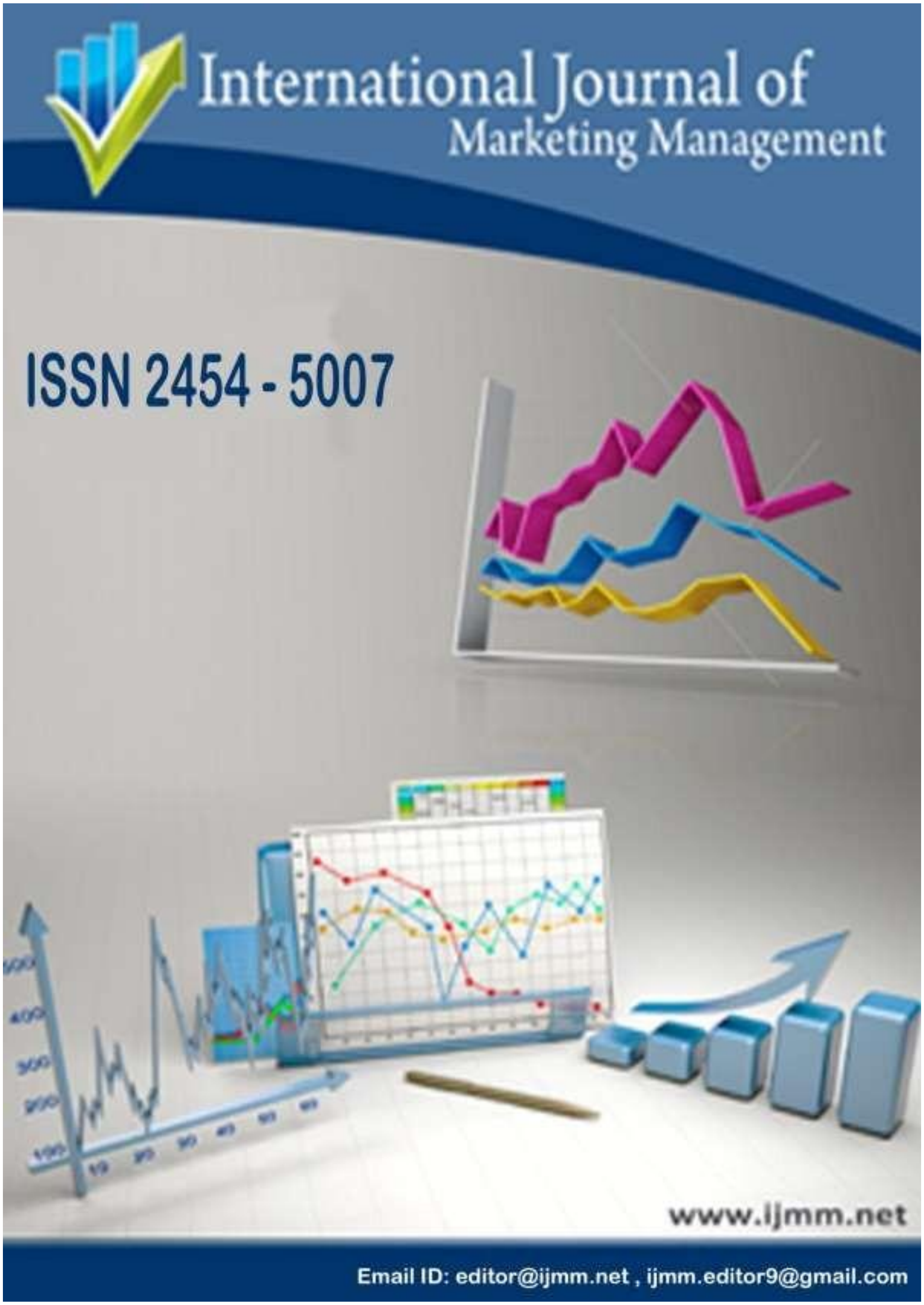
International Journal of
Marketing Management
ISSN 2454 - 5007
www.ijmm.net
Email ID: editor@ijmm.net , ijmm.editor9@gmail.com

International Journal of Marketing Management

ISSN 2454-5007, www.ijmm.net
Vol. 14 Issue. 2, April 2026

ROBOTIC ARM

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Abstract

The goal of this study is to create a model that can be used to design and manufacture cost-effective robotic arms by relating desired performances to the components that are necessary, their composition, and their cost. To establish this connection, one must be well-versed in the ideas of performance speed, power, accuracy, and precision. Rotational speed is a common measure of speed when discussing electric motors. The amount of force that a motor can transmit via an arm is called its torque, and it is a measure of its strength. The grouping of rounds determines their precision, whereas accuracy measures how near an average of many bullets is to the target's center. A robotic arm is comprised of many supporting components, the most important of which are the motors, bearings, and frame. All of these components are chosen according to the user's performance requirements.

