# Project Notes:

**Project Title:** Cost Effective Robotic Arm
**Name:** Hartej Anand

**Note Well:** There are NO SHORT-cuts to reading journal articles and taking notes from them. Comprehension is paramount. You will most likely need to read it several times, so set aside enough time in your schedule.

**Contents:**

# Knowledge Gaps:

This list provides a brief overview of the major knowledge gaps for this project, how they were resolved and where to find the information.

| Knowledge Gap | Resolved By | Information is located | Date resolved |
|---|---|---|---|
| What pieces should be used | Research on motors | https://docs.google.com/document/d/1uZKGL1l0lK4d68-SjZgcVwwDa2qvGxPrfz5fnGAMTqE/edit#heading=h.rh6eqbjyffdt | October 26 |
| How much torque is needed to lift the arm | Talking to professional | 25 kg motor (testing motor) was said to be good to complete the task | December 23 |
| The motor could not handle the torque of the arm. | Talking to a professional | The arm's shape was slightly modified to spread out and reduce the force. | February 7 |

# Literature Search Parameters:

These searches were performed between (Start Date of reading) and XX/XX/2019.
List of keywords and databases used during this project.

| **Database/search engine** | **Keywords** | **Summary of search** |
|---|---|---|
| Google Scholar | Robotic Arm | There are many robotic arm articles, which are summarized later |
| Google Scholar | Robotic Arm patents | There are surprisingly not many robotic arm patents as one patent contains many different possible iterations |
| Google Scholar | Arm grippers | There are many different types of arms, and many different ways of testing the arm, most of which include the use of expensive technology. |

# Tags:

| **Tag Name** | |
|---|---|
| #Robotics | #Robotic Arm |
| #Industrial | #Cheap |

# Article #1 Notes: Title

Article notes should be on separate sheets

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| | |
|---|---|
| **Source Title** | |
| **Source citation (APA Format)** | |
| **Original URL** | |
| **Source type** | |
| **Keywords** | |
| **#Tags** | |
| **Summary of key points + notes (include methodology)** | |
| **Research Question/Problem/ Need** | |
| **Important Figures** | |
| **VOCAB: (w/definition)** | |
| **Cited references to follow up on** | |
| **Follow up Questions** | |

# Article #2 Notes: SMART CITIES RELY ON SMART INFRASTRUCTURE TO MAKE PEOPLE'S LIVES BETTER

Article notes should be on separate sheets

| | |
|---|---|
| **Source Title** | SMART CITIES RELY ON SMART INFRASTRUCTURE TO MAKE PEOPLE'S LIVES BETTER |
| **Source citation (APA Format)** | *Smart cities rely on smart infrastructure to make people's lives better*. IEEE Climate Change. (2023, August 4). https://climate-change.ieee.org/news/smart-cities-infrastructure/?utm_source=dhtml_image&utm_medium=hp&utm_campaign=climate-change&hp_pos=7 |
| **Original URL** | https://climate-change.ieee.org/news/smart-cities-infrastructure/?utm_source=dhtml_image&utm_medium=hp&utm_campaign=climate-change&hp_pos=7 |
| **Source type** | Science Journal |
| **Keywords** | Smart cities ; United Nations ; |
| **#Tags** | #Robots ; #AI |
| **Summary of key points + notes (include methodology)** | The UN believes that by 2050, at least 60% of the world's population will be living in smart cities, cities where everything is equipped with technology like sensors. These cities will be used for energy conservation, waste management, and many other uses that will help the people living in the city. However, with tracking everyone's data, this city does provide a large problem about protecting people's information. |
| **Research Question/Problem/ Need** | What does the future of humanity look like, and how can it be improved? |

| | |
|---|---|
| **Important Figures** | **Examples of Smart Cities** according to **SustainableReview.com**:<br><br>• **Reykjavik, Iceland**, for harnessing geothermal power<br>• **Copenhagen, Denmark**, for cycling infrastructure<br>• **Stockholm, Sweden**, for pioneering waste management systems<br>• **Singapore** for a modeling urban greenery<br>• **Helsinki, Finland**, for leading in clean energy<br>• **Zurich, Switzerland**, for mastering sustainable mobility<br>• **Curitiba, Brazil**, for revolutionizing public transport<br>• **Amsterdam, The Netherlands**, for pushing boundaries in renewable energy<br>• **Vancouver, Canada**, for being an eco-friendly star<br>• **Berlin, Germany**, for cultivating urban farming<br>• **Melbourne, Australia**, for leveraging water conservation techniques<br>• **Oslo, Norway**, for championing electric mobility<br>• **Wellington, New Zealand**, for being a green capital<br>• **Portland, Oregon**, for making sustainable living easy<br>• **Seoul, South Korea**, for being an eco-innovation hub<br><br>List of existing smart cities |
| **VOCAB: (w/definition)** | **Megacity**: A large city, usually with over 10 million people<br>**Smart city**: A city that uses technology to make the city more efficient |
| **Cited references to follow up on** | https://ieeexplore.ieee.org/search/searchresult.jsp?newsearch=true&queryText=protecting%20privacy%20in%20smart%20cities<br>https://ieeexplore.ieee.org/document/9407841 |
| **Follow up Questions** | Will these cities become dangerous?<br>Will these cities be run by AI, or have AI to do certain jobs?<br>How different will life become if you move to a smart city? |

# Article #3 Notes: Bizarre polygons on Mars' surface hint that alien life on Red Planet was possible

| | |
|---|---|
| **Source Title** | Bizarre polygons on Mars' surface hint that alien life on Red Planet was possible |
| **Source citation (APA Format)** | Baker, H. (2023, August 17). *Bizarre polygons on Mars' surface hint that alien life on red planet was possible*. LiveScience. https://www.livescience.com/space/mars/bizarre-polygons-on-mars-surface-hint-that-alien-life-on-red-planet-was-possible |
| **Original URL** | https://www.livescience.com/space/mars/bizarre-polygons-on-mars-surface-hint-that-alien-life-on-red-planet-was-possible |
| **Source type** | Science Journal |
| **Keywords** | Mars ; Life on Mars ; aliens ; space |
| **#Tags** | #space |
| **Summary of key points + notes (include methodology)** | Cracks on Mars provide evidence of the fact that it used to have wet-dry cycles billions of years ago. Not only does the evidence provided by these cracks give hints of life, but it also gives hints of how life originally formed, even on Earth. Additionally, there were also some prior indications of life being possible on Mars. |
| **Research Question/Problem/ Need** | Is alien life possible on Mars? |
| **Important Figures** | |
| **VOCAB: (w/definition)** | **Nucleic Acids:** Build up cells and viruses<br>**molecular evolution:** Area of evolutionary biology |
| **Cited references to follow up on** | https://www.williamrapin.com/<br>https://science.jpl.nasa.gov/people/vasavada/ |
| **Follow up Questions** | Would life on Mars now be dead if it did ever exist?<br>How can you confirm if life ever existed?<br>How does 'how life formed' help us determine if life exists since it is possible life on Mars could be completely different? |

# Article #4 Notes: AI tool offers real-time brain tumor profiling during surgery, guiding treatment decisions

Article notes should be on separate sheets

| | |
|---|---|
| **Source Title** | AI tool offers real-time brain tumor profiling during surgery, guiding treatment decisions |
| **Source citation (APA Format)** | Harvard Medical School. AI Tool Offers Real-Time Brain Tumor Profiling during Surgery, Guiding Treatment Decisions. Medical Xpress - Medical Research Advances and Health News, 7 July 2023, medicalxpress.com/news/2023-07-ai-tool-real-time-brain-tumor.html. |
| **Original URL** | medicalxpress.com/news/2023-07-ai-tool-real-time-brain-tumor.html |
| **Source type** | Science article |
| **Keywords** | AI ; surgery ; tumor |
| **#Tags** | #AI ; #medicine |
| **Summary of key points + notes (include methodology)** | Researchers have developed an AI driven software/tool that can help neurosurgeons discover the DNA make-up of a tumor. This allows the surgeons to know what to do instantly, such as how much of the tumor they need to remove. The software will tell them the safe amount of tumor to remove while the patient is still on the operating table. The software can determine the DNA, which allows it to find the type of tumor and what medications work the best to treat it. This is a major improvement from the current method which takes a long time (a few days to weeks) and can also sometimes give wrong results due to the method of harvesting cells/tissue. While still being tested, the AI has a 93% accuracy. The tool is called CHARM (Cryosection Histopathology Assessment and Review Machine) and is available to researchers. It will continue to be updated as more about cancer is learnt. The tool still needs to be federally tested and approved by FDA, but shows promise to help improve modern cures and treatment for cancer. |
| **Research Question/Problem/ Need** | How can AI help doctors while they conduct brain surgery? |
| **Important Figures** | |
| **VOCAB: (w/definition)** | **Neurosurgeons**: surgeons who operate on the brain<br>**Informatics:** processing information and engineering systems |

| | |
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| **Cited references to follow up on** | https://dx.doi.org/10.1016/j.medj.2023.06.002<br>https://www.cell.com/med/fulltext/S2666-6340(23)00189-7<br>https://medicalxpress.com/news/2023-03-artificial-intelligence-genetics-cancerous-brain.html |
| **Follow up Questions** | How accurate is the data?<br>Can you make sure it won't give dangerous information? |

# Article #5 Notes: Guinea Pigbots

Article notes should be on separate sheets

| | |
|---|---|
| **Source Title** | Guinea Pigbots |
| **Source citation (APA Format)** | Hutson, M. (2023, July 13) *Can ai chatbots replace human subjects in behavioral experiments*. Science https://www.science.org/content/article/can-ai-chatbots-replace-human-subjects-behavioral-experiments |
| **Original URL** | https://www.science.org/content/article/can-ai-chatbots-replace-human-subjects-behavioral-experiments |
| **Source type** | Scientific Journal |
| **Keywords** | AI ; Humans ; chat GP3 |
| **#Tags** | #AI ; #chatbot |
| **Summary of key points + notes (include methodology)** | Chat GPT's ability to simulate human like text is surprisingly accurate, and can do more than just produce text. It can create moral judgements of text with a 95% accuracy compared to human responses gathered through surveys. This means, for example, that instead of evaluating responses from 464 people, chat GPT would be almost equally accurate. Chatbots already can accomplish many tasks from writing code to conducting therapy, and companies are thinking about using them to impersonate humans in studies. Last year, a study was done where a chatbot was given different variables such as political affiliation, age, and gender and the chatbot was able to complete the responses for missing variables with high accuracy. This means that chatbots and language models could form an accurate representation and are also cheaper than conducting actual surveys. In another study, it was found that Chat GPT could display realistic consumer behavior. The chatbot could make decisions based on facts such as income, what products were bought in the past, and if a consumer already owned a product. The results of the survey also are more useful as unlike people, the chatbot does not give "bland" information. Another interesting use of chatbots is to have them interact with each other to study more complex human interactions. Models can also be used to provide guidance on sensitive topics, like suicidal tendencies. However, like humans, language models can also show bias like false consensus bias where they overestimate their opinion. There is work underway to further refine language models and it is possible that these models might replace human participants in experiments in the future. |
| **Research Question/Problem/ Need** | Can AI replace humans for certain tasks? |

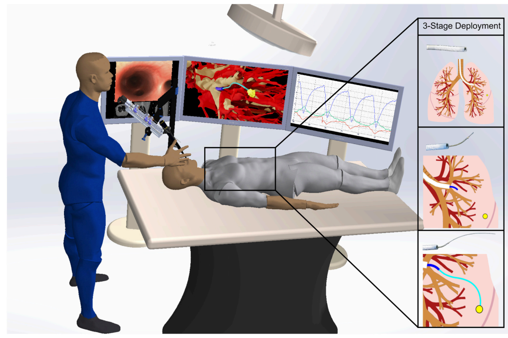
| | |
|---|---|
| **Important Figures** | |
| **VOCAB: (w/definition)** | **OpenAi**: An AI research laboratory (not a type of AI)<br>**Psycholinguistic:** a field of study that researches the use of language and comprehension<br>**social simulacra:** a technique that replaces real social interactions |
| **Cited references to follow up on** | |
| **Follow up Questions** | What is the moral issue with this?<br>How far can humans be replaced? |

# Article #6 Notes: Autonomous medical needle steering in vivo

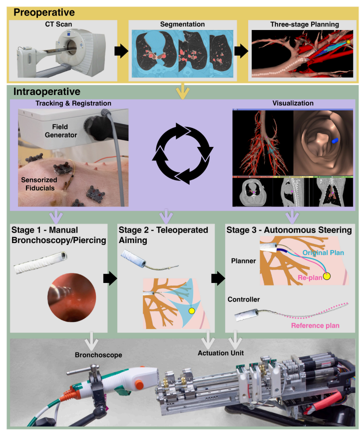
Article notes should be on separate sheets

| | |
|---|---|
| **Source Title** | Autonomous medical needle steering in vivo |
| **Source citation (APA Format)** | Kuntz, A., Emerson, M., Ertop, T., Fried, I., Fu, M., Hoelscher, J., Rox, M., Akulian, J., Gillaspie, E., Lee, Y., Maldonado, F., Webster, R., & Alterovits, R. (2023, September 20). Autonomous Medical Needle Steering in vivo. Medical robots, 8(82). https://doi.org/10.1126/scirobotics.adf7614 |
| **Original URL** | https://www.science.org/doi/full/10.1126/scirobotics.adf7614 |
| **Source type** | Research Article |
| **Keywords** | Robotics ; autonomous ; needle ; tissues |
| **#Tags** | #Robots ; #medicine |
| **Summary of key points + notes (include methodology)** | The article talks about using autonomous robots to safely operate on tissues, such as lungs. This makes the process safer and more efficient. Needles are used due to their limited invasiveness, and doing this is hard for humans. The methodology includes inserting a needle into the tissue, allowing for more precise procedures to take place. Using this procedure, the robot was able to successfully perform on lungs better than current human doctors, showing the possibilities of robots in the future. This can impact how lung cancer is treated in the future (and possibly other cancers). The challenges however include avoiding blood vessels that, if hit, can cause fatal problems. The method includes bronchoscopy to aid this problem. A physician uses a bronchoscope, and they can then turn on the autonomous needle. The system is able to alert the operator about the situation, and makes some decisions itself. This allows safer decisions to be made. This was experimented on a porcupine, and worked, but there are noticeable differences between the lungs of humans and other animals. |
| **Research Question/Problem/ Need** | How can robots optimize operations on moving tissue (such as lungs when you are breathing)? |

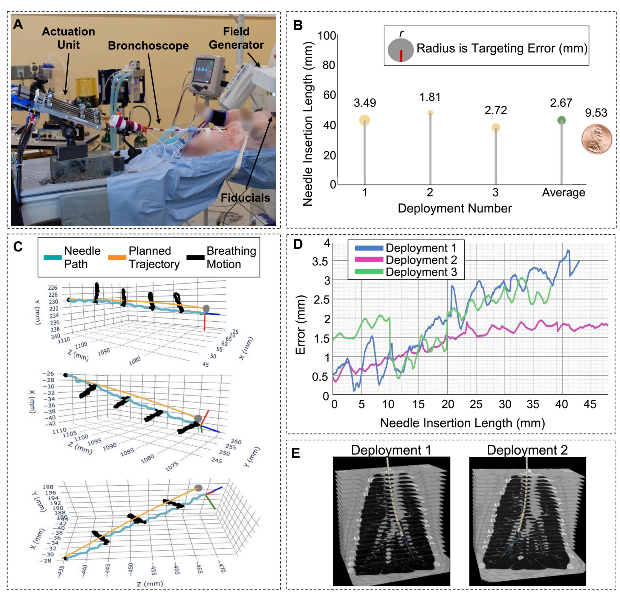
**Important Figures**




Model of how the process would look (left) and a zoom in of the lung & process (right) (white = bronchoscope, blue = needle)




