Automatic Antenna Pointing System for ALCOMSAT-1 with Robotic Arm

Zakarya KOURDI[1], Mohammed KHAOUANI[2], Ali Ahmed KANOUN[1], Fayza MERAD[1], Mohammed Amin RABAH[1], Boulnouar KHOUANE[1]

[1] Research and Development Unit, Satellite Development Center CDS, Algerian Space Agency ASAL, Oran, Algeria.

[2] Department of Science, Faculty Sciences, Hassiba BENBOUALI University Chlef, Algeria.

E-mail: zkourdi@cds.asal.dz

Abstract - The aim of this project is to enhance the efficiency of system assembly in Algeria by reducing the time required for installation and antenna pointing towards the ALCOMSAT-1 satellite. The robot arm will determine the antenna pointing parameters by matching the Algerian mapping system captured from a GPS sensor to the desired position of the pointing antenna towards the ALCOMSAT satellite. The recordings database will be translated into a dedicated driver that controls the robot's step-motors based on the SNR value. The spreadsheet records this information during the scanning and tracking stage and directs the antenna pointing according to the optimized algorithm using artificial intelligence.

Keywords - Robot; Arms; Antenna; Satellite; ALCOMSAT.

I. INTRODUCTION

Research in the field of 6-axis force/moment sensors for smart robot grippers has enabled high accuracy and efficiency in task implementation. Tlale et al. [1] developed a smart gripper with a contact sensor and circuit control, while Castro et al. [2] utilized an fx force sensor to control the jaw retractor. Ceccarelli et al. [3] contributed to this research area by studying force detection in the grasping direction, but did not specify the robot's finger controls [4]. Other studies have achieved position control in one direction while controlling the force normal to the contact surface [5].

Previous studies have focused on regulating antenna position using the bulk mass model to create automated antenna connections, as well as reducing antenna vibrations through open loop or state feedback methods [6-8]. To accomplish this, the robot was outfitted with 6-axis force/moment sensors that enable it to control forces F_X, F_Y, and moments M_X and M_Y to rotate the antenna simultaneously.

This control method allows for precise pointing, but it can be challenging in complex operational scenarios, particularly during orientation. To address the issue of lengthy and random point identification using only numbers, robots can integrate the 'Arduino code' model to 'program' the robot by moving its axes with this data. The robot can determine its precise location using the GPS card and software installed in the PC control.

The antennas are adjusted on three axes: azimuth, elevation, and polarization. The azimuth and elevation pointing mechanism is controlled by jacks, while the polarization adjustment is made with a motor. An electronic control circuit (Arduino) manages the three actuators (two cylinders and the motor). The control system considers the geographical position acquired by a GPS sensor and the position of the ALCOMSAT-1 satellite to adjust the azimuth and elevation. To eliminate bias, a signal sensor, such as a spectrum analyzer, can be used [9]. For concrete satellite pointing applications that require high precision and complex movements, a 6-axis robotic arm would be a suitable solution. For concrete satellite pointing applications that require high precision and complex movements, a 6-axis robotic arm would be a suitable solution. For satellite pointing applications that require high precision and complex movements, a 6-axis robotic arm is recommended. It is important to note that a simpler robot may not be sufficient. Figure 1 shows a standard Cartesian system robotic arm 3D printer, which is suitable for the requested task of movement under three axes with rotation.

The manufacturing technique for the chassis was a crucial decision among several options. Conventional manufacturing or laser cutting were the more practical choices due to the rarity of 3D printers and the high cost of their refill spools. However, the satellite development center in Oran had a 3D printer available, making it a viable option for this project.

Therefore, we utilized this opportunity to produce the various components of the robotic arm.

Fig. 1. Prototype elements of an antenna pointing system, Impression 3D of arm robotics.

The robot arm was designed using Solidworks 3D modeling software.

The base of the robot rotates to enable movement, while the first joint contains a servo motor that allows the arm to move at an absolute angle of 180 degrees around the vertical shaft, connecting the base to the clamp. It consists of several plexiglass parts that are connected by screws and servomotors, which control the arm's movements in the forward/backward and up/down directions.

The gripper is the robot's end effector used for grasping various objects. It consists of a servomotor that controls its opening and closing through a gear mechanism.

II. RESULT AND DISCUSSION

The control system uses data from a GPS sensor and the ALCOMSAT-1 satellite to adjust the azimuth and elevation. The signal sensor (SNR signal) is used for polarization adjustment. The tracker controls the rotation of axis 1, which must accompany this rotation at axes 2 and 3 to adjust the azimuth pointing to 220°. The elevation angle of the ALCOMSAT satellite is adjusted by holding axes 1 and 6 and moving the rest of the axes. To simulate the electrical circuit, we used the Proteus program, as shown in Fig. 2.