While servos and stepper motors require distinct mechanics and electronics to operate, they are both commonly used electro motors in arms used in residential and professional settings. In general, servos are more costly, have more features (such as internal position feedback, a feedback loop that can be connected to the outside world, and greater running speeds), and produce more torque. Stepper motors are often less expensive than servos, operate at low speeds, lack internal position feedback, and may be equipped with a gearbox to enhance torque. The formula for determining the necessary motor torque and, by extension, the motor's resolution, will be presented in this article. Deep groove ball bearings and angular contact bearings are the most common types of bearings used in robotic arms, however there are many others. Angular contact bearings work well with modest axial and radial stresses, such as those experienced at the arm's rotating base or inside the arm itself when dealing with high inertia. Deep groove ball bearings excel in applications where radial loads predominate, such as in an arm that handles low inertia loads. You may get the internal radial clearance by multiplying the bearing's bore and outer diameter by the arm's length; however, this leads to system imprecision, which is necessary for smooth and consistent bearing functioning. Using tubular material for the robotic arm's frame is recommended when the arm will be exposed to strong forces perpendicular to the arm. The optimal strength-to-weight ratio is achieved by using sheet metal when the arm is mostly used for light lifting loads. In order to improve this ratio, it is advised to use theoretical optimization tools. The displacement under load on the arm may be calculated using other modeling or finite element tools. In order to verify the accuracy of the models discussed in this article, a working prototype was created using the data given here. It was determined that the motor size model was correct. While the model provides a good approximation of the endeffector's accuracy, it fails to account for manufacturing errors.

Introduction

The goal of this study is to provide the groundwork for designing and manufacturing cost-effective robotic arms by developing a model that correlates performance goals with component needs, composition, and price. Figures 1, 2, 3, and 4 show examples of robot arms that are reasonably basic for the pick-and-place task. This study will examine the design process of robotic arms by doing this analysis.

These arms are complex enough to examine most facets of robotic arms, but not so complex that they are outside the purview of this article.
A great deal of recent progress has been made in the field of mechatronics, in both the software and hardware domains. Nowadays, in order to develop and bring new goods to market, many open source projects and start-ups use a wide variety of innovative technologies. Thanks to a plethora of fresh ideas, inventive individuals, and cutting-edge technology,

International Journal of Marketing Management
ISSN 2454-5007, www.ijmm.net
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3D printing is just one of many technologies that has seen tremendous price, quality, and accessibility improvements. See Table 1 for an example of a technology that has and is seeing a fast rise; 3D printing is one such example. In 2011, sales of desktop 3D printers were about 25,000 units; in 2015, that number jumped to over 250,000 units. Commercial 3D printers are currently sold by a plethora of firms, creating a highly competitive industry. When asked about ways to increase labor efficiency in the IT business, experts are optimistic about robotics and the use of robotic arms. The robotic arm segment of the robotics business has not yet been penetrated by the fast-growing area of 3D printing, and just a handful of firms have a dominant share of the market. Table1: Three-dimensional printer sales during the last nine years It is believed that such projects will propel robotic arms into the mainstream, much as they have propelled conventional 3D printing. The end effector may be guided in a variety of ways by integrating motors, gears, and bearings. Every permutation yields a unique robotic arm design, each with its own set of advantages and disadvantages.
be seen in Figure5, a cartesian robot was one of the first types of pick-and-place machines that could hardly be referred to be an arm robot. These robots are easily identifiable by their three linear motors, which allow for independent control of the x, y, and z axes. Their simple but sturdy design made them a game-changer in the pick-and-place robot industry and ensures their continued use today. Mills, plotters, and 3D printers often employ this configuration of motors, bearings, and frame. Figure 6 shows an articulated robot design, which emerged later and used three motors to provide three or more degrees of freedom. The resemblance to a human arm is a defining feature of this kind of robot. Not discussed in this study are a few additional kinds of robotic arms, such as SCARA, delta platforms, and parallel arm robots.