Procedure and illustration of software and hardware




Porcupine test results

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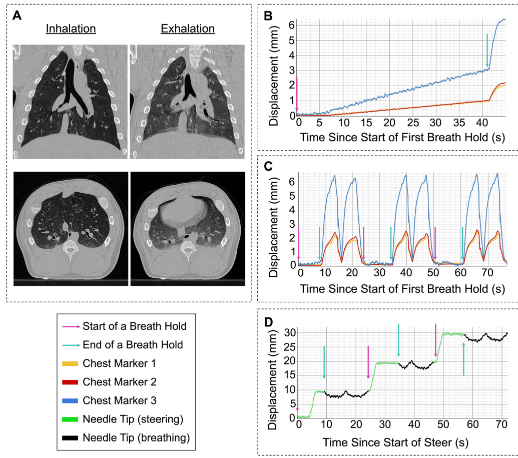
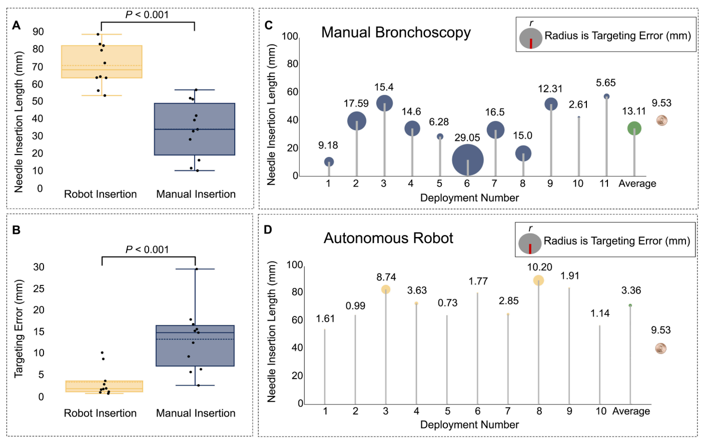


Charts of CT scans


Results from the experiments (manual bronchoscopy and automated robot system)
</td>
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<tr>
<td>VOCAB: (w/definition)</td>
<td>
Intratissue: Within the tissue<br>
Bronchoscopy: Using a camera to look through your air passages<br>
Vivo: A living object<br>
Teleoperating: Operating a machine from a distance<br>
Anatomical: Relating to the body
</td>
</tr>
<tr>
<td>Cited references to follow up on</td>
<td>
https://zenodo.org/record/8264222<br>
K. B. Reed, A. Majewicz, V. Kallem, R. Alterovitz, K. Goldberg, N. J. Cowan, A. M. Okamura, Robot-assisted needle steering. IEEE Robot. Autom. Mag. 18, 35–46 (2011).<br><br>
P. J. Swaney, A. W. Mahoney, B. I. Hartley, A. A. Remirez, E. Lamers, R. H. Feins, R. Alterovitz, R. J. Webster III, Toward transoral peripheral lung access: Combining continuum robots and steerable needles. J. Med. Robot. Res. 2, 1750001 (2017).<br><br>
A. Majewicz, A. M. Okamura, Cartesian and joint space teleoperation for nonholonomic steerable needles, in IEEE World Haptics Conference (IEEE, 2013), pp. 395–400.
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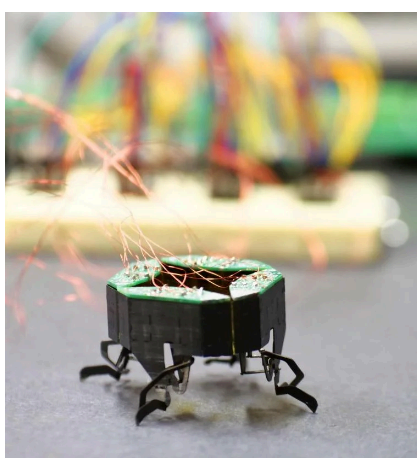
|---|---|
| | A. I. Chen, M. L. Balter, T. J. Maguire, M. L. Yarmush, Deep learning robotic guidance for autonomous vascular access. *Nat. Mach. Intell.* **2**, 104–115 (2020). |
| **Follow up Questions** | How far do the uses of this device expand?<br>Do humans still need to work with the robot or can this be changed in the future?<br>What if the device stops working, could a physician prevent any damage?<br>Is this easy to implement into hospitals? |

# Article #7 Notes: Tiny, shape-shifting robot can squish itself into tight spaces

Article notes should be on separate sheets

| | |
|---|---|
| **Source Title** | Tiny, shape-shifting robot can squish itself into tight spaces |
| **Source citation (APA Format)** | University of Colorado at Boulder. (2023, August 30). Tiny, shape-shifting robot can squish itself into tight spaces. *ScienceDaily*. Retrieved October 1, 2023 from www.sciencedaily.com/releases/2023/08/230830131742.htm |
| **Original URL** | https://www.sciencedaily.com/releases/2023/08/230830131742.htm |
| **Source type** | Science news article |
| **Keywords** | Robot; search and rescue ; insects ; |
| **#Tags** | #robot ; #searchAndResque |
| **Summary of key points + notes (include methodology)** | CLARI, a cockroach inspired robot, is able to change its shape to fit into different sized spaces. This allows it to crawl through the cracks and small spaces in broken buildings, providing opportunities for it to assist search and rescue teams. It works because each of its four legs has its own control chip, causing it to work like multiple robots. This allows a large variety of shapes to be formed. The future goals are to make this robot not attached to wires so it can move completely independently, and also add more legs so it can take on more shapes. |
| **Research Question/Problem/ Need** | How can insects inspire the way robots work? |
| **Important Figures** |  Image in linked article, included because I feel it is important to see the robot since it is not described like this |

| | |
|---|---|
| **VOCAB: (w/definition)** | **Articulated:** Multiple pieces connected by flexible pieces.<br>**modular design**: A system that is divided into multiple separate parts<br>**Hodgepodge:** Mixture, assortment<br>**Petite**: Small (small robot) |
| **Cited references to follow up on** | https://www.colorado.edu/<br>http://dx.doi.org/10.1002/aisy.202300181<br>https://www.colorado.edu/today/2023/08/30/tiny-shape-shifting-robot-can-squish-itself-tight-spaces |
| **Follow up Questions** | Other than locate people, what can this robot do?<br>How much can it survive? (when traveling in destroyed buildings with sharp cracks)<br>Does adding more legs cause it to be bigger, thus negatively impacting its work?<br>Do cockroaches' shape help with the design? If so, how will this impact the spider bot, if not, why the cockroach (and how since it is not shaped like a cockroach)?<br>Can it be squished from the top, or only the side? |

# Article #8 Notes: Research on Robotic Arm Movement Grasping System Based on MYO

Article notes should be on separate sheets

| | |
|---|---|
| **Source Title** | Research on Robotic Arm Movement Grasping System Based on MYO |
| **Source citation (APA Format)** | Wei, Y., & Jia, D. (2021). Research on robotic arm movement grasping system based on Myo. Journal of Physics: Conference Series, 1754 https://iopscience.iop.org/article/10.1088/1742-6596/1754/1/012173 |
| **Original URL** | https://iopscience.iop.org/article/10.1088/1742-6596/1754/1/012173/pdf |
| **Source type** | Research article |
| **Keywords** | Robotic arm ; prosthetics ; Machine Learning |
| **#Tags** | #robot #arm |
| **Summary of key points + notes (include methodology)** | The MYO is a motion sensor that was used to obtain coordinate mapping in Matlab. This allows it to map the human joint dynamics and improve how robots grasp and interact with objects. The methodology includes first measuring the motion signal of the upper and lower arm bones. This information is then processed, however, in order to get more accuracy, you need more expensive equipment. Processes such as filtering, extraction, and normalization were conducted (shown by figure 2). These processes were used by creating math equations. (This stage was machine learning) Then 5 adult males each conducted 4 different hand signals (figure 4). However, only certain robotic arms/hands were compatible with this (figure 5 is the tested one). According to figure 6 and table 1, during testing, BP was the most accurate model. Pictures of the models are shown in figure 7. Overall, this model was accurate, but operated completely independently and did not involve user input. Because it only worked by itself, this limited usage scenarios to ones it was trained for. It did need a MYO bracelet (figure 1) to operate, but was proven to be practical. |
| **Research Question/Problem/ Need** | How can sensors be used to increase the efficiency of robotic arms? |

**Important Figures**

Figure 1. MYO EMG acquisition equipment

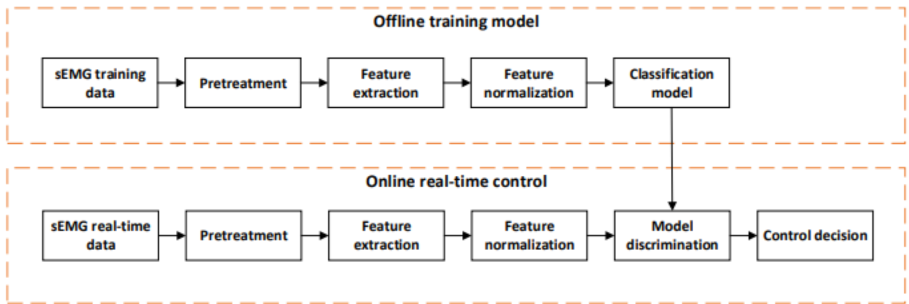



Figure 2. Myoelectric hand control system based on traditional methods

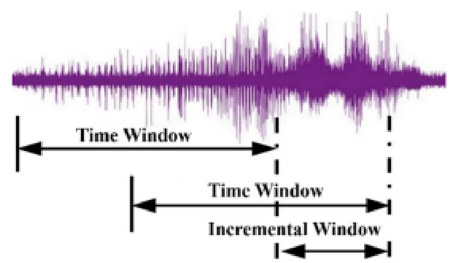



Figure 3. Time window and incremental window for extracting sEMG feature

Figure 4. Four gestures for recognition

Figure 5. RH56DF3 mechanical prosthetic hand

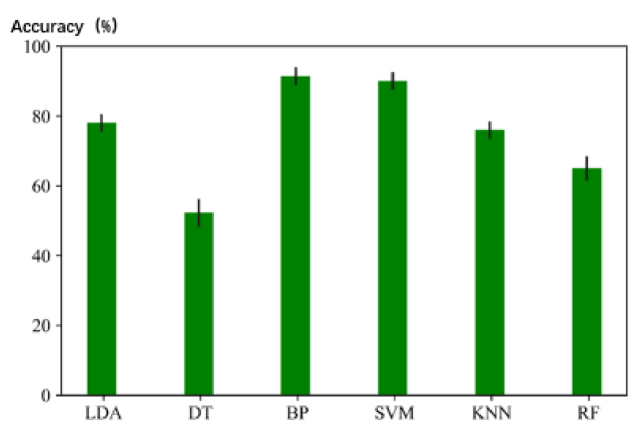
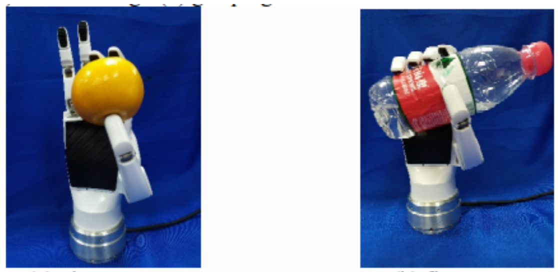



Figure 6. Comparison of different algorithm models

Table1. Accuracy comparison of different gestures

| | LDA | DT | BP | SVM | KNN | RF |
|---|---|---|---|---|---|---|
| fist | 85.0695 | 78.9985 | 95.9888 | 93.3399 | 84.4879 | 74.6666 |
| rest | 83.2965 | 62.2333 | 94.0931 | 92.9254 | 82.3654 | 72.6598 |
| ok | 77.7541 | 34.4338 | 89.0058 | 93.0000 | 73.5896 | 65.9999 |
| five | 73.1458 | 67.2536 | 93.7145 | 90.0001 | 77.6314 | 69.7763 |



(a) ok (b) five

Figure 7. Fetch results

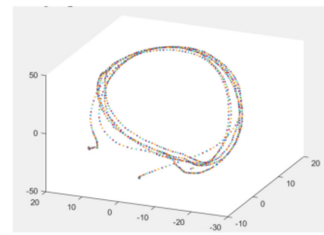


Figure 8. Simulation of robot arm end trajectory

**VOCAB: (w/definition)**

**MYO**: Gesture controlled armband / bracelet
**sEMG:** Used for studying / measuring muscle activity
**IMU:** Measures acceleration, orientation, and angles of forces
**Support Vector Machine:** a machine learning model that can classify problems and data sets
**IIR:** a recursive filter that compares inputs with previous inputs and outputs

**Cited references to follow up on**

Hiren K. Mewada, Jitendra Chaudhari.(2019) Low computation digital down converter using polyphase IIR filter[J]. Circuit World,45(3).

Jing Yang, Yingpeng Hu, Kaixi Zhang, Yanghui Wu.(2020) An improved evolution algorithm using population competition genetic algorithm and self-correction BP neural network based on fitness landscape[J]. Soft Computing, (prepublish).

Robotics;(2020) New Findings from Beijing University of Technology in the Area of Robotics Described (Calibration of Low Cost Imu's Inertial Sensors for Improved Attitude Estimation)[J]. Journal of Robotics & Machine Learning

**Follow up Questions**

How can user input be implemented?
How does this work with other types of robotic arms?
How gentle is the device (will the fist break a glass cup)?
It was mentioned that more precise equipment is more expensive, but how expensive was the equipment used?

# Article #9 Notes: Internet Controlled Robotic Arm

Article notes should be on separate sheets

| | |
|---|---|
| **Source Title** | Internet Controlled Robotic Arm |
| **Source citation (APA Format)** | Wan Muhamad Hanif Wan Kadir,(2012, August 25). Internet controlled robotic arm. Science Direct https://www.sciencedirect.com/science/article/pii/S1877705812026847 |
| **Original URL** | https://www.sciencedirect.com/science/article/pii/S1877705812026847 |
| **Source type** | Science article |
| **Keywords** | Robotic arm ; Internet controlled robot ; Arduino Uno ; Arduino Ethernet |
| **#Tags** | #robotics #arduino #household-tasks |
| **Summary of key points + notes (include methodology)** | According to the article, robots are either industrial or service (complete a set of repeated tasks other than manufacturing). The goal of the study was to create a robot arm that could be controlled online and be controlled to complete household chores. Using the SOAP protocol, the NOMAD-200 robot took 30 seconds to respond on the LINUX operating system. The Arduino Uno was used as the hardware. The arm is controlled by a human, so it does not have to be trained. The method included the user controlling the arm with the PC software, which controls a servo motor. The material was aluminum due to its lightweight and its strength. The electrical engineering aspect was using the arduino to move the 5 different components of the robot's mobility (figure 2). A servo motor was used because of high torque, and a 12V/1.2Ah Lead Battery was used. Once orders are sent to the motor, it is completed and then awaits the next command. Overall, the model was successful and could complete the given tasks with different angles. The article also concludes with the fact servo motors are very useful. |
| **Research Question/Problem/ Need** | Can people being online help them complete household chores? |

| Important Figures | |
|---|---|

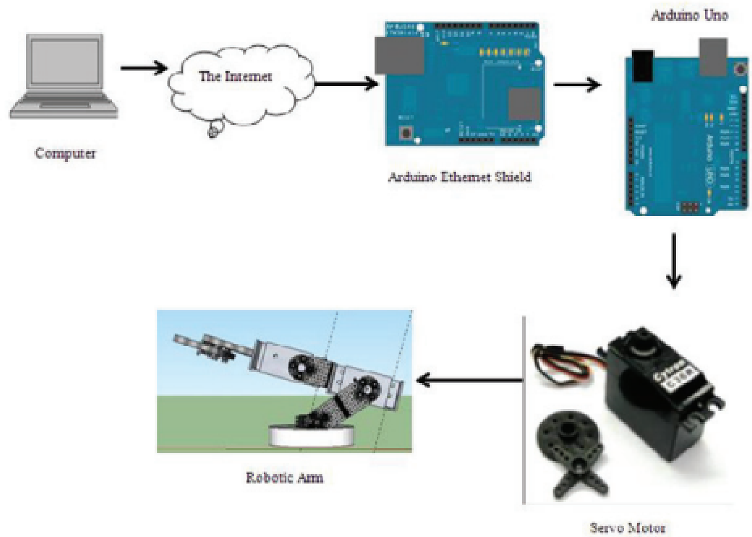



Fig 1: Project overview of internet controlled robotic arm.

