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Design and Fabrication of Animatronic Skull using 3D Printer

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***Abstract*: - The main aim is to further improve the developed human skull for a better AI interface. Development of different types of ancient skull to study their complexity and the way it functions are under progress. Also, development of the skull is not simple enough but it should be able to provide the exact details contained in original skull. Here, we are developing a 3D animatronic skull that will help medical students to study the complexity of the skull. This will also have all the actions and movements similar to normal human face/skull. The free movement of jaws, eye-lids and eye-ball movement, neck movements are few of it features.**

The 3D animatronic skull will have a better AI interface which will be used in assistive devices and can be used as tour guide, robot head and many more. By creating this kind of animatronic skulls will help the humans understand the way they are evolved and different types of skulls which we come across. This AI interface will create a robot head which will synchronize its jaw movements according to the audio played. They are also used in films to avoid expensive CGI animations. A few have even made it into the education field to present skull topics in a more amusing fashion. Amazingly, all of the motors and electronics are inside the skull, this makes the animatronic skull ideal for close-up viewing.

Keywords*: - *Animatronic skull, jaw movement, eyes and eye lids movement, CT scanning, servo motors and PLA plastic.

I. INTRODUCTION

The study of bones (osteology) was evolved day-by-day. 3D printing came into existence in 1984 and developed rapidly in the field of developing 3D animatronic objects. Hence People started creating the artificial structures of the bones for the study purpose.

Meanwhile CAD designing came into existence in mid-1960 and it is used in the design of tools and machinery and in the drafting. CAD is mainly used for detailed engineering of 3D models or 2D drawings of physical components, but it is also used throughout the engineering process from conceptual design and layout of products, through strength and dynamic analysis of assemblies to definition of manufacturing methods of components. Using CAD designing softwares, animatronic hardware objects are developed [1].

The skull is a structure that forms the head in vertebrates. It supports the structures of the face and provides a protective cavity for the brain. The skull is composed of two parts: the cranium and the mandible. In humans, these two parts are the neurocranium and the viscerocranium or facial skeleton that includes the mandible as its largest bone. The skull forms the anterior most portion of the skeleton and is a product of cephalisation, housing the brain, and several sensory structures such as the eyes, ears, nose, and mouth. In humans these sensory structures are part of the facial skeleton [2].

Ancient skull structures are studied and using those designs many people have developed individual working parts of the skull like jaws, eye-lids, eyes, neck movements. Using this references we have designed the 3D structure of entire skull with all the functional parts.

II. ANIMATRONICS

Animatronics is nothing but string driven component which resembles any living organism and performs the actions done by it. Animatronics came into existence in 1962 when the first animatronic bird introduced in the move called 'Mary Poppins'. Animatronics developed rapidly as the 3D printed object can be easy used to create animatronic object which are mostly used in movie CGI effect and many more. Animatronics along with Artificial Intelligence came into existence and evolved in the field of animations where the character called Pascal in the move is nothing but an animatronic object which introduced along with Artificial Intelligence.

Fig 1. Animatronic Bird in Movie –'Mary Poppins'

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III. DESIGN OF 3D ANIMATRONIC SKULL

The 3D printed objects are designed using CAD designer tools with the help of 3D scanner or any other means of designs. According to reference [3], CT scanned output can be used to design in CAD. The CT scan will have errors upto 1mm, which can be taken into design considerations and by adjusting the error using CAD tools we can design the original animatronic objects for 3D printing.

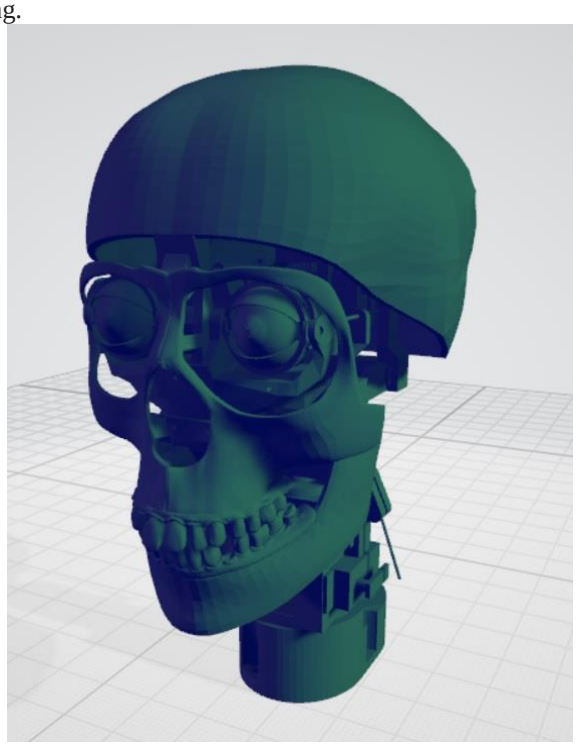

Fig 2. CAD Designed Animatronic Skull.