Literature survey

1.Transmission and Actuation Networks

The "Drive Train" is often named as the main factor that determines both accuracy and cost in the literature.
While high-ratio gearing (like Harmonic Drives) reduces backlash, it raises costs and makes torque management more complicated, according to research by Townsend (1988), which laid the groundwork for the transmission trade-offs. While servo motors are more reliable and have better high-speed performance, stepper motors with inexpensive magnetic encoders are becoming more practical for mid-range P&P jobs and drastically reducing the "entry price" for automation, according to recent comparative studies (Lopes et al., 2017).

2.The Chemistry and Kinematics of Structures

The "Power-to-Weight" ratio is a crucial performance statistic that is determined by the physical arrangement (topology) of the arm. When it comes to high-speed P&P, a large amount of research (such as Clavel, 1988 on the Delta Robot) contends that Parallel Kinematics is better than Serial Kinematics due to the reduced moving mass caused by the motors being stationary. Despite requiring a more intricate construction and a more constrained workspace, this combination enables accelerations surpassing. In the field of materials science, carbon-fiber-reinforced polymers (CFRP) have recently been the subject of research. While materials are more expensive, research shows that smaller, less expensive motors with the same cycle lengths may be made possible due to reduced inertia, indicating a "system-wide" cost neutralization (Kwon et al., 2021).

3. Models for Simplifying Performance-Cost Optimization

Mathematical modeling has replaced more traditional methods as researchers seek the "Pareto Optimal" design, which satisfies both performance and budget constraints. To achieve a happy medium between total mass (cost) and tip deflection (performance), Saravanakumar et al. (2014) used genetic algorithms in their multi-objective optimization study. Their research indicates that component interactions are too complicated for "rule of thumb" engineering, and so non-linear optimization is required. Total Cost of Ownership (TCO): Component choice impacts long-term expenses, which go beyond the original purchase price, according to the literature. Incorporating low-cost components into the original design phase should be done to account for the greater "Downtime Costs," according to Battaïa et al. (2018).

4. Versatility of End-Effector

Lastly, in the performance chain, there is the "composition" of the end-of-arm-tooling (EOAT). Traditional research has concentrated on inflexible

International Journal of Marketing Management

ISSN 2454-5007, www.ijmm.net
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mechanical claws; modern robotics emphasizes soft robotics. But the conversation turned to Soft Robotics by Rus & Tolley (2015). By using inexpensive elastomers for grippers, we may trade material complexity for sensor savings—the inherent compliance of the material takes care of the "delicacy" of the pick—thus reducing the requirement for costly force-torque sensors.

Methodology

The components used in the production of a robotic arm are chosen based on performance parameters. The following design brief details the project's expectations regarding the robotic arm's functionality. With the information acquired for this study, the robot arm may be programmed to achieve the necessary performance. Overarching goal of the model robot: To put some of the claims stated in this article about robotic arms to the test, we built this robot. Supporting small objects like a 3D print nozzle, a gripper, a full teacup, or a pen holder should be no problem for the prototype. The robot's precision and accuracy may be checked by attaching a pen fixture to its arm. You may make inferences from the findings by placing dots at several places and measuring their spread and distance to the reference values. The ideal robotic arm would be able to span the whole A2 sheet of paper (four sheets of A4) from its central position. This is the ideal arm length, which corresponds to the 364 mm diagonal of an A4 sheet of paper. The arm's acceleration and starting/stopping times should be under one second for a 100 mm movement. Considering the size of the robot arm, this is a respectable speed, and it's within the range of what most rivals can do. There are more expensive arms on the market that can achieve speeds far higher than 100 mm/s. The target payload weight is 500 g, which is about equal to half a liter of water or a full teacup. Precision and accuracy: Any systematic error or inaccuracy should not exceed 2 millimeters. It is also expected that the repeatability error or imprecision would be below 2mm. These are the exact measurements of robot arms sold in stores, such as the do-bot's.
Pick & Place (P&P) robotic arm implementations show how the theoretical compromises between component composition and performance act in practice. From small-scale solutions targeted for affordability to industrial systems with extreme accuracy, these implementations cover the gamut.