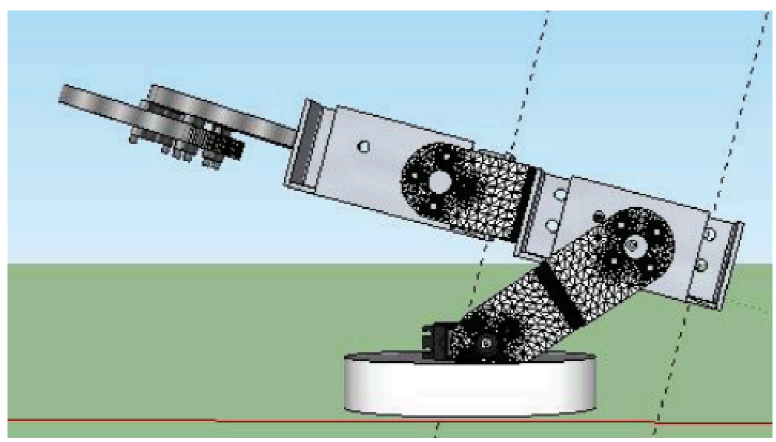


Fig 2: Side view of the internet controlled robotic arm

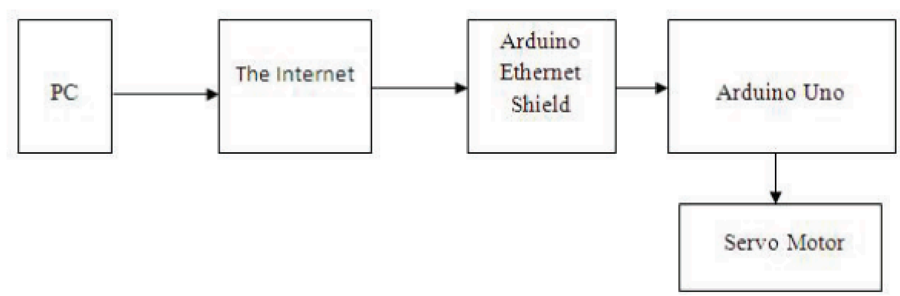



Fig 3: Specific block diagram of internet controlled robotic arm

Table 1: Specification of Internet Controlled Robotic Arm.

| Module | Specification |
|---|---|
| Supply from battery | 12 Volts DC |
| Power Consumption | Volts DC |
| Controller | Arduino Uno |
| Internet connector | Arduino Ethernet Shield |
| Programming language | Arduino language |
| Actuator | Servo motor |

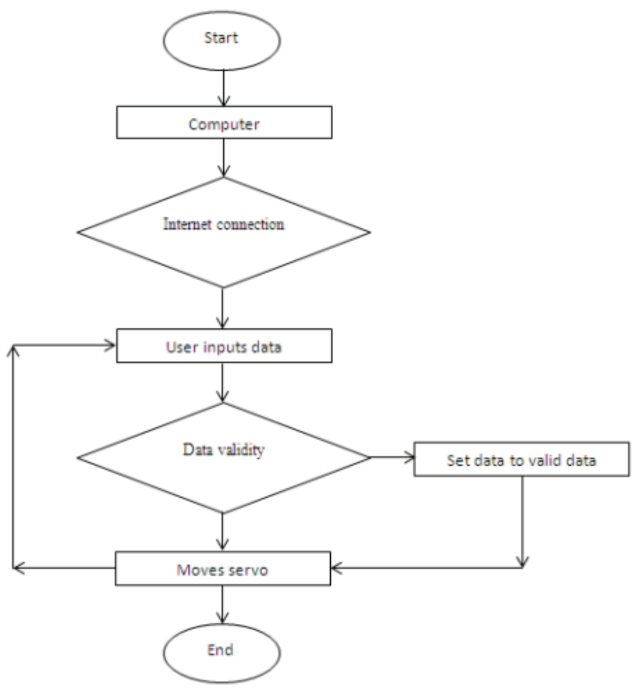
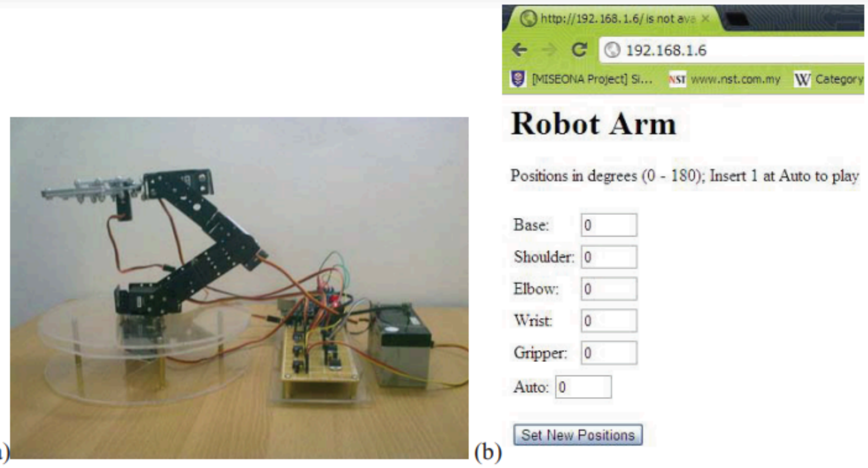



Fig 5: Flowchart of internet controlled robotic arm.




(a) (b)

Fig 6: (a) Completed internet controlled robotic arm and (b) Completed GUI for internet controlled robotic arm.

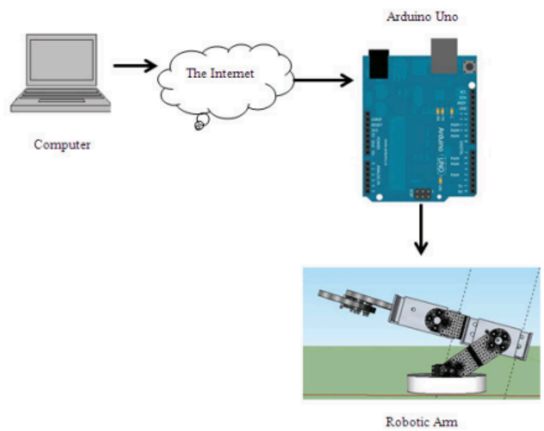



Fig 7: The internet controlled robotic arm.

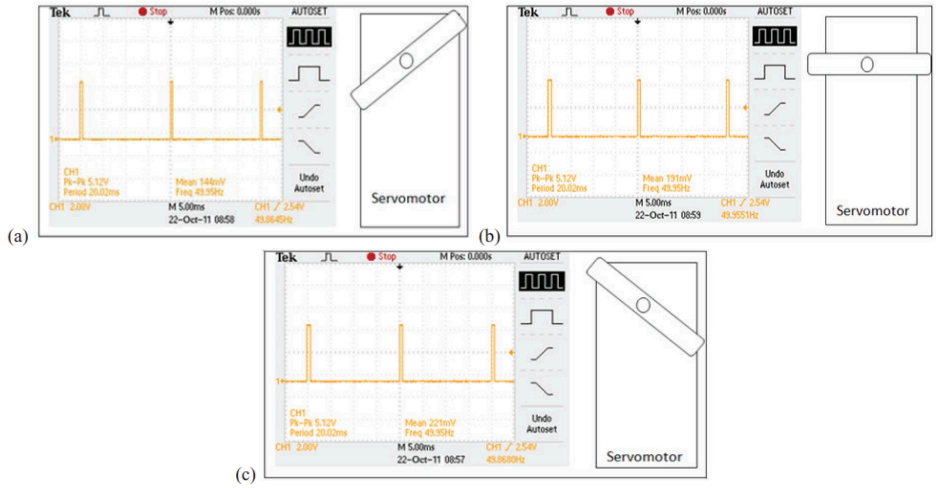



Fig 8: (a) Servo motor rotating counter clockwise and its pulse, (b) Servo motor rotating at neutral position and its pulse and (c) Servo motor rotating at clockwise position and its pulse.

Table 2: Servo motor pulse width and location

| Pulse width | Angle | Comment |
|---|---|---|
| 0.6 mS | -45 degree | Minimum pulse length |
| 1.5 mS | 0 degree | Centre position |
| 2.4 mS | 45 degree | Maximum pulse length |

**VOCAB: (w/definition)**

**Arduino Uno:** microcontroller board to control the motors and robot
**Arduino IDE**: Arduino software for programming the Uno
**GUI**: Graphical user interface
**Gripper:** the claw / actual robot, not the piece on the end of the claw

**Cited references to follow up on**

R. C. Luo , K. L. Su,.A multi agent multi sensor based real-time sensory control system for intelligent security robot. IEEE International Conference on Robotics and Automation, vol. 2, 2003, pp.2394 .2399. [2] Riazollah Firoozian, “Servo Motors and Industrial Control Theory.” Springer; 1st edition (December 8, 2008). [3] Massimo Banzi. “Getting Started with Arduino”, O’Reilly Media, Inc, 1st Edition, pp. 21 – 22, 2011. [4] Arduino entry, http://en.wikipedia.org/wiki/Arduino accessed on 10th December 2011 at 10.30 a.m

**Follow up Questions**

What scale was used for the price, as the inexpensive stuff was 15-25 dollars.
Is the robot mobile or possible to become mobile?
Can users see what is going on easily if they can’t see the actual robot?

# Article #10 Notes: Modeling and Analysis of a 6 DOF Robotic Arm Manipulator

Article notes should be on separate sheets

| | |
|---|---|
| **Source Title** | Modeling and Analysis of a 6 DOF Robotic Arm Manipulator |
| **Source citation (APA Format)** | Iqbal J, (2012). Modeling and analysis of a 6 DOF robotic arm manipulator - researchgate. (n.d.). https://www.researchgate.net/profile/Jamshed-Iqbal-2/publication/280643085_Modeling_and_analysis_of_a_6_DOF_robotic_arm_manipulator/links/55c0a56b08aed621de13cf59/Modeling-and-analysis-of-a-6-DOF-robotic-arm-manipulator.pdf?origin=publication_detail |
| **Original URL** | https://www.researchgate.net/profile/Jamshed-Iqbal-2/publication/280643085_Modeling_and_analysis_of_a_6_DOF_robotic_arm_manipulator/links/55c0a56b08aed621de13cf59/Modeling-and-analysis-of-a-6-DOF-robotic-arm-manipulator.pdf |
| **Source type** | Research article |
| **Keywords** | Robot arm ; modeling ; Modeling of robot; Robot kinematics; Robotic system simulation; Analysis of Serial mechanism |
| **#Tags** | #robot #arm |
| **Summary of key points + notes (include methodology)** | The article focused on predicting the motion of physical systems. This includes the motion of joints using kinematic modeling. This can be applied to industrial robots which assemble, spray, etc, and these require a pick and place process. The robot has different parts, such as the wrist and waist, and the motions of these parts are limited as a safety procedure. It is controlled through pendant, but the downside is that pendant must be reprogrammed whenever the position of the object moves. The kinematics are based on Denavit-Hartenburg parameters. They are useful for expressing and modeling joint positions, where the minimum value is more ideal. Matlab was used to graph the models, as seen below. This was able to be used to create a 3d model in the x, y, and z axises. The test was entering the pickup and drop off positions, illustrated in figure 11. During testing, it was found that the margin of error is +- 0.5 cm, part of this being due to a raised platform from which the robot picked the object from. |
| **Research Question/Problem/ Need** | Can a robotic pick and place arm be modeled for better results? |

## Important Figures

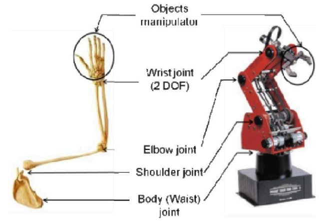



**Fig. 1. Joints configurations in ED7220C.**

**TABLE I.**
**SALIENT FEATURES OF ED7220C**

| Feature | Description |
|---|---|
| Position precision | ±0.5mm (approx.) |
| Movement speed | 100mm/s (max.) |
| Load capacity | 1 Kg |
| Weight | 33 Kg |
| Range Of Motion (ROM) | Wrist - Pitch: 260°, Roll:360°<br>Elbow: 172°<br>Shoulder: 90°<br>Waist: 310° |

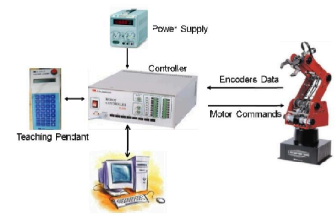



**Fig. 2. Arm shown with other system components.**

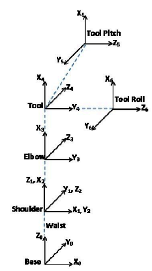



**Fig. 4. ED7220C — Coordinate assignment.**

**TABLE III.**
**ED 7220C — DH PARAMETERS**

| Symbol | Joints (*i*) 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| $\alpha_{i-1}$ | 0 | -90° | 0 | 0 | -90° | 0 |
| $a_{i-1}$ | 0 | 0 | $L_2$ | $L_3$ | 0 | 0 |
| $d_i$ | $L_1$ | 0 | 0 | 0 | 0 | $L_4$ |
| $\theta_i$ | $\theta_1$ | $\theta_2$ - 90° | $\theta_3$ | $\theta_4$ | $\theta_5$ | 0 |

Using the general form of the transformation matrix for

3(

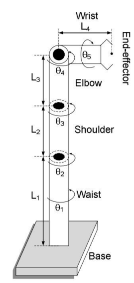



**Fig. 3. ED7220C — Kinematic model.**

**TABLE II.**
**ED 7220C — LINK LENGTHS**

| Joint | Waist | Shoulder | Elbow | Wrist |
|---|---|---|---|---|
| Symbol | $L_1$ | $L_2$ | $L_3$ | $L_4$ |
| Link Length [mm] | 385 | 220 | 220 | 155 |

Figure 6 shows MATLAB plot for this joint configuration.

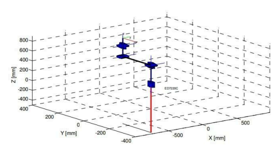
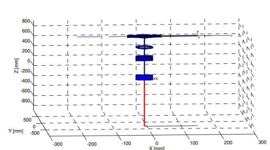


**Fig. 6. Plot for joint angle configuration [90° 90° -90° -90°].**

Figure 7 shows the plot for joint angle configuration [$t_1$ $t_2$ $t_3$ $t_4$] as [0 90° 90° 0] with the forward transformation as

$$ {}^{0}_{6}T = \begin{bmatrix} 0 & 0 & -1 & 65 \\ 0 & -1 & 0 & 0 \\ -1 & 0 & 0 & 165 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$



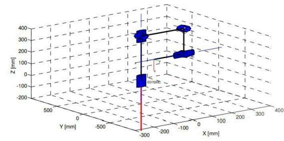


**Fig.7. Plot for joint angle configuration [0 90° 90° 0].**

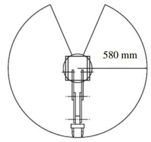



Fig. 8. Workspace in XY.

