

## Arm-like Mechanism User Interface for 3D Animation

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**Abstract:** Character animation is traditionally accomplished using traditional input devices such as keyboards, mouse, joysticks, programming pads or motion capture systems with elevated costs making them unavailable to common users. However, 3D User Interfaces such as electromechanical sensors, depth maps and vision tracking have been changing how we interact with information in several applications and common use devices. Animation using 3D user interfaces allows more natural, fluent and precise queues of motion, which is why this work presents the implementation of an anthropomorphic mechanism for motion capture through flexion/extension and abduction/adduction with an arm mechanism of four Degrees of Freedom. The goal is to present the feasibility of assembling a low cost device that allows tracking suitable motion for performing an animation on a virtual character.

**Keywords:** 3D animation, interaction, robotics, virtual reality.

### 1. INTRODUCTION

Character animation is currently achieved through several devices such as keyboards, mouse, joysticks, programming pads, motion capture systems and recently with 3D User Interfaces (3DUI), that are changing our interactions with our surroundings [1] [2] [3] [4] [5] [6]. Main drawbacks for mainstream use of animation is hardware and software costs along with advanced knowledge in the subject, this problem have been addressed by lowering costs and ease of development of platforms for character motion with edutainment purposes [7], puppetry controllers based on gloves and depth maps [8][9], and electromechanical devices such as the *Qumarion* [10] which allows 3D motion capture through a humanoid-like input device, or haptic devices such as the *Sensable Phantom* for touching and manipulating virtual objects [11].

Current advances in electromechanical components have allowed the development of several robotic input devices that serve as training tools in industrial [12], medical [13], military [14] and educational applications [15][16][17]. Bio-inspired robotics has stimulated advances in anthropomorphized devices that mimics living structures and improve robotics uses locally or remotely in safe and hazardous environments [18] [19].

The impact of robotics is reflected on its worldwide embracement which has resulted in low-cost devices, sensor, kits and other components that are being used by hobbyists and teachers for motivating the use of robotics outside the industrial or research context [20]. With current availability of affordable robotic kits [21], 3D

user interfaces such as the Kinect or the Leap Motion, robotics control kits (Arduino, phidget) [22], and 3D authoring open source software (Blender3D), have resulted in an increased interest from users with several.

Considering the advantages of didactic robotics kits, their effects and challenges as educational tools for strengthen critical, technological and scientific attitudes [23], this project presents the design and development of a robotic arm for animating virtual avatars, the objective is to offer a motion capture alternative based on a low-cost anthropomorphic arm that allows configuring the arm as a suitable input for anthropomorphized characters animation.

The paper is organized as follows, in Section 2 the kinematics analysis is presented; in Section 3 the System's Architecture is covered; in Section 4 the results are presented; finally, in Section 5 the conclusions.

### 2. KINEMATICS

The human upper member is composed of the arm the forearm and the hand, its workspace varies according to its degrees of freedom (DOF) present in the shoulder, elbow and wrist, along with their corresponding lengths. For this work, the upper member is analyzed a serial mechanism represented by the kinematic model in Fig. 1.

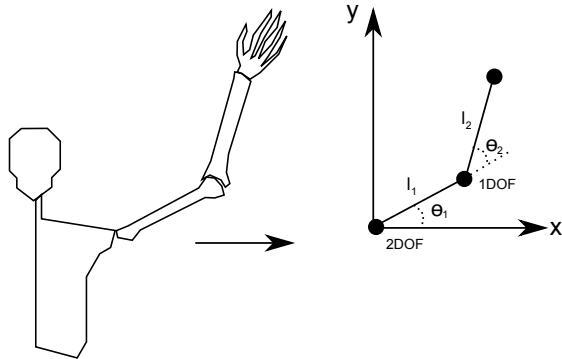


Fig. 1 Arm kinematic model.