The CAD designer used to make such animatronic skull are Auto-CAD and CATVIA, where these tools design the 3D animatronic objects. The animatronics skull is created in similar manner where the design ideas are obtained using one of the means mentioned above and designed using CAD tools. Later the CAD designed file in .Stl format is given to the 3D printer to print the 3-Dimensional object designed using CAD. The animatronic skull designed here is a string controlled, servo driven, which performs actions similar to human being where it has eye movements, eyelid movements, neck movements and jaw movements.

IV. SERVO DRIVEN MOVEMENTS

As the name implies, the movements of the animatronic skull is controlled by servo motor. It can also be called as string controlled skull, since the name animatronic is nothing but the string pulled 3D objects.

For this animatronic skull, 9 servo motors are used. Among them, 5 are micro servo motors (9g HXT900) remaining 4 are standard servo motors. The use of standard servos is due to the accurate actions and to perform neck movements where the entire skull is rested. All the links between the servo and the skull parts are ball joints so the circular movement of servo motor is converted to linear actions of the skull parts.

Eye movements are controlled with the help of 2 servo motors with one moving horizontal direction and other moving vertical direction. Eyelids are controlled with 2 servos, each side one servo. The 2 servos for eyelids are moved synchronously. Neck movement is based on ball joint movements where the entire skull is rested on that ball joint. Jaw movement is designed in such a way that the jaw can move according to the audio provided for it.

Fig 3. Ball Joint Link

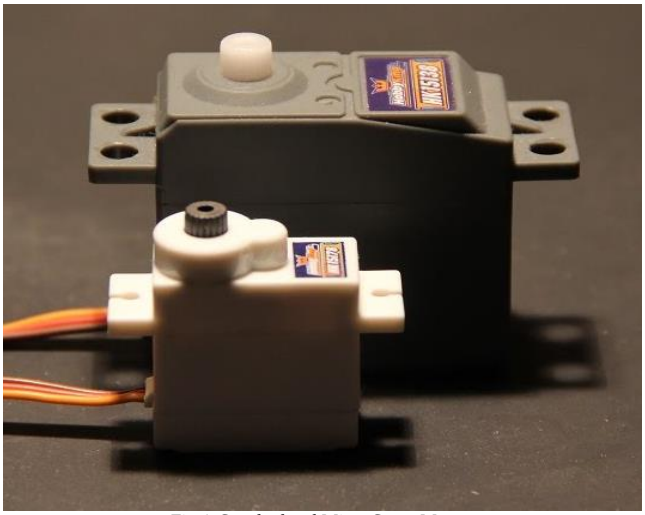

Fig 4. Standard and Micro Servo Motors

V. 3D PRINTER

The main component is 3D printer. The CAD designed skull should be printed to obtain the 3D object. We have used 'JULIA INTERMEDIATE' 3D printer to print the skull parts.

The design is done with respect to individual parts rather than entire skull at once. This is because, the movements will not be happened if we print entire skull. So, individual parts are printed and assembled with the help of screw.

❖ JULIA INTERMEDIATE

The 3D printer requires the following components to print the desired object:

a. PLA plastic.
b. SD card (with design in .Stl format)
c. Acetone.
d. Power supply.

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❖ PLA PLASTIC

PLA is known for poly-lactic acid, which is a polymer ranges from amorphous glassy to crystalline polymer. The main features of this plastic is:

a. The melting point: 205- 225°C
b. BED temperature: 60-65°C
c. Thickness: 1.75mm

Printing is done layer by layer where the bed will move in 2 Dimensional axis and the 3rd axis will be moved by the base on which the printing process takes place. The base is coated with acetone so the printed object will come out easily without sticking to it.

VI. CIRCUIT COMPONENTS

This paper include work from domains like mechanical and electronics. The design parts are covered by mechanical domain and electronics domain contributes for the work of skull, which is the movements and audio synchronization.

a. Arduino Board
b. DF mp3 Player
c. KA2284 Module
d. Servo Motor
e. Speaker
f. Wires

Arduino Board: It is a microcontroller board based on ATmega328 which is used to control all digital and analog components by building interactive object which can sense and control both physically and digitally.