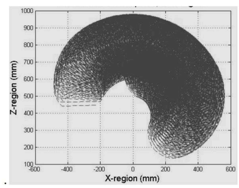



Fig. 9. Workspace in XZ.

The corresponding 3D MATLAB plot is illustrated in Figure 10.

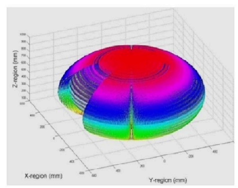



Fig. 10. 3D Workspace.

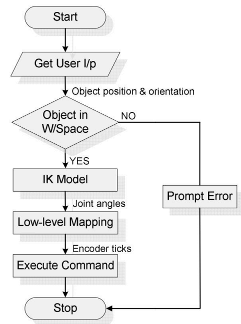



Fig. 11. IK model implementation.

| | |
|---|---|
| **VOCAB: (w/definition)** | **kinematic modeling:** modeling an object's force and direction<br>**Salient:** noticeable and/or important |
| **Cited references to follow up on** | Wang Z., Xilun D., Alberto R. and Alessandro G., "Mobility analysis of the typical gait of a radial symmetrical six-legged robot", Mechatronics, Vol. 21, No. 7, pp. 1133-1146, 2011<br>Raza ul Islam, J. Iqbal, S. Manzoor, A. Khalid and S. Khan, "An autonomous image-guided robotic system simulating industrial applications", 7<br>th IEEE International Conference on System of Systems Engineering (SoSE), Genova, Italy, pp. 314-319, 2012<br>J. J. Craig, "Introduction to robotics: Mechanics and control", Prentice Hall, 2nd edition, pp.84. |
| **Follow up Questions** | How would the angle of the object being manipulated affect the procedure?<br>How can different clamps be more accurate? |

# Article #11 Notes: Robot Claw: from manufacturing to marine research

Article notes should be on separate sheets

| | |
|---|---|
| **Source Title** | Robot Claw: from manufacturing to marine research |
| **Source citation (APA Format)** | *Universal Robots (2021) Robot claw: From Manufacturing to Marine Research*. Collaborative robotic automation. (n.d.). https://www.universal-robots.com/blog/robot-claw-from-manufacturing-to-marine-research/ |
| **Original URL** | https://www.universal-robots.com/blog/robot-claw-from-manufacturing-to-marine-research/ |
| **Source type** | Research Article |
| **Keywords** | Robotic claw : grippers |
| **#Tags** | #robotics #gripper |
| **Summary of key points + notes (include methodology)** | There are different types of grippers, most of which consist of 2 pieces that hold something. Softer grippers are often used for handling food. They can also be used in space to handle instruments or underwater to handle jellyfish. Hydraulic claws are strong, but are not too accurate with about a 1% accuracy with clamp force due to pressure switches. Mechanical claws are used for batch production, and are cheaper but take longer to operate. They are also able to be used in situations where hydraulics might be too dangerous, such as heat. Mechanical claws are operated with different possible types such as pistons or electromagnet. Parallel grippers (the 2 finger ones) can usually only complete pinch and grab processes. However, they can be made to easily handle different shapes. There are also safety procedures possible that can make it safe to be used with humans, such as the hand-e Gripper. 3 fingered grippers are good for grasping circular objects and are often more powerful, but lack flexibility. It also automatically centers objects that it grabs. Some grippers use compressed air to handle soft food. |
| **Research Question/Problem/ Need** | What are the different types of grippers, how do they work, and what are they used for? |

| | |
|---|---|
| **Important Figures** | <br>RG2 claw with flexible fingers<br><br><br>Multi clawed arm for higher productivity.<br><br><br>3 fingered claw (3FG15 gripper) |
| **VOCAB: (w/definition)** | **Gripper:** the part of the robot that grabs<br>**Palletizing:** moving or stacking |
| **Cited references to follow up on** | |
| **Follow up Questions** | How does this apply to marine research other than jellyfish?<br>How do more fingers help or take away from the robot?<br>What are advantages of different method to operate the claw? |

# Article #12 Notes: Fast and "soft-arm" tactics [robot arm design]

Article notes should be on separate sheets

| | |
|---|---|
| **Source Title** | Fast and "soft-arm" tactics [robot arm design] |
| **Source citation (APA Format)** | Bicchi, A., & Tonietti, G. (2004, June). Fast and "soft-arm" tactics [robot arm design]. IEEE Robotics & Automation Magazine, 11(2). https://doi.org/10.1109/MRA.2004.1310939 |
| **Original URL** | https://ieeexplore.ieee.org/abstract/document/1310939?casa_token=yRZJbhgY8TYAAAAA:_F3_TvzpBKCECp-HwcSnn5-GOXni4-i8xINmIGoKCNvLTVtfZRlfLT4iBqFnYzwZuMX8coHong |
| **Source type** | Research article |
| **Keywords** | Robots ; Human friendly ; accurate |
| **#Tags** | #robotics #arm |
| **Summary of key points + notes (include methodology)** | There are many things that can go wrong with a robot that works with humans: malfunctions, human error, software, accuracy, ect. These conditions are somewhat limited by the task the robot is expected to complete. The robots should however use sensors for safety. Injuries with the gripper can be very severe, but can also happen anywhere in the system. A HIC (Head Injury Criteria) value that is 1000 or over is a severe head injury. The maximum velocity is usually reached in less than 15 seconds. An important thing to take into account when discussing safety is how to not hinder the effectiveness of the robot too much. If the safety mechanisms prevent the robot from properly completing the task, then it is not useful. By adding a link, the HIC value can be reduced (Figure 4), and acts as a simple safety feature. It is also important to reduce transition stiffness (the spring effect when moving things) as that can cause injuries. It is therefore recommended to use elastic joints. This can also be used with lower velocities, that therefore reduce the transition stiffness. |
| **Research Question/Problem/ Need** | How can safety be addressed with robots that work with humans? |

**Important Figures**

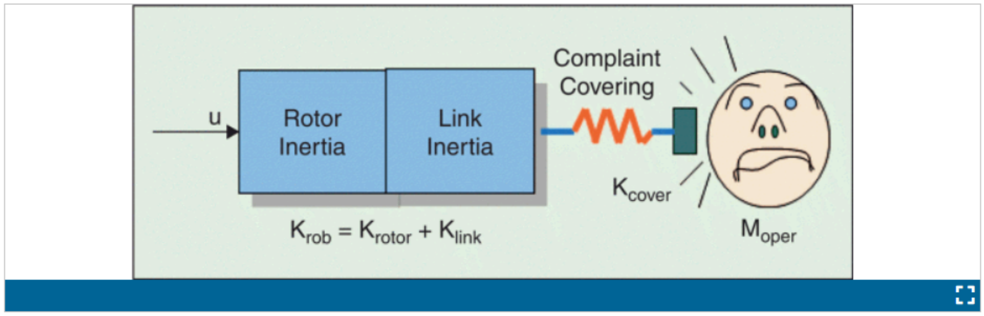



**Figure 1.**
Simplified model of the impact between a rigid lOaFrobot arm and an operator.

A model showing a HIC value of 100 (acceptable)

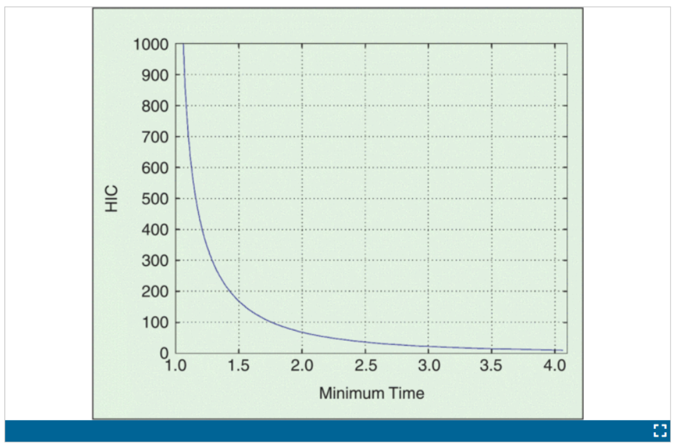



**Figure 3.**
The safety-performance tradeoff curve for the rigid single joint case.

A model showing the ratio of  HIC value : time

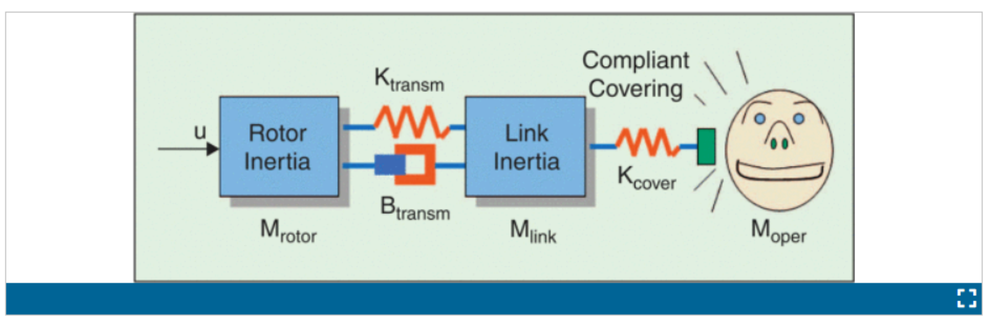
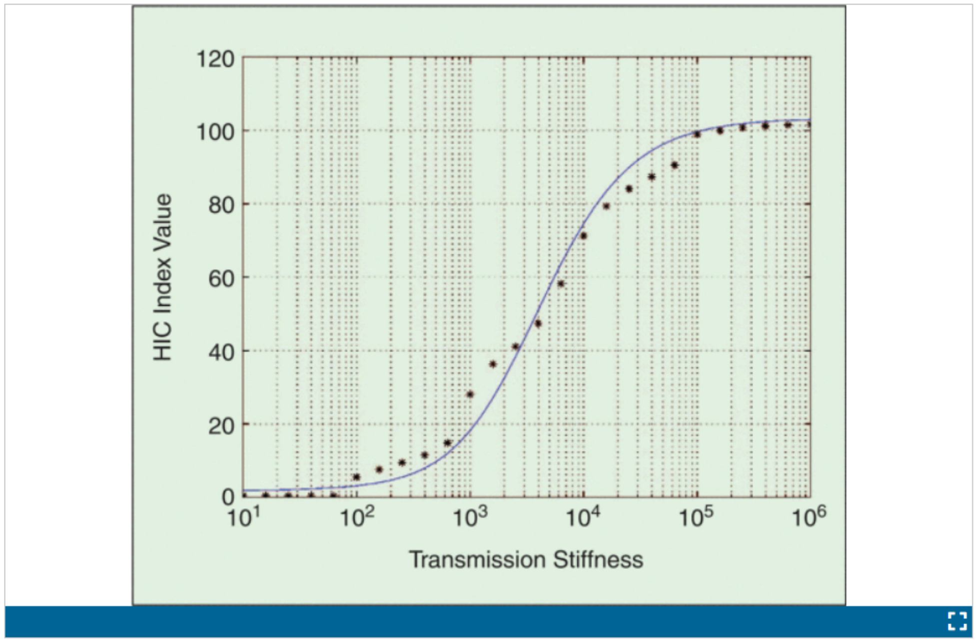
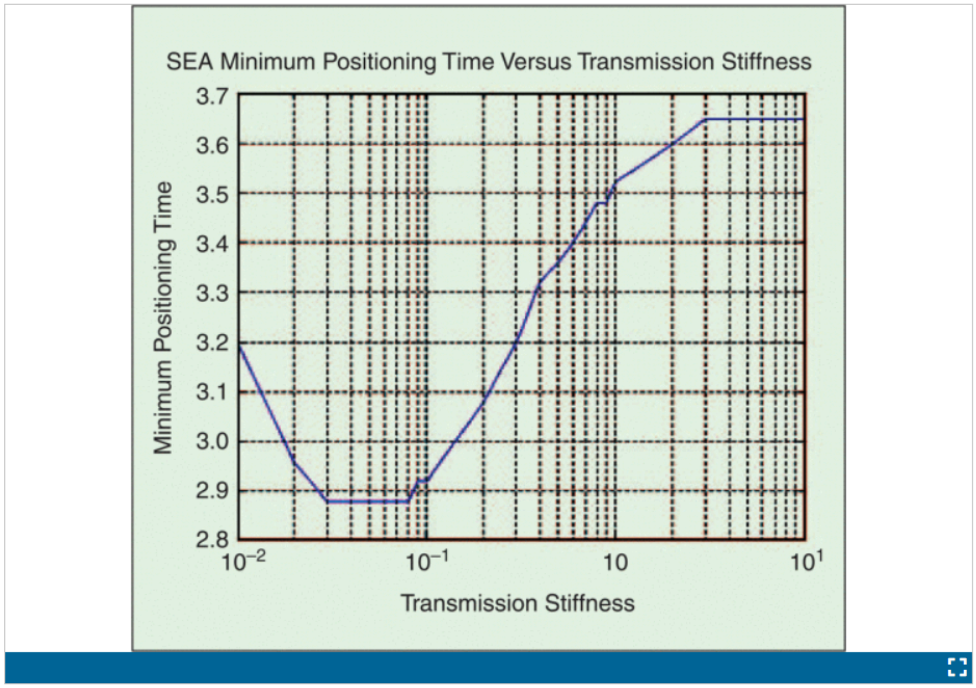
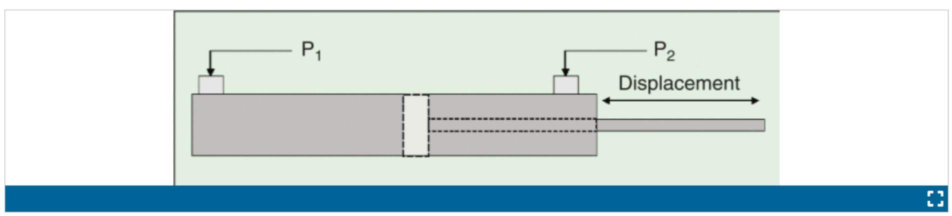



**Figure 4.**
The interposition of an elastic transmission between the actuator and the link is a classical approach for reducing injury risks.

