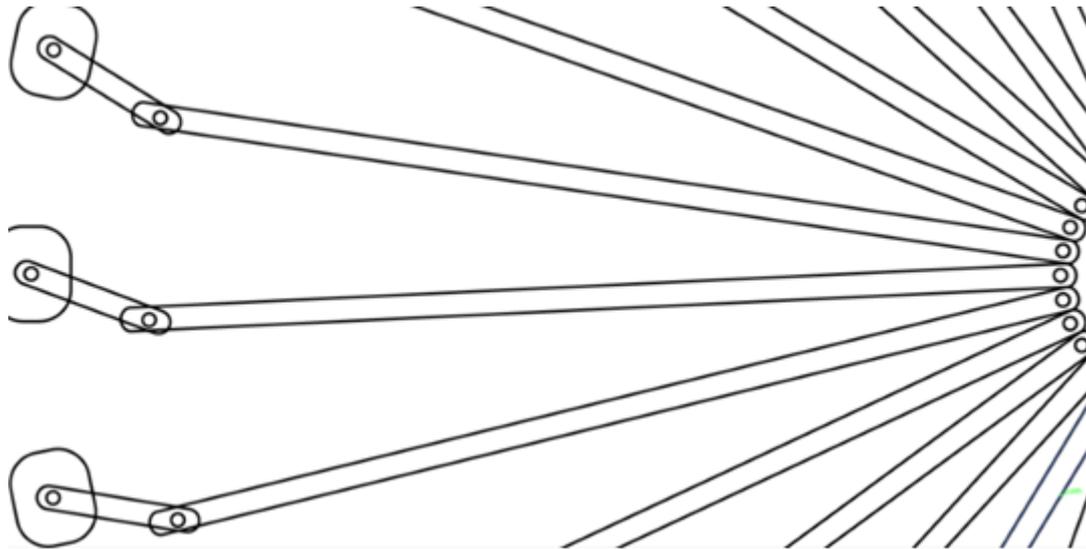
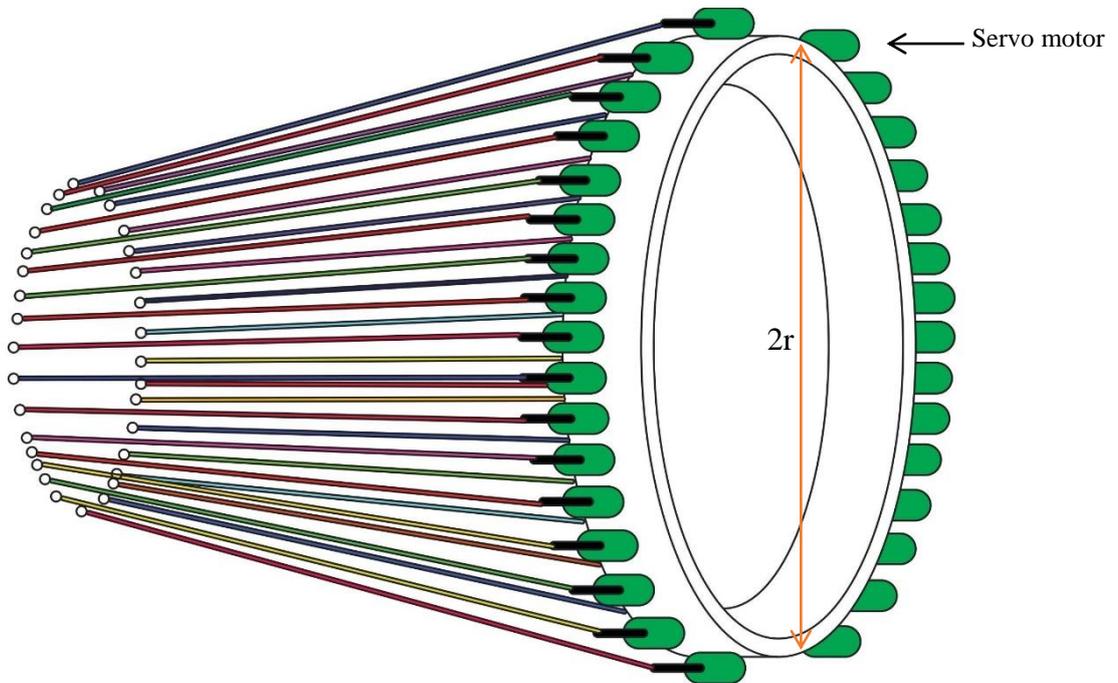**Figure 15:** Placements of servo motors and fingers (2D view)