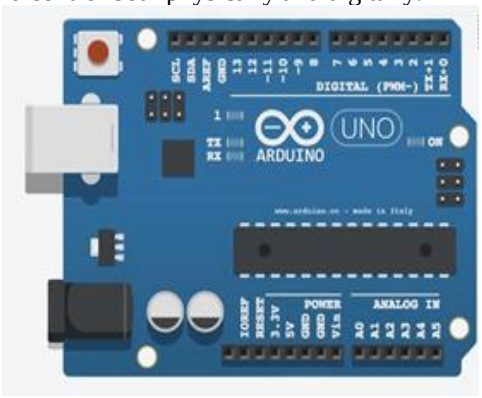

Fig 5. Arduino Board

Arduino consist of 5 analog pins and 14 digital pins along with 5v power supply, Vin, and ground for both 5v and Vin. These are few basic pins which are made use to perform the operation.

The code for eye movement, eyelids movement, neck movement are based on C programming used in arduino app. Myservo header is used to include all the keywords for servo motor and the code is written considering 3 values as the top, bottom and the middle. The eye movements is based on the matrix code where the horizontal and vertical based movements are made to move side-wise and also up-down respectively. Remaining movements are also similar to this.

DF mp3 Player: It is a small and low cost mp3 player which takes the input from the memory unit and gives directly to the speaker and analog output. The DF player perfectly integrates hard decoding module, which supports common audio formats such as MP3, WAV and WMA. Through a simple serial port, any music can be played without any other underlying operation.

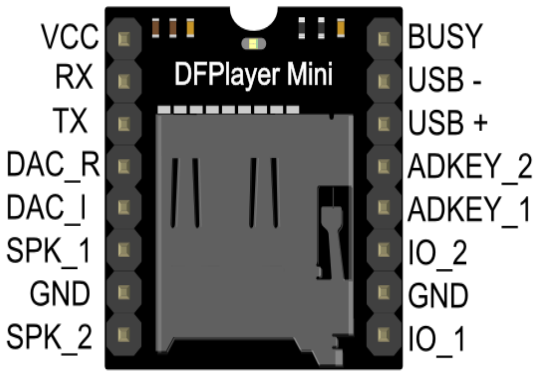

Fig 6. DF MP3 Player Mini

The input to the DF mini is through the TX and RX pins and from the SD card inserted. The files should be saved in format as '001', '002', so on. More than 100 files can be saved in this SD cared and played continuously one after the other. The busy pin indicates the status of the DF player.

SPK_1 and SPK_2 are the 2 pins connected to the speaker where the audio is given directly to speaker through it. DAC_R is the output which acts as the input to the potentiometer where the audio frequency range is segregated and given as analog input to rduino. Later the servo is driven accordingly. VCC is the 5v input to the DF player mini and GND is the ground for the DF player mini. The receiver RX is connected to the rduino through a resistor of value 1k.

KA2284 Module: It is a signal meter module where the audio input is taken from the DF player mini and the audio is split into 5 frequency levels which is indicated by the LED's in fig 7(a). The KA2284 module in fig 7(b) is tied to the signal that goes into the middle 3 LEDs so that based on the level in fig 7(c) the jaw is moved. This method of getting signal from signal meter is called hack and the hack has the connections as follows: the D2 LED is connected to A1, D3 is connected to A2 and D4 is connected to A3 of rduino board analog inputs.

Once the whole thing is working you have to tune the signal meter module using the onboard potentiometer to get the signal just right for the jaw movement. If you just fiddle with it while the audio is going you will get it looking good. I might add that the signal to the servo is meant to open the jaw, not close it. Meaning, the hardware of the jaw should be normally closed and opens when the audio starts getting louder on the hacked signal meter [4].

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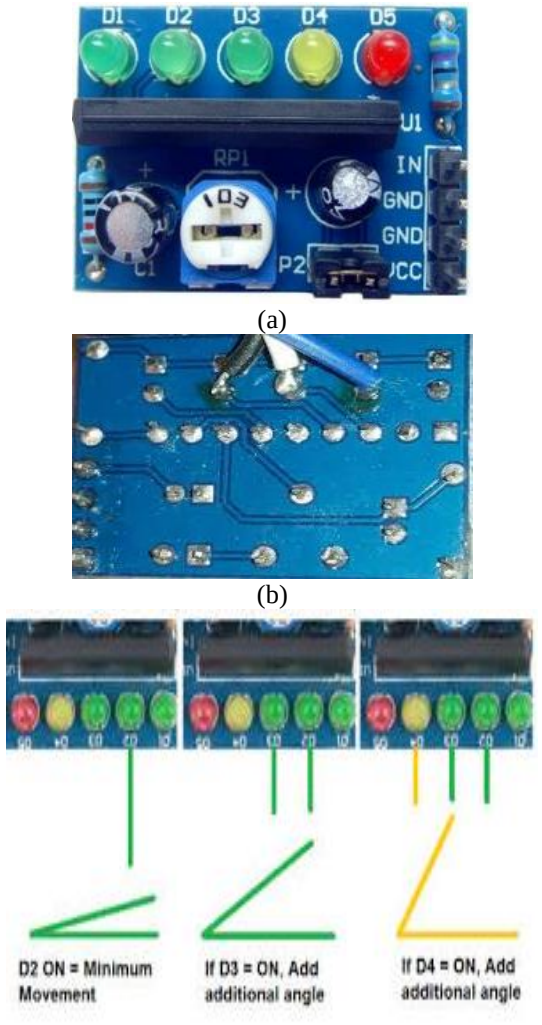