A model similar to figure 1, but with a link that reduces the HIC value

| | |
|---|---|
| |   **Figure 5.** Head-injury coefficients evaluated for the impact of a link of effective inertia $M_{\text{link}} = 0.1$ kg elastically coupled to a rotor of inertia $M_{\text{rot}} = 1.2$ kg by a transmission with $B_{\text{transm}} = 0$, as $K_{\text{transm}}$ varies. The rotor and link are assumed to move uniformly at velocity $v = 10\ m/s$: before impact. Data points are obtained by simulation, while the solid curve is calculated using the compound inertia formula (4). <br>Model showing the ratio of HIC value : stiffness |

| | |
|---|---|
| | <br><br>**Figure 6.**<br>The minimum time necessary to reach a given positional goal under safety constraints and actuator saturation, as a function of the transmission stiffness, for an elastic transmission.<br><br><br>**Figure 13.**<br>Even a simple off-the-shelf two-way air cylinder can be used as a linear VST actuator. Increasing air pressure in proportion in both chambers increases the overall stiffness of the rod, while the equilibrium of the rod under an external load can be displaced by a differential in chamber pressure.<br><br>A second possibility of the design |
| **VOCAB: (w/definition)** | **Actuation:** Causing a machine to operate<br>**VSA:** Variable-stiffness actuation<br>**VST:** Variable-stiffness transition<br>**Brachistochrone:** A smooth curved graph where point B is less than point A |
| **Cited references to follow up on** | |
| **Follow up Questions** | Is it safer with this design, or completely safe? |

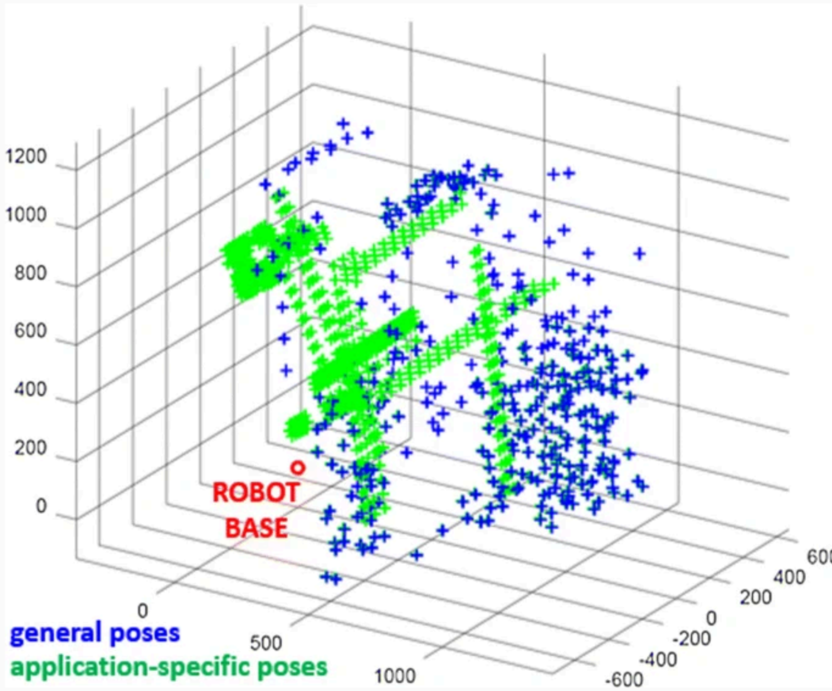
# Article #13 Notes: Geometrical calibration of a 6-axis robotic arm for high accuracy manufacturing task

Article notes should be on separate sheets

| | |
|---|---|
| **Source Title** | Geometrical calibration of a 6-axis robotic arm for high accuracy manufacturing task |
| **Source citation (APA Format)** | Lattanzi, L., Cristalli, C., Massa, D., (2020, October 12). Geometrical calibration of a 6-axis robotic arm for high accuracy manufacturing task. The International Journal of Advanced Manufacturing Technology. https://doi.org/10.1007/s00170-020-06179-9 |
| **Original URL** | https://link.springer.com/article/10.1007/s00170-020-06179-9 |
| **Source type** | Research Article |
| **Keywords** | Robotic arm, calibration, accuracy |
| **#Tags** | #robotic arm #accurate #industrial |
| **Summary of key points + notes (include methodology)** | It is essential for robotic arms that complete important tasks (such as putting together an airplane) to be very accurate. Therefore a system was made that uses a laser camera system to detect position, and this was made to create a more accurate arm. This was tested and modeled (figure 7), and showed a much more accurate path that the arm took to complete the task. The laser was fixed with a magnet, and proved to be useful, and could possibly be used to detect other things, such as the level of chocolate in my project since that is not constant. This was also modeled in an online simulation, and proved to have a little bit of error, but much better than without the laser. |
| **Research Question/Problem/ Need** | How can the accuracy of a robotic arm meant for important industry tasks be improved? |

**Important Figures**

Fig. 7




Selected robot positions for the identification procedure (distances are expressed in millimeters): general positions (blue), task representative positions (green)

Position of the arm for different tasks

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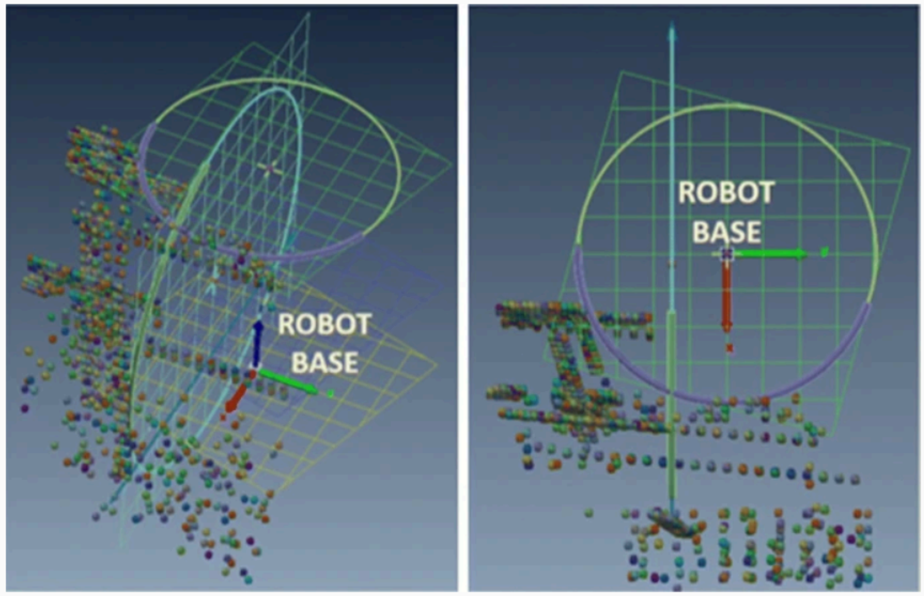
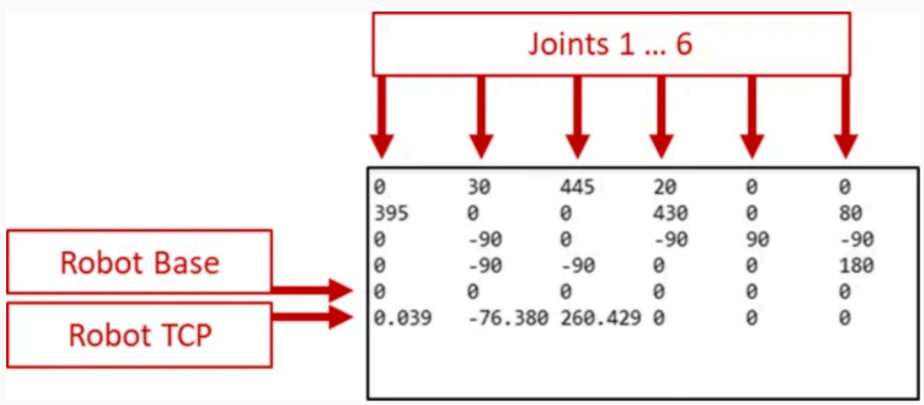
**Fig. 8**




Robot positions measured by the laser tracker and used for the robot geometrical identification procedure

More precise model

**Fig. 11**




Example of file describing the theoretical robot Denavit-Hartenberg (DH) matrix (angular values are expressed in degrees, linear values in millimeters)

Positions of arm

</td>
</tr>
<tr>
<td>VOCAB: (w/definition)</td>
<td>
kinematic calibration: Enhancing robot positions and orientations<br>
extrinsic: not part of nature, outside forces<br>
TCP position: point used to move the robot into a position<br>
TcpToolOrigin: a software used to track the position
</td>
</tr>
</table>

| | |
|---|---|
| **Cited references to follow up on** | Conrad KL, Shiakolas PS, Yih TC (2000) Robotic calibration issues: accuracy, repeatability and calibration. In: Proceedings of the 8th mediterranean conference on control & automation<br><br>Kluz R, Trzepieciński T (2014) The repeatability positioning analysis of the industrial robot arm. Assembly 34(3):285–295<br><br>Elatta A, Gen LP, Zhi FL, Daoyuan Y, Fei L (2004) An overview of robot calibration. Inform. Technol. J. 3:74–78<br><br>Borm JH, Meng CH (1991) Determination of optimal measurement configurations for robot calibration based on observability measure. Int. J. Robot. Res. 10:51–63 |
| **Follow up Questions** | Does the process drastically change for more/ less joints?<br>Why was the front-right point chosen?<br>Why was the temperature important when testing?<br>How was rotation of the gripper and base accounted for?<br>Why do the models not show 6 joints? Is it simplicity or was it modeled differently? |

# Article #14 Notes: Joystick controlled industrial robotic system with robotic arm

Article notes should be on separate sheets

| | |
|---|---|
| **Source Title** | Joystick controlled industrial robotic system with robotic arm |
| **Source citation (APA Format)** | Rahman, R., Rahman, M., Bhuiyan, J., (2019). Joystick controlled industrial robotic system with robotic arm. 2019 IEEE International Conference on Robotics, Automation, Artificial-intelligence and Internet-of-Things. doi: 10.1109/RAAICON48939.2019.18. |
| **Original URL** | [https://ieeexplore.ieee.org/abstract/document/9087500/figures#figures](https://ieeexplore.ieee.org/abstract/document/9087500/figures#figures) |
| **Source type** | Research article |
| **Keywords** | Robotic arm, joystick, industrial |
| **#Tags** | #robotics #industrial #remote |
| **Summary of key points + notes (include methodology)** | With more robots taking over the workplace, the goal of this project was to create a cheap robot that can be operated remotely. This is important as robots can operate tedious and hazardous tasks. The arm utilized a servo drive which consisted of servo motors and an Arduiono mega. The Arduino mega was programmed to take commands from a joystick, and was proven to be extremely accurate and able to complete tasks. The prototype could carry 2-3 pounds and the controller itself had a range of 15 meters. The article did mention some difficulties, such as a motor malfunction, which was fixed by replacing the motor. Overall, the product was user friendly and could finish its task, but future steps include adding a camera, increasing durability, and adding autonomous features. |
| **Research Question/Problem/ Need** | The need is a cheap, versatile robot that can increase the rate of production and decrease workplace mishaps. |

**Important Figures**

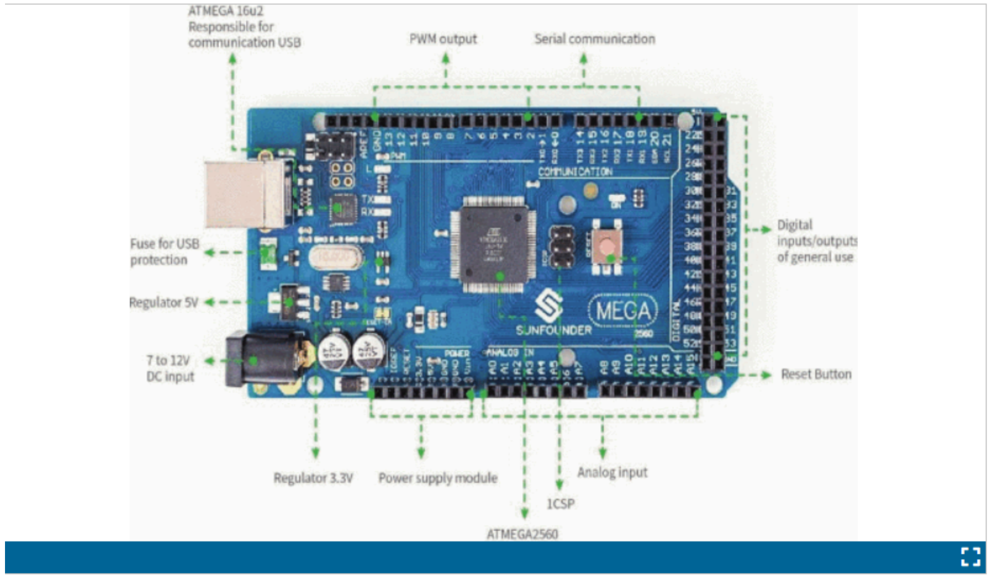



Figure 1: Arduino mega with labeled parts

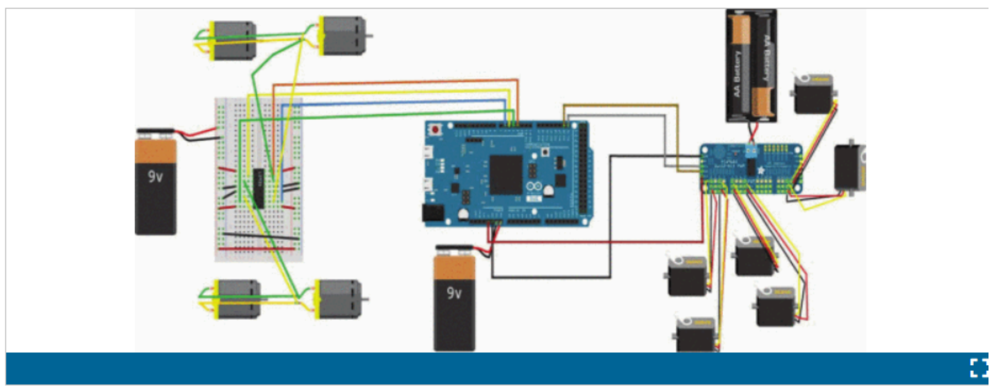
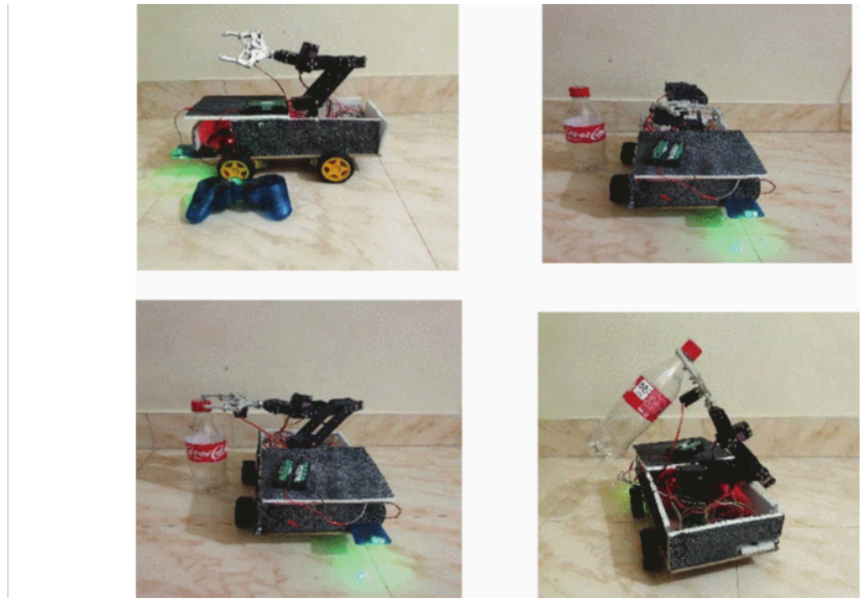



**Fig. 2.**
Circuit diagram of the robot (drawn in fritzing)

| | |
|---|---|
| | <br>Figure 4: experimentation |
| **VOCAB: (w/definition)** | **Potentiometers:** a device to measure electromotive force<br>**Analog Input:** sensors that produce a voltage in response to an event |
| **Cited references to follow up on** | Mohd Ashiq Kamaril, Yusoff Reza, Ezuan Samin, Babul Salam and Kader Ibrahim, "Wireless Mobile Robotic Arm", International Symposium on Robotics and Intelligent Sensors Procedia Engineering, vol. 41, pp. 1072-1078, 2012.<br><br>"IoT Based Pick and Place Robot", International Journal of Recent Trends in Engineering and Research, vol. 4, no. 3, pp. 217-223, 2018.<br><br>"Control of robot arm by using reference arm and LabView", Revista Tecnica De La Facultad De Ingenieria Universidad Del Zulia, 2016, [online] Available: 10.21311/001.39.2.1. |
| **Follow up Questions** | How does the robot being on wheels affect the rest of the system?<br>What specific tasks can this be applied to?<br>Could other types of controllers be attached? |