Figure 16: Placement of 32 fingers with servo motors in proposed filling yarn presenter prototype
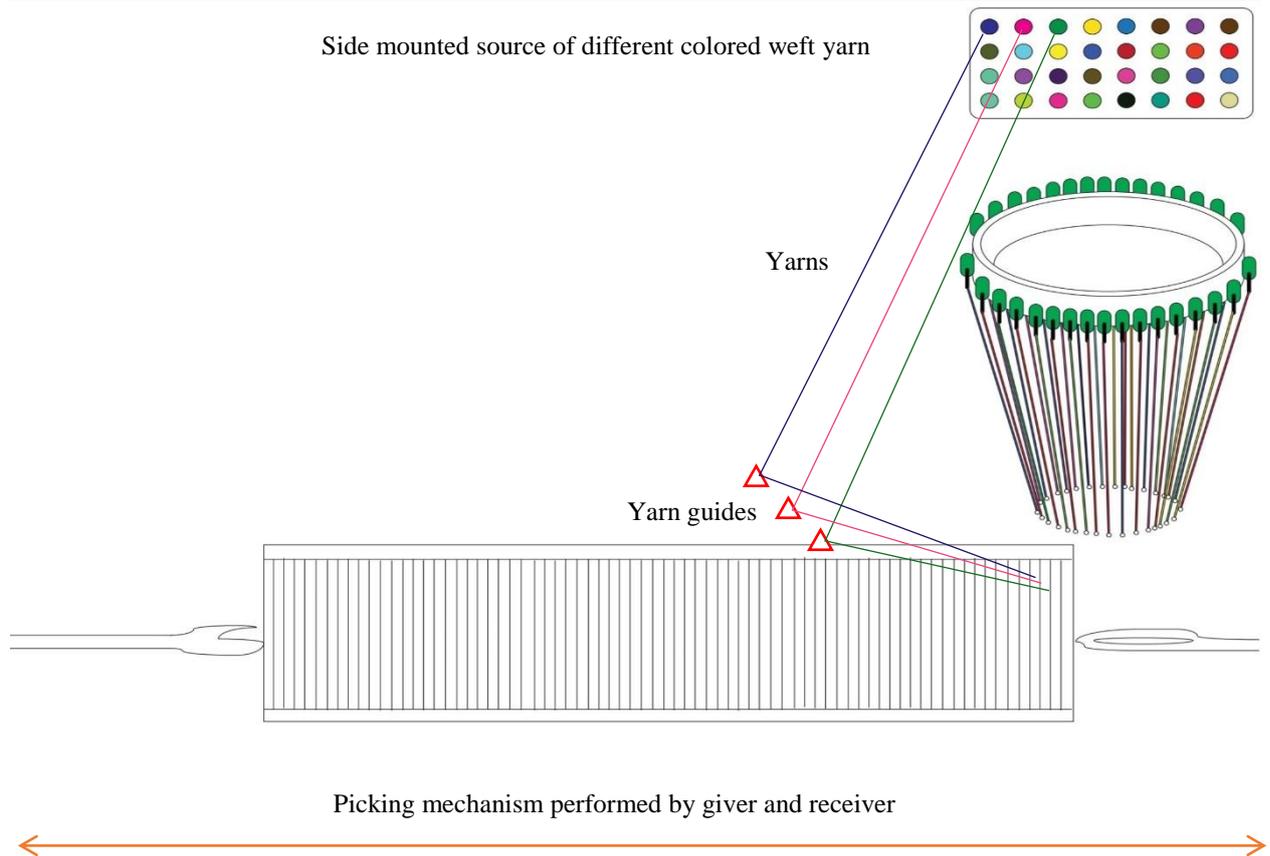
Figure 17: Final proposed design (performing actions using 3 yarns)

8. Conclusion

A prototype filling yarn presenter has been established. The mechanism comprises of an Arduino mega microcontroller in conjunction with a set of analog and digital input unit and LCD output unit to control the servo motor regulated presenter fingers as per the inputs given by the users. But servo motors used in our project are not industrial grade, thus we didn't get our desired speed and filling yarn presenter accuracy. Despite of having speed constraints we have successfully performed to present filling yarn through the individual four fingers in front of the Giver (E).

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