Considering the simplicity of the kinematics problem due to its four DOF, the Denavit-Hartenberg (DH) notation was chosen for solving the forward kinematics [24]. Through the homogenous transformation matrix presented in Eq. (1), vertical and horizontal positions for each joint can be calculated using each of the known link rotations, where  $i$  identifies the mechanism segment,  $\theta$  represents the flexion/extension rotation,  $\alpha$  represents abduction/adduction rotation, and  $d$  represents each member length. This approach allows using the robotic arm application as the goal is to animate a virtual arm through the mechanism motion.

$${}_{i-1}T_i = \begin{bmatrix} \cos\theta_i & -\sin\alpha_i \cos\theta_i & \sin\alpha_i \sin\theta_i & a_i \cos\theta_i \\ \sin\theta_i & \cos\alpha_i \cos\theta_i & -\sin\alpha_i \cos\theta_i & a_i \sin\theta_i \\ 0 & \cos\alpha_i & \cos\alpha_i & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}, \quad (1)$$

### 3. SYSTEM ARCHITECTURE

The proposed main system is composed of three subsystems for motion capture, data processing and user feedback, as presented in Fig. 2. Included in the feedback subsystem, its two outputs, from a visual cue obtained with a computer monitor were the virtual avatar is moved using the animatronic interface, and a text file feedback, containing yaw, pitch and roll information for each linkage.

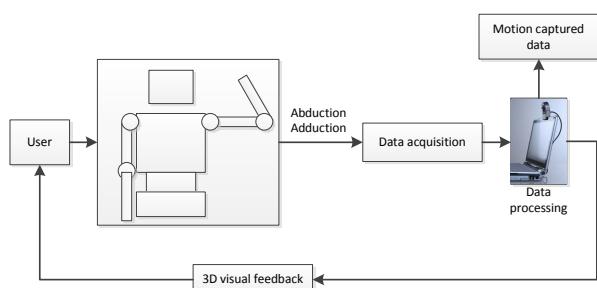


Fig. 2 System diagram.

#### 3.1 Motion capture

The motion capture subsystem consists of an

electromechanical structure composed of an anthropomorphic arm mechanism. Motion capture is accomplished using an inertial sensor attached to each link, allowing abduction and adduction rotation sensing, after the user manipulates each serial mechanism to the target positions. The mechanism is designed to move as a human arm with 3 DOF and its prototyped using a home 3D printer which offers versatility as it depends on ABS supplies rather than machinery availability often found when prototyping with metals. The serial mechanism chain possesses 2DOF at its shoulder-like joint and 1 DOF at the elbow and wrist, as presented in Fig. 3. The mechanism joints are fixed by friction obtained from adjusting the both plates of every link, allowing parts movement without losing the target position. Each link is composed of two hollow cases for supporting each sensor and coupled with screws for assembling the arm.

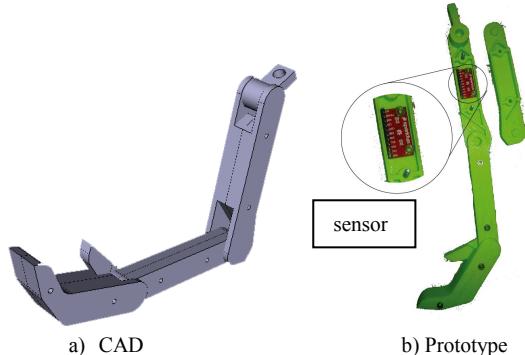


Fig. 3 Designed mechanism.

#### 3.2 Data Processing

The data processing subsystem captures the motion information, filters it and prepares it for mapping on the virtual avatar joint; the goal is to capture the angular data and send it to the virtual object while saving it for further analysis. The data acquisition is accomplished using an *Arduino Mega* board receiving analog inputs from two gyroscopes positioned in each link of the mechanism. The gyroscope was chosen over variable resistors and encoders due to physical and assembly constraints required to implement the mechanism as a feasible low-cost user interface for virtual animation.

Raw data from the gyroscope with noise and jittering may affect the animation; however filtered data using a Kalman filter [25] offers more accurate information for translating to the virtual world, resulting in adequate motion data. The data transmission is done using Processing [26], which is a programming and development environment that is compatible with the Arduino board.

#### 3.3 Data Visualization

The motion data feedback is programmed in three forms, through a 3D canvas that allows the user animating a virtual object through motions on the arm-like mechanism; through the GUI giving information regarding the performed motion; and finally, a plain text file with rotation information of the motion

captured.

The 3D visual feedback is implemented through Processing OpenGL compatibility for creating virtual worlds. For correctly mapping the captured motion data from the gyroscopes, the kinematics model proves useful for achieving the motion goal for successfully representing the inputs from the animatronic structure.

#### 4. RESULTS

Results are presented by following the system's diagram in Fig. 2, going from the mechanism, data acquisition and processing, and feedback. The first step solved the kinematics problem which allows knowing where the joints are in the virtual space. The kinematics problem was solved and validated using both Matlab® and Processing that allowed reproducing the mechanical arm motion and work area as presented in Fig. 4, by importing OBJ models created in CAD software. The DH algorithm offered sufficient information for being implemented in Processing by either taking advantage of the primitive properties and their transformations or importing customized virtual parts, resulting in a virtual 3D representation of the arm.