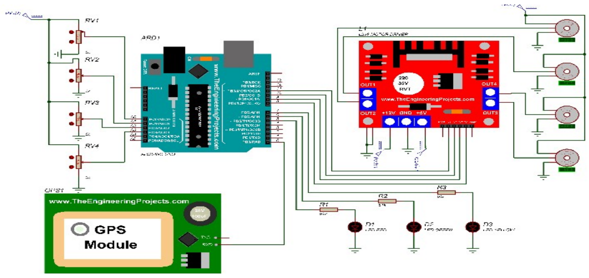

Fig. 2. Electrical schematic circuit of the Robot in Proteus.

The necessary components for connecting electronics to a robot in Proteus. The circuit diagram is simple and requires an Arduino board and a GPS card module to communicate with the PC. The control pins of the six servo motors are connected to six digital pins of the Arduino board.

The project's mechanical and electrical systems have specific fixed specifications, divided into different parts and including various points. The primary constraint is to ensure the safety of the engineer and customer's equipment. To prevent damage to the equipment and injury to the user, the arm must have software restraints and mechanical stops. An easily operable emergency stop must also be in place in case of any issues. Torque limiters are installed to prevent system damage. In addition, the management of wiring will be taken into consideration.

The robot arm is designed to position the customer's antenna towards the ALCOMSAT-1 satellite. Several constraints must be considered for this functional component. The angle of attack for the manipulator clamp should be relatively large to avoid collisions with external elements. The arm's effective range is estimated to be within a 1.50-meter radius, which comfortably covers most of the satellite's coverage range.

Another important consideration is the system's ability to withstand harsh environmental conditions, such as extreme temperatures and humidity levels.

Additionally, the system's total cost must be financially feasible for the company, with all components, materials, electronic equipment, and tools being affordable and readily available.

Additionally, we will discuss the open-source nature of the project and provide explicit details on the design and manufacturing process to ensure accurate reproduction or improvement of the system. The majority of materials will be produced at the CDS-Oran center. The programming must be clear and concise to facilitate the engineer's use of the project.

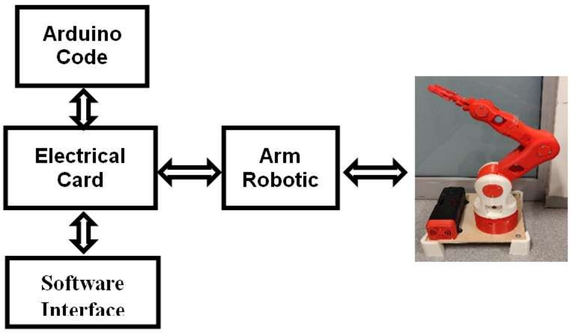

Fig. 3. Synoptic diagram of the operation of the robot.

To power the circuit, an external power source capable of providing 5V and 15V and operating at least 2A of current is required.
This is because the Arduino cannot handle the current amount that all components can draw. Once connected, the Arduino can be programmed and software can be created.

To enable serial communication of the GPS module and the servo library, include the Software Serial library in the code. The text has been improved to adhere to the characteristics of objectivity, comprehensibility, conventional structure, clear and objective language, format, formal register, structure, balance, precise word choice, and grammatical correctness. Specifically, a clear and logical structure has been maintained, biased language has been avoided, and precise technical terms have been used. Additionally, it has been noted that the Arduino Mega comes with the necessary libraries, eliminating the need for external installation. Next, I defined the six servos, GPS module, and variables to store current and previous servo positions. I also created arrays to hold positions or steps for automatic mode.

Finally, I ensured that the software for the robotic arm reads SNR data and sends commands to the Arduino to point the antenna.

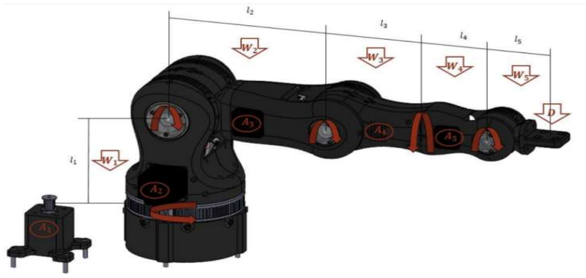

Fig. 4. Link frames of 6-axis articulated robot. Robotic arm completely stretched out. Ai-represents the actuators; Wi-represents the weight of each link; li-distance between joints; D-represents the weight of a device.