# Article #15 Notes: Mobile Robot Positioning:Sensors and Techniques

Article notes should be on separate sheets

| | |
|---|---|
| **Source Title** | Mobile Robot Positioning:Sensors and Techniques |
| **Source citation (APA Format)** | Wehe, D., Fend, L., Borenstein, J., Everett, H. R. (1996). Mobile Robot Positioning:Sensors and Techniques. Journal of Robotic Systems Vol 14, 4. https://onlinelibrary.wiley.com/doi/epdf/10.1002/(SICI)1097-4563(199704)14%3A4%3C231%3A%3AAID-ROB2%3E3.0.CO%3B2-R. |
| **Original URL** | https://onlinelibrary-wiley-com.ezpv7-web-p-u01.wpi.edu/doi/epdf/10.1002/(SICI)1097-4563(199704)14%3A4%3C231%3A%3AAID-ROB2%3E3.0.CO%3B2-R |
| **Source type** | Journal Article |
| **Keywords** | Roboti; sensors |
| **#Tags** | #Robotics; #sensors; #extensions |
| **Summary of key points + notes (include methodology)** | The goal of the article is to use sensors to position a robot. This is based off of equations using Energy, and the article is trying to minimize errors. One thing looked at was the OmniMate due to its ability to correct such errors. Accelerometers and gyroscopes were also looked at, but some of these can be expensive. Magnetic and Fluxgate compasses were also used due to their sensor properties, and are much cheaper. The article mostly focused on mechanisms for testing, and other than the above, triangulation, GPS, signals, and a few other methods were used. One other example is a landmark detection, which looks for something of s specific shape/ size. However, many of these systems were large or expensive. The results were all compiled into a table. |
| **Research Question/Problem/ Need** | How can sensors be used on a mobile robot for positioning? |
| **Important Figures** | $E_{\max,\mathrm{syst}} = \max(r_{c.g.,cw};\ r_{c.g.,ccw}).$ <br> where <br> $r_{c.g.,cs} = \sqrt{(x_{c.g.,cw})^2 + (y_{c.g.,cw})^2}$ <br> and <br> $r_{c.g.,ccw} = \sqrt{(x_{c.g.,ccw})^2 + (y_{c.g.,ccw})^2}.$ <br> Formula of the odometry |

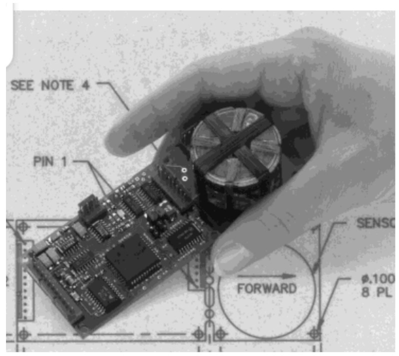



Figure 5: fluxgate sensor

| System & description | Features | Accuracy: Position [mm] | Accuracy: Orientation [°] | Effective range | Ref. no. |
|---|---|---|---|---|---|
| Odometry on TRC LabMate, after UMBmark calibration. Wheel-encoder resolution: 0.012 mm linear travel per pulse | | 4×4 meters square path: smooth floor: 30 mm 10 bumps: 500 mm | Smooth floor: 1–2° With 10 bumps: 8° | Unlimited | 8 |
| CLAPPER and OmniMate: Dual-drive robot with internal correction of odometry. Made from two TRC LabMates, connected by compliant linkage. Uses 2 abs. rotary encoders, 1 linear encoder. | | 4×4 m square path: smooth floor: ~20 mm 10 bumps: ~40 mm | Smooth floor: <1° 10 bumps: <1° | Unlimited | 9 |
| Complete inertial navigation system including ENV-O5S Gyrostar solid state rate gyro, START solid state gyro, triaxial linear accelerometer and 2 inclinometers | | Position drift rate: 1–8 cm/s depending on frequency of acceleration change | Drift: 5–0.25°/s After compensation drift 0.0125°/s | Unlimited | 14,15 |
| Andrew Autogyro and Autogyro Navigator. Quoted minimum detectable rotation rate: ±0.02°/s. Actual minimum detectable rate limited by deadband after A/D conversion: 0.0625°/s. Cost: $1000 | | Not applicable | Drift: 0.005°/s | Unlimited | 17 |
| KVH Fluxgate Compass. Includes microprocessor-controlled fluxgate sensor subsystem. Cost <$700 | | Not applicable | Resolution: ±0.5° Accuracy: ±0.5° Repeatability: ±0.2° | Unlimited | 18 |
| CONAC™ (computerized opto-electronic navigation and control). Cost: $6,000. | Measures both angle and distance to target | Indoor ±1.3 mm Outdoor ±5 mm | Indoor and outdoor ±0.05° | >100 m | 19a |
| Global Positioning Systems (GPS). Cost: $1,000–$5,000. | | Order of 20 m during motion, order of centimeters when standing for minutes | Not applicable | Unlimited | Various vendors |
| Landmark Navigation | | <5 cm | <1 deg | ~10 m | Various research projects |
| Model Matching (map-based positioning) | | Order of 1–10 cm | Order of 1–3 deg | ~10 m | Various research projects |

Table 1: results

**VOCAB: (w/definition)**

**Odometry:** using sensors to estimate position
**OmniMate:** Platform that corrects odometry errors
**Fluxgate:** Highly magnetic ring cores

**Cited references to follow up on**

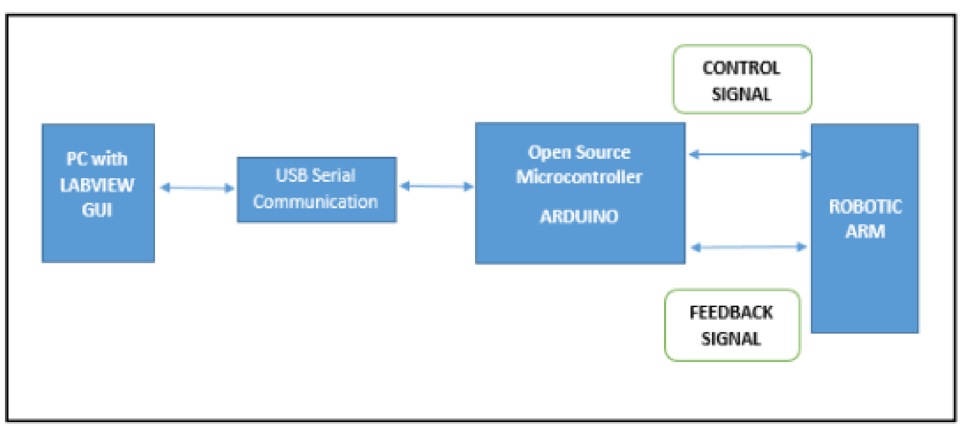
I. J. Cox, ‘‘Blanche—An experiment in guidance andMD, 1992.navigation of an autonomous mobile Robot,’’IEEE24. Trans. Rob. Autom.,7(3), 193–204, 1991.

K. W. Jo¨rg ‘‘World modeling for an autonomous mobilerobot using heterogenous

| | |
|---|---|
| | sensor information,''Rob. Auton. Syst.,14,159–170, 1995 |
| **Follow up Questions** | Is there any obvious advantage to one type or the other in certain tasks?<br>Are distance sensors or other more commonly used items better choices?<br>Can all of these systems be effective to a robotic arm? |

# Article #16 Notes: Four Degree of Freedom Robotic Arm

Article notes should be on separate sheets

| | |
|---|---|
| **Source Title** | Four Degree of Freedom Robotic Arm |
| **Source citation (APA Format)** | T. Younas, M. F. Khan, S. Urooj, N. Bano and R. A. Younas, (2019). Four Degree of Freedom Robotic Arm. 2019 IEEE 6th International Conference on Engineering Technologies and Applied Sciences (ICETAS). doi: 10.1109/ICETAS48360.2019.9117354. |
| **Original URL** | https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9117354 |
| **Source type** | Journal Article |
| **Keywords** | Robotic arm; DOF |
| **#Tags** | #Robotics |
| **Summary of key points + notes (include methodology)** | Based on previous studies, this article aims to model and simulate a four DOF robotic arm. This arm was made from Arduino Mega, however it was also tested on Arduino Uno. Arduino Mega was recommended, and while it was not stated why, it was most likely to be because of the better and more expensive software. The methodology is to use a forward kinematic model, which aligns itself by taking the current positions of the joints, and uses this information to align itself. They then used the D-H equation for each transformation, and can find the location of the arm which is on the fourth axis. |
| **Research Question/Problem/ Need** | How can a robotic arm be modeled and simulated? |
| **Important Figures** |   Figure 1: systems diagram |

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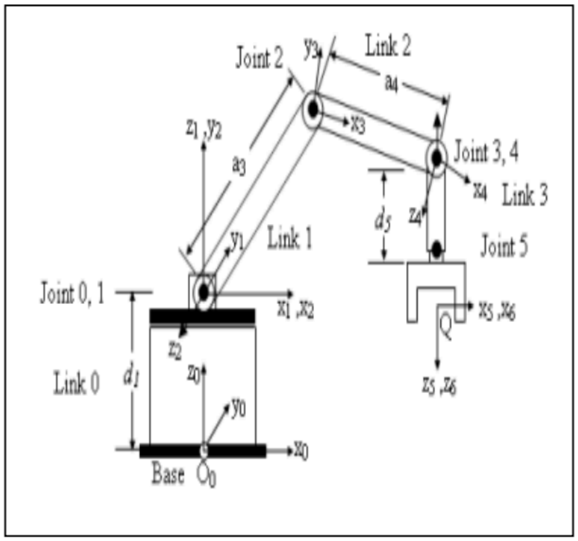
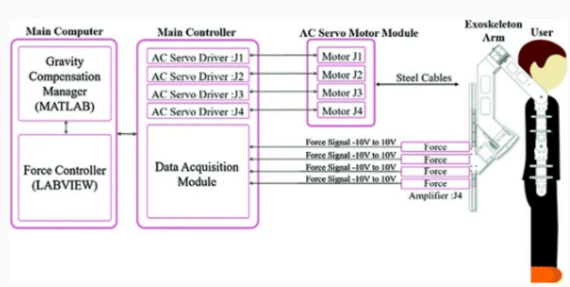
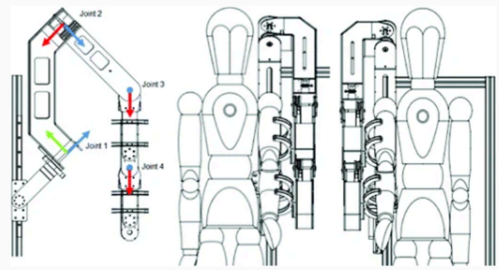


Figure 2: model of the arm with labels
</td></tr>
<tr><td>VOCAB: (w/definition)</td><td>DOF: Degree of Freedom - the number of joints<br>GUI: Graphical User Interface<br>Cartesian space: a space that has some sort of real number value</td></tr>
<tr><td>Cited references to follow up on</td><td>K. E. Clothier and Y. Shang, “A Geometric Approach for Robotic Arm Kinematics with Hardware Design, Electrical Design, and Implementation,” J. Robot., 2010<br><br>Younas, T., Akbar, M. A., Motan, I., Ali, Y., & Atif, M. (2017). Design and fabrication of an autonomous multifunctional robot for disabled people. In 2017 4th IEEE International Conference on Engineering Technologies and Applied Sciences (ICETAS) (pp. 1-6). IEEE<br><br>M. AbuQassem , Simulation and Interfacing of 5 DOF Educational Robotic Arm,Islamic University of Gaza , Electrical Enginnering Departmant<br><br>R. N. Jazar, Theory of Applied Robotics. Boston, MA: Springer US, 2010<br><br>Mouli, C. C., Jyothi, P., Raju, K. N., & Nagaraja, C. (2013). Design and Implementation of Robot Arm Control Using LabVIEW and ARM Controller. IOSR Journal of Electrical and Electronics Engineering, 6(5), 80-84</td></tr>
<tr><td>Follow up Questions</td><td>Can the arm correct itself, and if so, how was this programmed?<br>How did Urduino Mega or Arduino Uno affect the overall performance?<br>Why were five servo motors used if this was a 4 DOF robotic arm?<br>Can this easily be applied to other DOFs?</td></tr>
</table>

# Article #17 Notes: 4 DOF Exoskeleton Robotic Arm System for Rehabilitation and Training

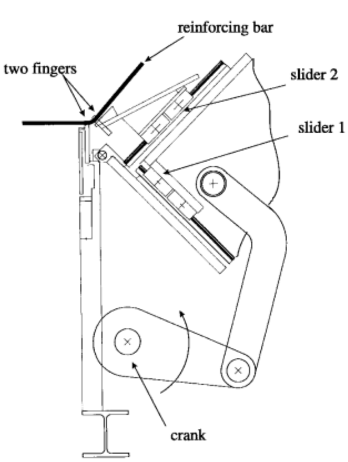
Article notes should be on separate sheets

| | |
|---|---|
| **Source Title** | 4 DOF Exoskeleton Robotic Arm System for Rehabilitation and Training |
| **Source citation (APA Format)** | Charoenseang, S., Panjan, s., (2018). 4 DOF Exoskeleton Robotic Arm System for Rehabilitation and Training. Lecture notes in Computer Science Vol. 10917. https://link.springer.com/chapter/10.1007/978-3-319-91397-1_13 |
| **Original URL** | https://link.springer.com/chapter/10.1007/978-3-319-91397-1_13 |
| **Source type** | Conference paper |
| **Keywords** | 4 DOF; robotic arm |
| **#Tags** | #robotics |
| **Summary of key points + notes (include methodology)** | In order to solve the problem of many stroke patients dying, the article strives to make a wearable arm to help stroke patients. This will help the rehabilitation process. The arm would guide the used, and therefore help them recover. Servo motors with a 180 degree range were used. However, this design was also heavy due to all of the motors. In order to make it more lightweight and easier to wear, the motors were not mounted on the robot, and wire signals were used instead. A limited range of motion for each joint was purposely put in for safety. The arm can also record things such as posture for the doctors to look at. |
| **Research Question/Problem/ Need** | Making a better 4 DOF robotic arm to help stroke patients. |
| **Important Figures** | Fig. 1.   Figure 1: systems diagram of the arm |

| | |
|---|---|
| | Fig. 2.   Figure 2: model of the robotic arm |
| **VOCAB: (w/definition)** | **Exoskeleton: Outer body of a device**<br>**angle-force mappings:** Measures the angle but not distances<br>**GRNN:** Measures functional approximation |
| **Cited references to follow up on** | Perry, J.C., Rosen, J., Burns, S.: Upper-limb powered exoskeleton design. IEEE/ASME Trans. Mechatron. 12(4), 408–417 (2007)<br><br>Mao, Y., Agrawal, S.K.: A cable driven upper arm exoskeleton for upper extremity rehabilitation. In: 2011 IEEE International Conference on Robotics and Automation (ICRA). IEEE (2011)<br><br>Yu, W., Rosen, J., Li, X.: PID admittance control for an upper limb exoskeleton. In: American Control Conference (ACC). IEEE (2011) |
| **Follow up Questions** | How does the size difference in users affect the arm?<br>Does the arm use external parts to model posture?<br>Could two arms improve efficiency?<br>Is the arm adjustable in size? |