The composition places a premium on dependability, accuracy, and speed in high-pressure industrial settings, rather than cheap upfront cost. Systems such as the Fanuc Delta series or those used in Ocado's fulfillment centers have a parallel kinematic framework, making them ideal for high-speed packaging. This arrangement allows for rates of up to 200-300 picks per minute by keeping hefty motors on a fixed frame and moving the payload with lightweight arms.
Cobots with 6 degrees of freedom: Six degrees of freedom (DoF) provide for complicated twisting and re-orienting of components, which is useful in automotive and electronics assembly. Although the component cost is greatly increased, they achieve repeatability < 0.05 mm using high-end Harmonic Drive gearing.
Educational and Cost-Effective Applications Moving toward "sufficient performance" at a low price point is the new paradigm for small-scale manufacturing or educational research. Systems Based on the Arduino/Raspberry Pi: A lot of these setups use cheap SG90 or MG90S servo motors in conjunction with open-source controllers like the Arduino Uno or ESP32. Constructed for less than $500, these prototypes can manage modest loads (10-30g) at low speeds with an accuracy of around 97%. Stepper Motor Integration: In order to save money and get more torque, research-grade implementations often use stepper motors instead of costly servos. However, these motors need complex software management to avoid "step loss" while moving at high speeds.

Composition Tailored to Each Use Case

The effectiveness of the implementation in certain niches is determined by the choice of end-effector (EOAT) and sensing: Vision-Guided Sorting: By integrating a Pixy2 camera or a USB web camera, inexpensive arms may execute intricate sorting tasks based on shape or color without requiring costly, precise mechanical placement.
When deciding between vacuum grippers and multi-fingered mechanical grippers, it's common practice to choose the former for flat, lightweight items (such as electronics or food) because of their simplicity and affordability.

Table1 comparision table

International Journal of Marketing Management

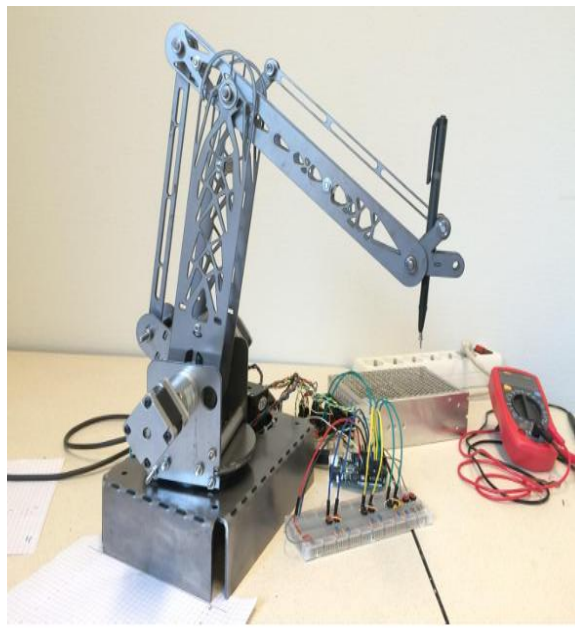
ISSN 2454-5007, www.ijmm.net
Vol. 14 Issue. 2, April 2026

Implementation Type	Controller	Actuators	Performance	E C
Industrial (Delta)	PLC / High-end IPC	AC Servos	Extreme Speed (>200 ppm)	H
Collaborative (6-DoF)	Proprietary / ROS	BLDC + Harmonic Gear	High Repeatability (<0.1mm)	M (
Research (Open-Source)	Arduino / ESP32	Steppers / Hobby Servos	Basic Task Completion	L