Fig 7. (a) KA2284 Module, (b) hacked signal meter and (c) angle of jaw opening.

Servo Motor: The jaw movement is pulled by the servo motor. We have already discussed about servo motors in servo driven movements section.

Speaker: Speaker is the main component for audio to be audible for us. The speaker is connected to the DF player mini that has pin connections SPK_1 and SPK_2 which are specifically provided for the audio input to the speakers.

Wires: Wires play an important role to connect the components together. Wires which are required for connections are male-to-male, male-to-female, and female-to-female.

VII. CIRCUIT FOR SERVO CONTROLLED JAW MOVEMENT OF THE SKULL

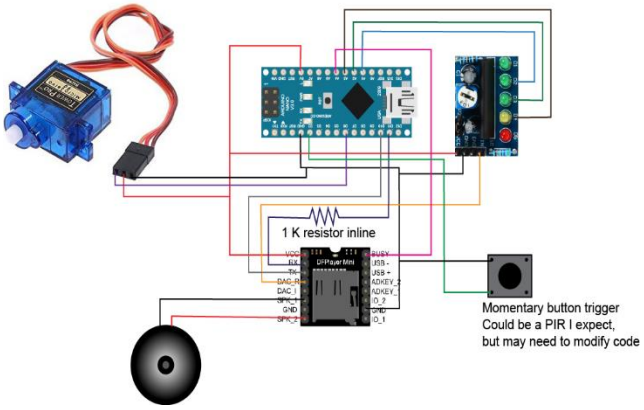

Fig 8. Jaw Movement Circuit

This circuit is based on the micro controller, we can also use microprocessor but the circuit will become complicated than that of micro controller circuit. The code is written in C programming and dumped into arduino board. Since it is a micro controller, we need not have to dump the code again and again. The DF player will hold the audio files and when requested it sends to the speaker and signal meter so that the servo will be controlled accordingly.

VIII. APPLICATIONS

- Animatronics: The title itself represents the basics is animatronics. The field of animatronics developed rapidly due to the introduction of an animatronic bird in a movie called 'Mary Poppins' in 1962. Animatronics along with artificial intelligence evolved later on, which led to introduction in movies and for other CGI effect. In a movie called tangled, the character named Pascal is nothing but animatronics along with AI.
- Medical Study: Designing the parts of the body using 3D printer help in providing detailed knowledge about the anatomy of any organism. Few countries will not allow students to touch and examine patients, they provide dolls to learn. So, providing 3D printed objects will have a better details and cost effective.
- Surgical Use: 3D object can be printed using plastic or using metal, etc. Any part or bone damaged in an accident can be replaced by the metal printed 3D part similar to it. We already have record of maxillary-cavity bone replaced and any other bones which are present in hands and legs and other parts of the body.
- Robotics: The animatronic skull is a part which can be used as robot head. We can design silicon skin and can put on top of it, so it we can get lip movements as well. The eyes can be provided with IR sensors or Ultra-sonic sensors so that I can sense the objects in front of it and skip that while walking. We can also advance it by using cameras.
- Artificial Intelligence: Animatronic skull can be a good example for AI development. We can use Alexa instead of recorded audio, so that anything we ask, it replies. We can also use it as tour guide in museums.

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IX. CONCLUSION

This paper is mainly based on the evolution of technology and development of Artificial Intelligence. The field of animatronics along with AI can make anything possible. The creation of animatronic skull included few individual contribution of eye movements. But this animatronic skull includes eye movement, eyelids movement, jaw movement and neck movement. This design of any object using 3D printer has many applications in present world. 3D technology developed in the field of science and has a great use in surgical field (medicine). Using 3D printer we can design the entire structure of anatomy and can be printed using it. The skull has its use in the field of robotics which can be developed with even more advanced technology with the help of AI.

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