# Article #18 Notes: Servo Motor Selection Criterion for Mechatronic Applications

Article notes should be on separate sheets

| | |
|---|---|
| **Source Title** | Servo Motor Selection Criterion<br>for Mechatronic Applications |
| **Source citation (APA Format)** | H. J. van de Straete, P. Degezelle, J. De Schutter and R. J. M. Belmans. (1998) Servo motor selection criterion for mechatronic applications. IEEE/ASME Transactions on Mechatronics, vol. 3, 1, pp. 43-50,, doi: 10.1109/3516.662867. |
| **Original URL** | https://ieeexplore.ieee.org/abstract/document/662867 |
| **Source type** | Journal article |
| **Keywords** | Robotic arm; servo motors |
| **#Tags** | #robotics #motors |
| **Summary of key points + notes (include methodology)** | The article talked about finding the best motor to operate a robot. The findings were that a Synchronous servo motor worked better than a normal servo motor. The test conducted in the article only covers dynamics, and not accuracy or other tests. The article used a lot of formulas to express the ability of the motor to lift the dynamic loads, using torque and other parameters such as motor current (in this case, they are proportional). The goal was to find a motor with maximum speed and torque, which was found to be the synchronous servo motor. |
| **Research Question/Problem/ Need** | Finding a motor with maximum speed and torque to best lift a dynamic load. |
| **Important Figures** | <br>Figure 4: model of the robot used (with labeled parts) |

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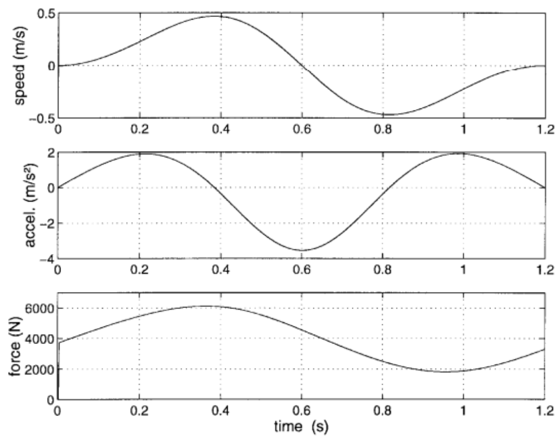
<tr><td></td><td>

Figure 5: A graph of the speed, acceleration, and required force (respectivly) to time</td></tr>
<tr><td>VOCAB: (w/definition)</td><td>synchronous servo motor: A servo motor that rotates with the use of magnets<br>Normal Servo Motor: A motor used for precise and consistent movements<br>Dynamic load: a load which changes over time (different weight)</td></tr>
<tr><td>Cited references to follow up on</td><td>M. A. Rahman, “Special section on permanent magnet motor drives,”<br>IEEE Trans. Ind. Electron., vol. 43, pp. 245–342, Apr. 1996<br><br>P. Chedmail and M. Gautier, “Optimum choice of robot actuators,”<br>ASME J. Eng. Ind., vol. 112, no. 4, pp. 361–367, Nov. 1990<br><br>C.-H. Chen, “Integrated design methods for motion control systems,”<br>Ph.D. dissertation, Dep. Mech. Eng., Katholieke Universiteit Leuven,<br>Heverlee, Belgium, 1993.</td></tr>
<tr><td>Follow up Questions</td><td>How did the dynamic load work?<br>Why was this arm design used (it is a loss less efficient than most arms)?<br>How can the equations be modified to account for accuracy?</td></tr>
</table>

# Article #19 Notes: Design and Fabrication of an Affordable SCARA 4-DOF Robotic Manipulator for Pick and Place Objects

Article notes should be on separate sheets

| | |
|---|---|
| **Source Title** | Design and Fabrication of an Affordable SCARA 4-DOF Robotic Manipulator for Pick and Place Objects |
| **Source citation (APA Format)** | S. F. Noshahi, A. Farooq, M. Irfan, T. Ansar and N. Chumuang. (2019) Design and Fabrication of an Affordable SCARA 4-DOF Robotic Manipulator for Pick and Place Objects. 14th International Joint Symposium on Artificial Intelligence and Natural Language Processing (iSAI-NLP), Chiang Mai, Thailand, , pp. 1-5, doi: 10.1109/iSAI-NLP48611.2019.9045203. |
| **Original URL** | https://ieeexplore.ieee.org/abstract/document/9045203 |
| **Source type** | Journal Article |
| **Keywords** | Robotic arm; Affordable; 4 DOF |
| **#Tags** | #robotics #cost-effective |
| **Summary of key points + notes (include methodology)** | Similarly to my project, this arm strives to create a robotic arm that can be used in the workplace, but be affordable. This model uses a wireless radio system, and is operated by servo motors. The arm can be fast and decrease risk for humans. The final arm could lift up to 2 kg. The prototype was designed with virtual tools and 3d modeling before the physical model was made. The final product was controlled by a human, as the goal was not to automate the process, but to prevent humans from getting hurt. The testing tested different materials for the gripper and exoskeleton. The 4 DOF design was chosen to be used as more DOF were predicted to be too expensive, but the final price is not stated in the article. |
| **Research Question/Problem/ Need** | Making an affordable robotic arm to minimize human involvement |

**Important Figures**

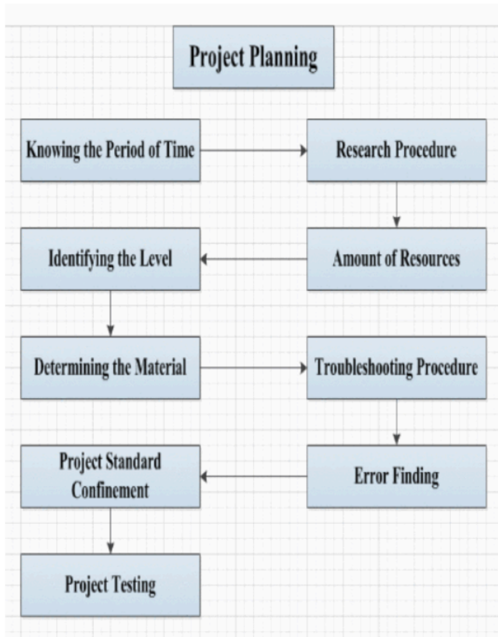



Figure 1: planning and methodology

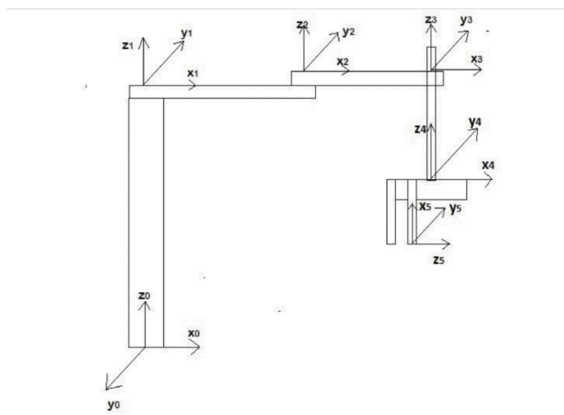



Figure 2: model of the mobility of the arm

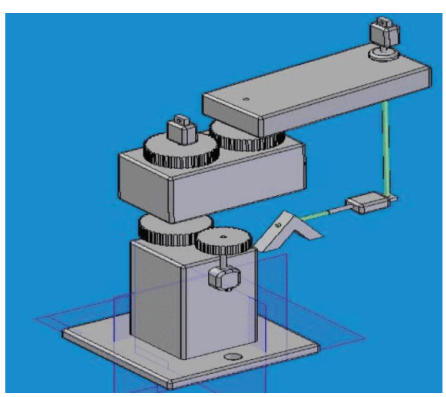


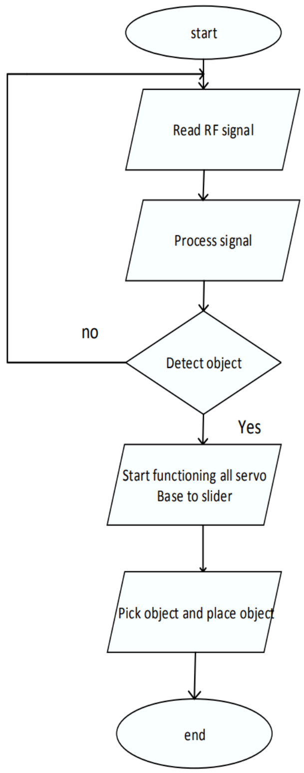
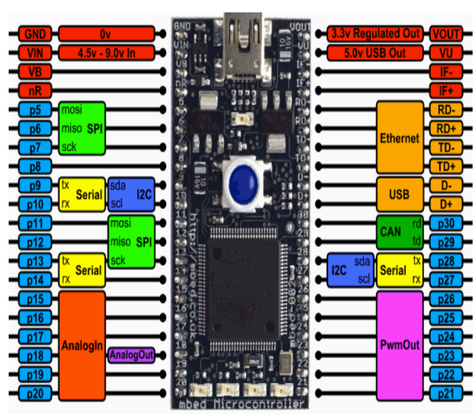
Figure 3: 3d model of the arm

| | |
|---|---|
| **VOCAB: (w/definition)** | **SCARA:** Selective Compliance Articulated Robot Arm, can move in all 3 dimensions, but best in x and y<br>**PLC system:** Programmable Logic Controllers; industrial grade computers |
| **Cited references to follow up on** | Aadil Farooq, Sadman Shafi, Zahid Ullah, Moomal Quresh, Narumol Chumuang, "A Lightweight Controller for Autonomous Following of a Target Platform for Drones", 2023 IEEE International Conference on Cybernetics and Innovations (ICCI), pp.1-6, 2023.<br><br>Muhammad Umar Anjum, Umar Shabaz Khan, Waqar Shahid Qureshi, Ameer Hamza, Wajih Ahmed Khan, "Vision-Based Hybrid Detection For Pick And Place Application In Robotic Manipulators", 2023 International Conference on Robotics and Automation in Industry (ICRAI), pp.1-5, 2023.<br><br>S. S. Arawade, "State of Art Review on SCARA Robotic Arm", International Journal of Advanced Research in Science, Communication and Technology, pp.145, 2021. |
| **Follow up Questions** | In ‘next steps’, would the DC motors still be an affordable arm, or would it be a different project?<br>How much did this arm cost to make?<br>How would large scale manufacturing work with a cheap product? |

# Article #20 Notes: Design And Development Of 5-DOF Robotic Arm Manipulators

Article notes should be on separate sheets

| | |
|---|---|
| **Source Title** | Design And Development Of 5-DOF Robotic Arm Manipulators |
| **Source citation (APA Format)** | Jadeja Y., & Pandya, B., (2019). Design And Development Of 5-DOF Robotic Arm Manipulators. INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH Vol 8, 11. https://www.researchgate.net/profile/Yagna_Jadeja/publication/353244149_Design_And_Development_Of_5-DOF_Robotic_Arm_Manipulators/links/60eefb3e9541032c6d3e749d/Design-And-Development-Of-5-DOF-Robotic-Arm-Manipulators.pdf |
| **Original URL** | https://www.researchgate.net/profile/Yagna_Jadeja/publication/353244149_Design_And_Development_Of_5-DOF_Robotic_Arm_Manipulators/links/60eefb3e9541032c6d3e749d/Design-And-Development-Of-5-DOF-Robotic-Arm-Manipulators.pdf |
| **Source type** | Research Journal |
| **Keywords** | Robotic arm ; 5 DOF ; design and development |
| **#Tags** | #robotics |
| **Summary of key points + notes (include methodology)** | The goal of the article is to design a robotic arm that can assist in dangerous tasks such as defusing bombs, or other tasks such as agriculture. The robot is a better choice than humans because it doesn't get tired and can also complete tasks that humans cannot complete due to the harsh conditions. The arm can also assist people who cannot complete certain tasks due to disabilities. The article also describes many other arms that were created by others. The robotic arm that was made in the article used a mbed pin microcontroller, and this was the only piece that was recommended from outside sources rather than tested for. A servo circuit was set up, and ultrasonic sensors were used. The arm was programmed in C. While the arm did work, it was considered "time consuming, stressful, and no viable financially", so therefore an unsuccessful experiment. |
| **Research Question/Problem/ Need** | A 5 DOF arm to assist humans in hazardous tasks. |

| | |
|---|---|
| **Important Figures** | <br><br>Figure 2: flowchart of system<br><br><br>Figure 4:Micro controller |
| **VOCAB: (w/definition)** | **Servo Circuit:** the inside of a servo motor<br>**Mbed:** A device similar to an arduino unit |
| **Cited references to follow up on** | Nanditha Nirmal, A.S Revathi, ―Robotic Arm Imitating Human Hand Movement,‖ International Journal of Computer Science & Engineering Technology (IJCSET), vol. 7, no. 11, Nov 2016<br><br>Arian Faravar, ―Design, Implementation and Control of |

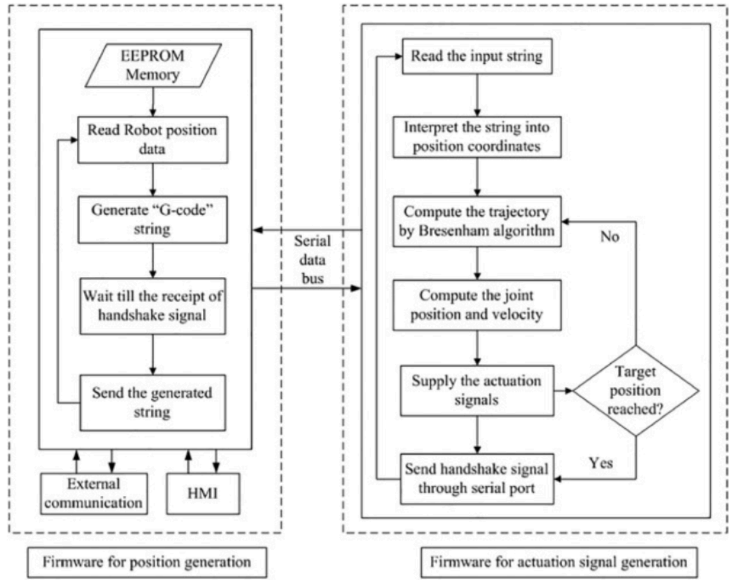
| | |
|---|---|
| | a Robotic Arm Using PIC 16F877A Microcontroller,‖ Institute of Graduate Studies and Research, 2014.<br><br>P. Adeeb Ahammed, and K. Edison Prabhu, ―Robotic Arm Control Through Human Arm Movement Using Accelerometers‖, International Journal of Engineering Science and Computing, 2016, ISSN 2321 3361.<br><br>A. Elfasakhany, E. Yanez, K. Baylon, and R. Salgado, ―Design and development of a competitive low-cost robot arm with four degrees of freedom,‖ Modern Mechanical Engineering, vol.1, no. 02, pp.47. FHGH<br><br>A. Reshamwala, R. Singh, ―A Review on Robot Arm Using Haptic Technology,‖ International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol. 4, Issue. 4, April 2015 |
| **Follow up Questions** | What could be changed to make the process better?<br>What difficulties were encountered?<br>Would a different DOF have made it a successful project?<br>Were there any complications with the Mbed? |

# Article #21 Notes: Design of a 4 DOF parallel robot arm and the firmware implementation on embedded system to transplant pot seedlings

Article notes should be on separate sheets

| | |
|---|---|
| **Source Title** | Design of a 4 DOF parallel robot arm and the firmware implementation on embedded system to transplant pot seedlings |
| **Source citation (APA Format)** | Rahul, K.., Raheman, H. & Paradkar, V., (2020). Design of a 4 DOF parallel robot arm and the firmware implementation on embedded system to transplant pot seedlings. Artificial Intelligence in Agriculture Vol 2, pages 172-183. https://doi.org/10.1016/j.aiia.2020.09.003 |
| **Original URL** | https://www.sciencedirect.com/science/article/pii/S258972172030026X |
| **Source type** | Research Article |
| **Keywords** | Robotic arm; 4 DOF ; design |
| **#Tags** | #robotics |
| **Summary of key points + notes (include methodology)** | The parallel robotic arm was controlled by two separate microcontrollers. The controllers then powered stepper motors and modeled them with kinematic equations. The arm also utilized multiple sensors so it could observe its environment. It also used belts and pulleys other than only joints. The arm also has a memory so it can follow user instructions. Therefore the robot was given codes, and could complete a task based off of this (similar to how when you press a button, a rc car does something). The arm itself was made out of 3d printed materials. The arm then was assigned to automate the task of transplanting vegetable seeds. The goal was to also make this a smooth motion. Kinematic equations were used to aid in the modeling. A keypad was then added to let the user put what command they want, and then the robot would complete it. The arm had a success rate of 93.3%, taking on average 3.5 seconds to complete a cycle. |
| **Research Question/Problem/ Need** | Making a robotic arm to help in the agricultural field. |