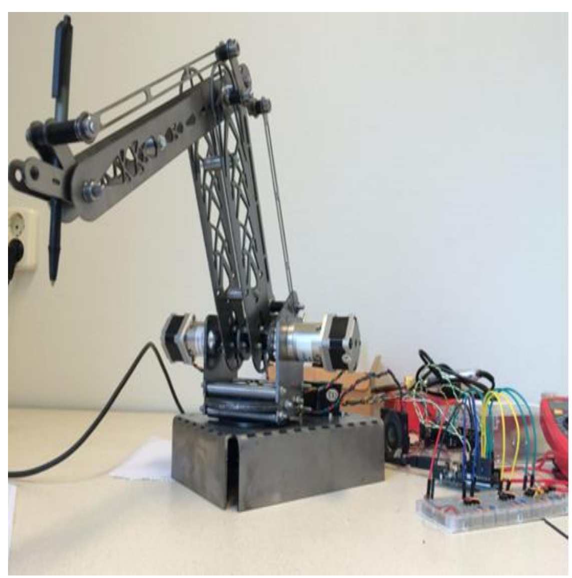
The lack of consideration for the bolts' thickness was the first issue. There were two spots where this became an issue, both in the heavily populated shoulder region. Bolts from the motor clamping hub and the bolts used to attach the motors to the shoulder plate came into contact with each other. The combination of utilizing tapered bolts and drilling smaller holes fixed the problem. Resolving the issue of the arm being limited to a maximum angle of 45 degrees was achieved by bringing the stabilization closer to the shoulder plate; this was caused by bolt interference with the motor clamping hub and the horizontal stabilizers. Another little issue was caused by the end effector stabilizer rod's positioning (on the backside). Positioned horizontally beneath the shoulder, this rod's pivot point follows the arm's natural axis of motion. The stabilizer rod wants to go horizontal when the upper arm does, too, and then it crashes into the shoulder axel. Changing the location of the pivot point—while ensuring it doesn't touch the elbow axis—could fix this.

The elbow axel is almost in the center of the stabilizer rod when the arm is nearly horizontal, sitting just in front of it. Less horizontal stability is the end outcome of this. Figure 89: stabilizer for end effector bends An issue that arose throughout the construction was a short circuit that happened during the soldering procedure on one of the large easy driver boards. In its stead, the hip motor is powered by a standard simple driver board. For the highest speed test, this board was linked to the shoulder motor driver board, which is a large, easy-to-handle board, since it has less power and is enabled with 1/8th microstepping mode. It might pass the speed test when connected to a huge easy board. The arduino was selected because to its user-friendly programming interface; nevertheless, an issue with its clock speed surfaced during testing and programming. In order to start and stop across a 10-centimeter distance in one second, the Arduino has to deliver pulses to the simple driver board that is operating on 1/8th microstepping at a faster rate.

RESULTS



Robotic arm



International Journal of Marketing Management

ISSN 2454-5007, www.ijmm.net

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Finished robot arm

Conclusion

This article set out to dissect a robotic arm from every angle, looking at its individual parts and how they interact with one another and the system as a whole. Concurrently, we will investigate potential avenues for developing and manufacturing reasonably priced, high-quality robotic arms, and we will build a model to forecast and correlate intended performances with necessary components, their composition, and their cost. This article contains all the necessary information to construct the prototype arm, including the recommended frame construction, bearings, and motors. A robotic arm was subsequently constructed as a result of this. Therefore, the goal of dissecting the robot arm's parts and learning how and why they function was accomplished. The paper's model for determining the necessary motor torque was tested and found to be accurate. Furthermore, this research offered a methodology for predicting a robot arm's accuracy using the worst-case scenario for bearing play, motor resolution, backlash, and frame deflection. The model's worst-case prediction was 1.59 mm, whereas the actual precision was 1.5 mm. Based on these findings, it seems that the model is correct for this test. The model, however, does not account for the inaccuracies that emerge from the tolerances in the fitting of the lower arm to the elbow axel and the upper arm to the shoulder axel. Including these would increase the forecast while keeping the actual accuracy within the limits.

References

Motors: baldor.com SERVO CONTROL FACTS, A HANDBOOK EXPLAINING THE BASICS OF MOTION solarbotics.net Industrial Circuits Application Note, Stepper Motor Basics bimba.com, Guajardo G., A BIMBA Whitepaper, Stepper vs. Servo: Which is Better Served with My Electric Cylinder? micromo.com, a member of the FAULHABER GROUP, Stepper Motor Technical Note: Microstepping Myths and Realities http://blog.misumiusa.com The great debate: Stepper or Servo? Bearings: mit.edu FUNdaMENTALS of Design, Topic10, Bearings Timing belts sdp-si.com HANDBOOK OF TIMING BELTS AND PULLEYS lasersaur.com T-3 THE WORLD OF TIMING BELTS