The Center Development of Satellites (CDS) designed and manufactured a 6-axis articulated robot for tracking and pointing antennas. Figure 1 illustrates the robot, and its joint orientation frame is shown in Fig. 2. Table 1 presents the robot's kinematic specifications for antenna tracking.

Table 1. Situation of arm robot function.

Mode	Base	Arm		Antenna		
		Shoulder	Elbow	Azimuth	Elevation	Polarization
Initial [°]	0	45	120	0	5	0
Case 01	-45..0	45..90	120	180..225	5	0
Case 02	-45.. -35	45..90	120	215..225	5	0
Case 03	-40	90	120..90	220	5..35	0
Case 04	Ok	Ok	95	Ok	30	0
Case 05	Ok	Ok	Ok	Ok	Ok	-45..45
Case 06	Ok	Ok	Ok	Ok	Ok	0
Case 07	Ok	Ok	Ok	Ok	Ok	Ok

The table displays the robotic arm and antenna of our project in action, along with the algorithm utilized, presented below.

The process of positioning an arm robot involves a systematic series of steps aimed at enabling the robot to point its antenna to a specific location. The process begins with initialization, where the robot arm and sensors are prepared, and the location of the target object is defined. Subsequently, the object is located using sensors or a vision system, and a collision-free path is planned to approach it. Upon reaching the object, the robot executes the planned path, adjusts its trajectory if necessary, and securely grasps the object using a gripper mechanism.

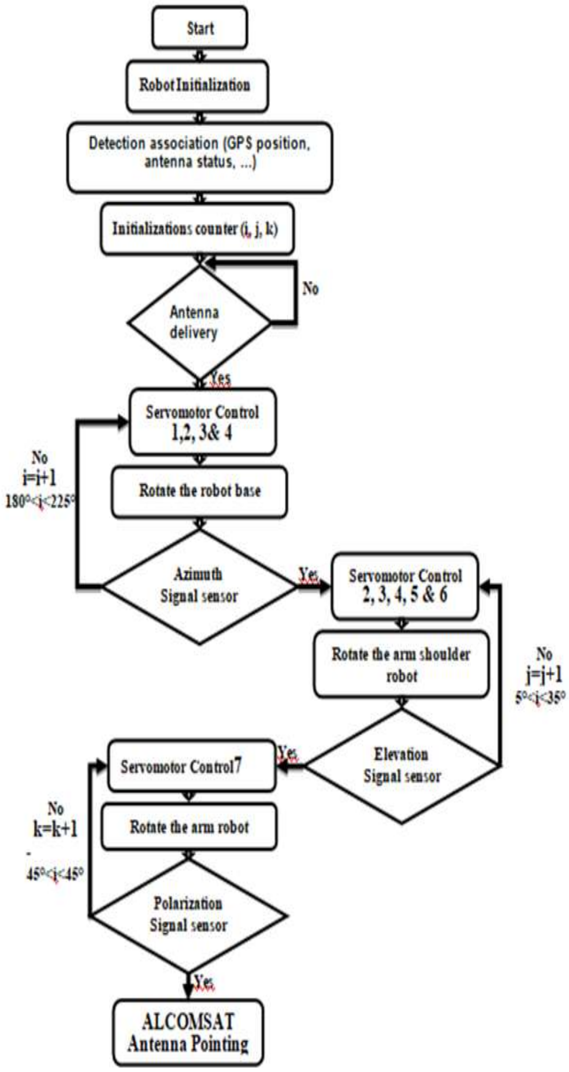

Fig. 5. Operational algorithm for running a robot.

The object is then lifted and moved to a designated location, with the robot navigating through obstacles as needed. Finally, the object is released at the desired location, completing the task. This algorithm provides a framework for programming robotic arms to perform a variety of manipulation tasks with efficiency and accuracy.

III. CONCLUSION

This paper describes the development of a 6-axis arm antenna designed to function as an intelligent robot's gripper for pointing the antenna and accurately perceiving the position of the ALCOMSAT-1 satellite.

Controllers were implemented for the antenna's azimuth, elevation, polarization, and attitude degrees of freedom.

The work aims to balance control complexity and vibration reduction efficiency, enabling robust antenna controllers and coordination with the arm robot.

Future research will focus on studying a different dimension of the antenna (1.2 m, 1.8 m) and perceiving all positions in Algeria for pointing with the gripper of the arm robot.

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