**Important Figures**




Flow chart of robot firmware

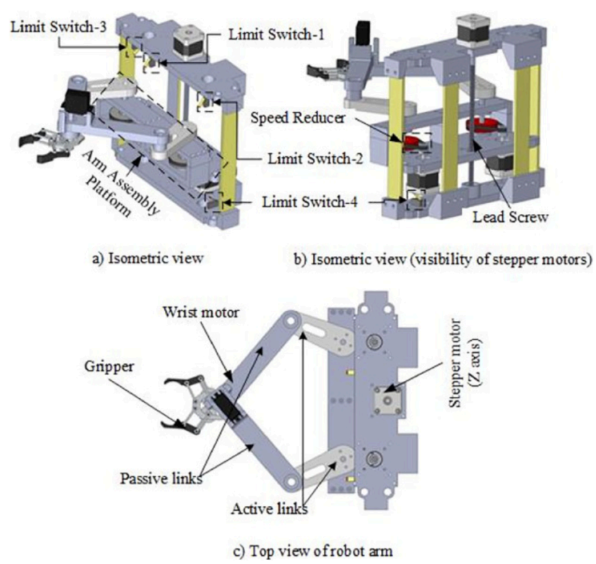



Figure 4: design on the arm (CAD model)

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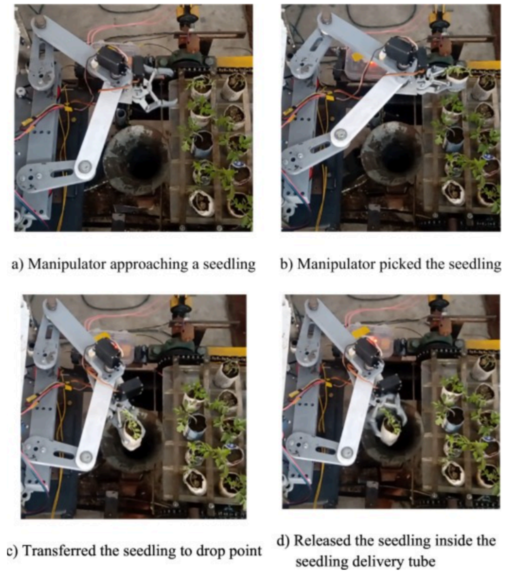
| | <br>Figure 14: testing of the arm |
| **VOCAB: (w/definition)** | **Parallel Robotic arm:** a device that uses multiple computer controlled parts on one claw<br>**RTOS:** real time operating system<br>**ROS:** Robot operating system<br>**Trajectory Points:** 2d and 3d visual points of trajectories |
| **Cited references to follow up on** | Angeles, 1997<br>J. Angeles<br>Fundamentals of Robotic Mechanical Systems: Theory, Methods, and Algorithms (2nd edition), Springer-Verlag, New York (1997)<br><br>Araujo et al., 2015<br>A. Araujo, D. Portugal, M.S. Couceiro, R.P. Rocha<br>Integrating Arduino-based educational mobile robots in ROS<br>J. Intell. Robot. Syst., 77 (2) (2015), pp. 281-298<br><br>Tiansong et al., 2019<br>L. Tiansong, G. Feng, Y. Yilong<br>Design of low-cost desktop robot based on 3D printing technology and open-source control system |
| **Follow up Questions** | Why were servo motors used in the end?<br>Could this be applied to other tasks as well?<br>Did the dirt affect the function?<br>If the process is so short, why is the arm needed? |

# Patent #1 Notes: Robotic arm

Article notes should be on separate sheets

| | |
|---|---|
| **Source Title** | Robotic arm |
| **Source citation (APA Format)** | Rhodes, G. W., Hill, J. W., Smith, C. M., & Grimm, T. M. (1985). Robotic arm (US/US4806066A). UMI MICROBOT Inc. https://patents.google.com/patent/US4806066A/enefficieny. |
| **Original URL** | https://patents.google.com/patent/US4806066A/en |
| **Source type** | Patent |
| **Keywords** | Patent ; robotic arm |
| **#Tags** | #patent |
| **Summary of key points + notes (include methodology)** | This patent is for different types of robotic arms. It includes different axes. The patent explains how the robotic arm works, picking up and grabbing things. It will have different moving pieces that will move the pieces around the home base. It is not clear, but it seems this was the first robotic arm. A motor would be used to operate each piece. Also, instead of only using normal motors, the patent talks about including a cable/pulley drive. Sensors can also be added on the pieces to give a better understanding of the position of the arm. This model, unlike most other models I looked at in the above articles, uses stepper motors instead of servo motors, but there is no explanation. I believe though that they can be used in an open loop, similar to what is described in the patent. The majority of the patent is describing the design and functionality piece by piece. |
| **Research Question/Problem/ Need** | To make a robotic arm. |

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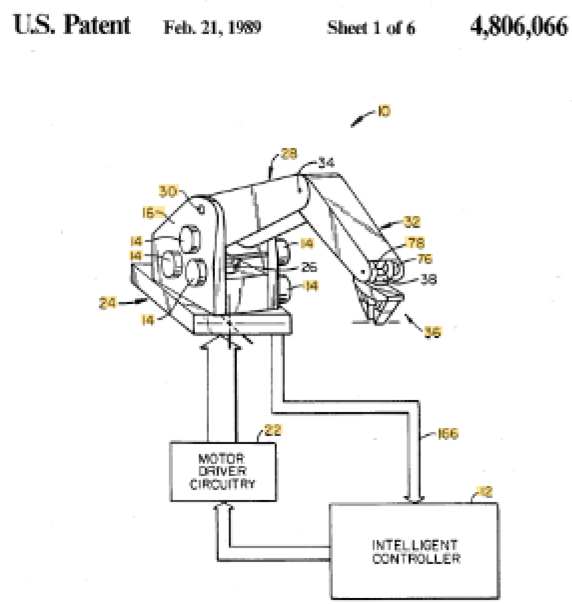
| **Important Figures** | <br>Image of the robotic arm (labeled) (patent has what each number stands for with a small explanation [key is not here due to length and readability]) |
| **VOCAB: (w/definition)** | **Stepper motor:** A motor with an open loop function<br>**differential drive pulleys:** two pulleys (with different diameters) working together<br>**phototransistor element:** An element sensitive to light (usually a light sensor) |
| **Cited references to follow up on** | "International Machine Intelligence Robot System User's Manual", Publication No. 10898, Publ. Master Rev. A, International Machine Intelligence; 330 Potrero Avenue, Sunnyvale, CA 94086, Mar. 1983, selected pages.<br><br>Brochure, ASEA Industrial Robot System IRb 60 , Jun. 1975, eight pages. *<br><br>Minicomputer Control Robot s Six Electrohydraulic Servoactuators , Hydraulics & Pneumatics, Feb. 1982, pp. 53 58. * |
| **Follow up Questions** | How did the pulley systems help the design?<br>How did the light sensors help the arm?<br>Would servo motors work better (since they seem to be more commonly used now)? |

# Patent #2 Notes: Robotic arm and robotic surgical system

Article notes should be on separate sheets

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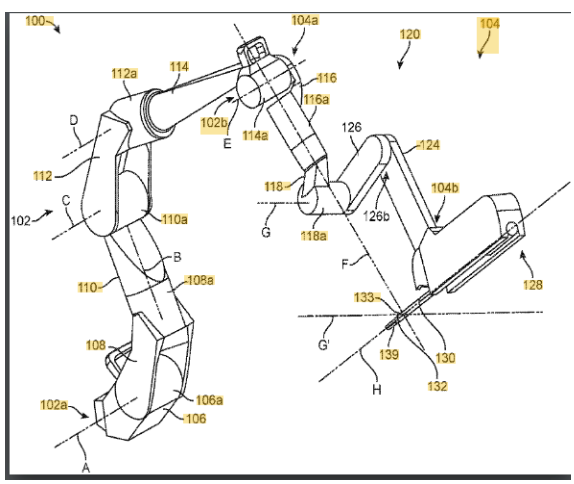
|---|---|
| **Source Title** | Robotic arm and robotic surgical system |
| **Source citation (APA Format)** | Egan, D. T., Kosari, S. N., Kilroy, P. E. G., & Koeing, K. S. (2020). Robotic arm and robotic surgical system. (US/US20210045817A1). SRI International Inc. https://patents.google.com/patent/US20210045817A1/en?q=(robotic+arm)&oq=robotic+arm |
| **Original URL** | https://patents.google.com/patent/US20210045817A1/en?q=(robotic+arm)&oq=robotic+arm |
| **Source type** | Patent |
| **Keywords** | patent ; robotic arm |
| **#Tags** | #patent |
| **Summary of key points + notes (include methodology)** | Since robotic assisted surgery has been more popular, the patent strives to develop a robotic arm that can complete surgery. Using motors and rotating systems, the arm had over 6 DOF, meaning it could be extremely mobile. The device also utilized a claw to hold the tool, rather than the tool being a part of the arm (which was the case with one of the above articles). The design is not finalized, as the patent mentions alternate or additional mechanisms could result in a practical device. There are many different mechanisms used in this arm, but it is not explained how they work together and/ or if there is a reason that these mechanisms were chosen. |
| **Research Question/Problem/ Need** | A robotic arm for a surgical system. |
| **Important Figures** | <br>Figure 1: Model of the robotic arm |

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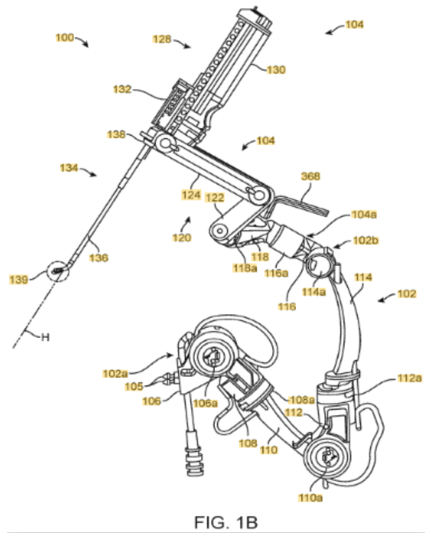
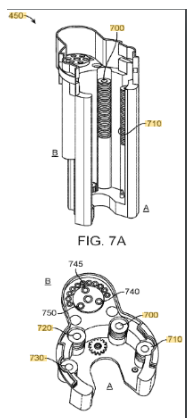
| | <br><br>Figure 2: model of the robotic arm (view with other labeled parts)<br><br><br><br>Figure 3: model of the claw |
| **VOCAB: (w/definition)** | **cross sectional view:** A view of the inside of a model<br>**Carriage:** moving mechanism<br>**Pretension:** Ability to do something |
| **Cited references to follow up on** | https://patents.google.com/patent/US7646161B2/en?q=(robotic+arm)&oq=robotic+arm&peid=60c7c62ffaca8%3Aa29%3A3916e648<br><br>https://patents.google.com/patent/US8004229B2/en?q=(robotic+arm)&oq=robotic+arm&peid=60c7c64e34958%3Ab64%3A763770c7 |
| **Follow up Questions** | How can safety be ensured during testing?<br>How do the different pieces work together?<br>Is there a way to prevent all the mechanisms from being contaminated if the pieces are hard to clean? |

# Patent #3 Notes: Kinematic design for robotic arm

Article notes should be on separate sheets

| | |
|---|---|
| **Source Title** | Kinematic design for robotic arm |
| **Source citation (APA Format)** | Gilbertson, S., Webber, J., & Wilson, R.. (2016). Kinematic design for robotic arm. (US/US9827678B1). X Development LLC. https://patents.google.com/patent/US9827678B1/en?q=(robotic+arm)&oq=robotic+arm |
| **Original URL** | [https://patents.google.com/patent/US9827678B1/en?q=(robotic+arm)&oq=robotic+arm](https://patents.google.com/patent/US9827678B1/en?q=(robotic+arm)&oq=robotic+arm) |
| **Source type** | Patent |
| **Keywords** | Patent; Robotic arm |
| **#Tags** | #patent |
| **Summary of key points + notes (include methodology)** | This patent is for a robotic arm that is on a wheeled base. A specific purpose for the arm is not stated, but the patent states it can complete a variety of tasks. The arm has four rotational joints, and many other normal joints. The design states that it is robust and can lift many things. It can also fold / change height to accomplish different tasks. For example, there is a tray on which it can carry things such as trash, and then the arm can throw those items away. That was the example, but there are also many other uses for this arm. The robot is autonomous. |
| **Research Question/Problem/ Need** | How can a robot be made to minimize human involvement in tasks? |

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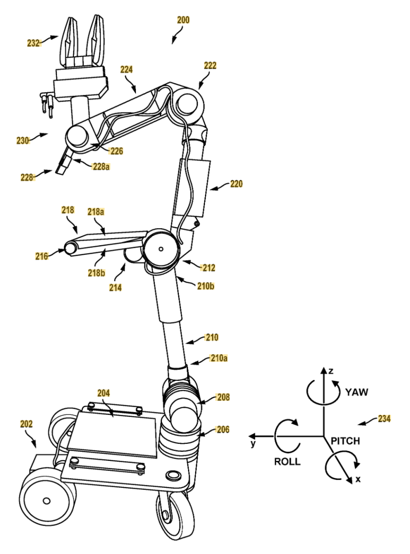


Figure 1: model of the arm

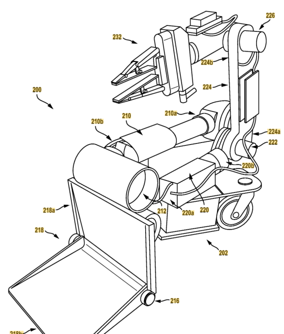

Figure 3

Arm folded
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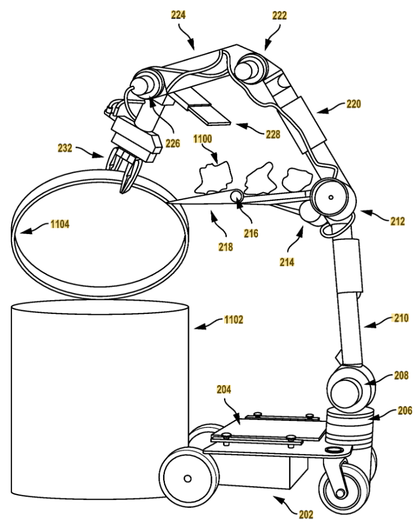
| | <br>Figure 11: Arm carrying items |
| **VOCAB: (w/definition)** | **end effector:** The claw of the arm<br>**Base linkage:** mechanical pieces for mobility<br>**actuated joint:** Easier to control systems |
| **Cited references to follow up on** | Smart End Effectors for Robotic Assembly (Abstract), Assembly Engineering, vol. 30, Issue 8, Aug. 1987.<br><br>Mark Prigg, "Google's terrifying two legged giant robot taught how to CLEAN: Researchers reveal Ian the Atlas robot can now vacuum, sweep and even put the trash away," DailyMail.com, Jan. 16, 2016. |
| **Follow up Questions** | Since yard work was mentioned, how would the wheels affect performance?<br>Are sensors used for this design?<br>How heavy items can this carry?<br>What types of items can be gripped with this arm? |