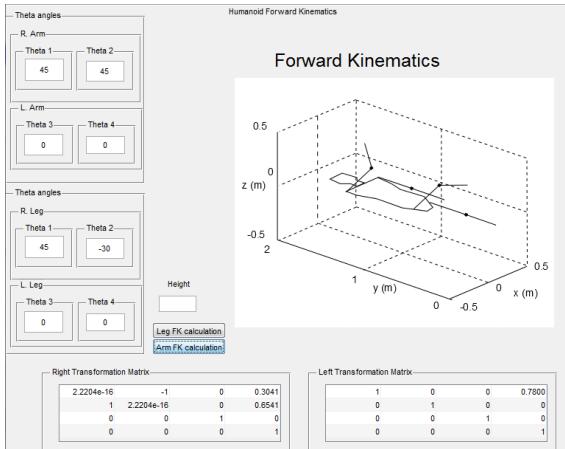


Fig. 4 Kinematics validation.

Considering the arm number of DOF, the mechanism was designed for encasing the sensors within the structure, gaining protection and isolation from the environment. The mechanism was wired internally for communicating the sensors with the board, thus, communicating with the processing environment by transmitting *XYZ* captured motion to the virtual objects. For improving motion capture and improve the signal a Kalman filter was applied for smoothing the data, resulted in smooth motion from the processed data.

Motion is recorded using the *XYZ* gyroscope outputs which monitoring user movements through the arm's links so rotational information can be chosen for animating the virtual character or object through each joint rotation as presented in Fig. 5. Each joint was

tested using an Arduino UNO, and the overall arm with an Arduino MEGA, in both scenarios the data was correctly transmitted and recorded to the virtual character representing each of the arm segments rotation.

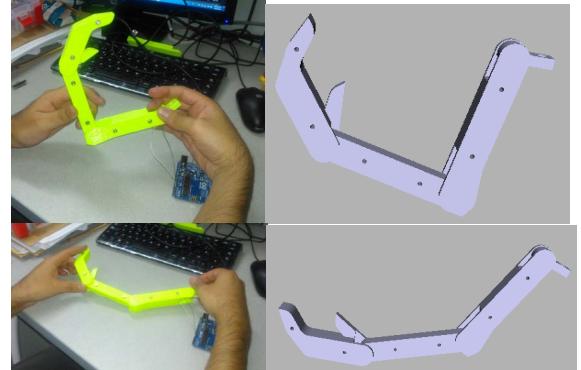


Fig. 5 Arm mechanism joint and animation test.

For validating the mechanism and its animation purpose, a small survey was applied to students familiar and unfamiliar with character animation. The questions were centered on user experience, ease of animation and utility through a mechanical arm representing part of the virtual characters. As a result, non-experienced user found easier to use the mechanism for capturing suitable data for posterior key framing, while experienced user founded less intuitive due to the habit of using traditional UIs. Users manifested interest in the production pipeline of the mechanism as the low-cost approach open opportunities for developing custom mechanism for different needs.

#### 5. CONCLUSIONS

An animation method based on an arm-like user interface such as the one presented in this work allows capturing motion data for animating a 3D character. The presented user interface in this paper offers a low-cost user interface alternative for animating virtual objects, which in comparison to traditional and expensive UIs allows capturing motion constrained to an anthropomorphized customizable form. According to the users the mechanism has a potential for easing the key framing animation process as the mechanism can be designed for acquiring and saving the necessary information moving the virtual object. While motion is limited by the mechanism and motion data is easily read, the user still requires to configure character and animation properties such as collisions, handlers and skeletons that reacts accordingly to the capture information. The use of a 3D home printer allowed speeding the assembly and fabrication process as no specialists were required for making each part of the mechanism, which can be designed with CAD software. The approach presented caused interest among the users due to the inherent possibilities of creating more complex systems at a low-cost that could result in easier and more accurate capture data for animation; however this solution addresses the problem from a didactic

approach which is not desirable when producing robust production animations as experienced users take advantage of their skills.

At this point, several other applications can be derived from this motion capture system. Future works will tend to cover application in robotics education and physical hand therapy as the capture data could serve to diagnose and treat patients with hand afflictions in order to recover or improve dexterity. Additionally, the output data will be formatted for complying with motion data formats such as \*.bvh which is compatible with software such as Autodesk Motion Builder.

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