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A Prototype Development of an Autonomous Fork Lifter Robot

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Abstract: This paper addresses a working prototype of an autonomous fork lifter industrial robot. It includes four encoder DC motors to move the whole assembly and two DC motors to run the lifter. The proposed system is based on a chain mechanism used in moving the fork. The body of the system is made up of aluminum and partially Iron alloy with the dimensions of (21×12×2). In order to ensure the smooth movement of the robot, the body of the system moves with the help of continuous track or tank treads. We used Arduino mega to drive motors for the locomotion of the robot. We also used the camera vision to detect the boxed luggage to be replaced somewhere. The camera and the whole system operates with raspberry pi microcontroller.

Keywords: Industrial robot; tank tread; fork lifter; Arduino mega; raspberry pi.

1. INTRODUCTION

Things produced or assembled in a factory need to be moved from one place to another. Factory needs to run supplies in and out of the building or work places. Most of the time the material made in factory or raw material is shifted using different methods. One of the modern method used is the fork lifter which can be implemented as autonomous fork lifter robot (Pires, and Paulo, 2005). The robot is being used in both military and civilian industries.

Using human labor both directly or inside a fork lifter risks both human life and industrial economy in terms of time, cost, and efficiency. To solve this problem, an autonomous fork lifter robot can be best suited. This robot can do all the work using its vision. By using this robot in ware houses or other places to shift the luggage, a very important problem of modern industry may be resolved. This project could be one of the highest industrial demands in future. As modern industry focuses on making many products in less time and cost effectively. In short, focusing on less cost and more profit rule this project may lessen the production time and labor cost.

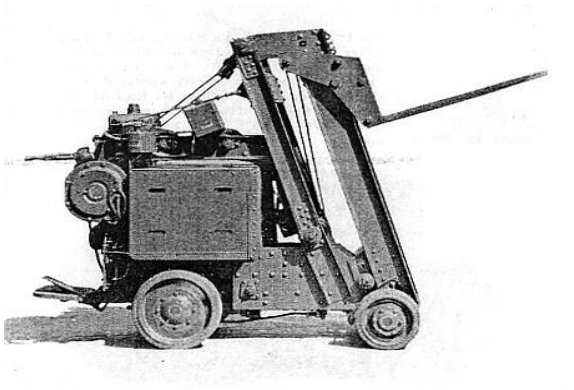

Fig.1. First fork lifter which looks like modern manual lifter
http://carpal.com.ar/novedades_ampliada.asp?pagina=ampliada&id=11715

2. LITERATURE REVIEW

a. Historical background

Before 20th century, the lifting work in shops and industry was casually done by the laborers. The grains and other small pieces material was transported in sacks mostly. The hard material like military equipment or other iron made material was transported in boxes. To ensure the quality preservation, the material was wrapped in paper or foam. The delicate things like glass and ripe fruit was also packed in boxes to ensure their preservability. The point is to handle all these things when no machine was used at that time, specially their loading and unloading. All the work was done by the laborers. The strong laborers take the material in those boxes where they are to be destined. The ultimate machine they used was a wheel cart(Miyazaki, *et al.*, Honda Motor Co Ltd, 2001),wherein the things were placed first and then unloaded according to the requirement, which was done by men.

In those times, the heavy industry was not a common place. Usually, military equipment, cars, and heavy-duty machines were made in mega industry. Labor was cheap and desired by industries to do every kind of work. The labor rights were not so elaborated. Cities were developing

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industries and people from villages were willing to do much work in little wages. So, for lifting and shifting of even explosives were done by labors by hand. The things remained same until 1906, when the first lifter truck was introduced which usually used in railway platforms and factories(Garcia, Equipment Co. of America, 1981). They can lift heavy weights. Soon they were powered by engine and got more speed than before and hence more power.

Fig.2. Modern era autonomous fork lifter aka AGV robot lifters
https://en.wikipedia.org/wiki/Automated_guided_vehicle

In 1927, first fork lifter was introduced operated just like before but can lift much heavier loads at some angle(Kooi, and Meijer, 1985).. The design was a little clumsy but good in working. From those days, the fork lifter found many applications in many fields of life. So, the improvement started from that time.

b. Manual fork lifters

Fork lifers were invented mainly as manually operated luggage shifting device. They have different types in manual operation too. They are operated by operator in both standing and sitting positions. They are powered by motors or engines. The body is made of wrought iron. The forks are controlled by manual switches near the controlling handles. The wheels are usually made of special rubber. The stability ratio is kept in mind while manufacturing the machine. To operate the lifter, a skillful worker is needed. Otherwise, without a skillful operation, it could harm the material and people around. The lifters are capable of lifting weights up to many tones depending on the strength of the lifter mechanism.

c. Autonomous fork lifter robots

With the rise of 4th industrial revolution in 1990s, the digital market has been emerged. With the emergence of mechatronics and robotics field in engineering, the designers looked forward the advancements in this field and industrial automation started. New machines were being introduced every week. The old concepts were fading off. Industries wanted more output in less time. The efficient work became the ultimate objective of every industry. Robotic arms and CNC machines were entering in industry (Pages, *et al.*,2001), Due to all these factors, the need to revolutionize the ware houses became important need specially for mega industries.

So, autonomous fork lifter was introduced(Gilbert, Les Equipements Industriels, 1994). It came not only with ware house applications but applications in many other places. The places like no parking areas etc. The sensors replaced the human operator mind. The efficiency of the machine has been increased. This robot can operate in human concentrated environments. This means it is human friendly. When anything comes on its way, it halts the operation and waits. Going for a specific target, rarely it could be deviated from its path. In its initial times in industry, they were line followers. But as the time passed it became objective following means no line is needed to complete a specific objective. Robot just follows the command for a specific area of the warehouse and advances towards it. If the ware house is not designed properly, maybe there is a need of human worker or a roof crane to pick and place the luggage. As we say about the modern models of these robots, they are very concise and can lift much heavier loads. They have better stability and power. So, this was all important and main points about this robot.

3. MECHANICAL STRUCTURE

a. Mechanical part

Mechanically the robot discussed in this paper robot is a (21×12×2)" machine. It is made of different materials in different parts. Following are some of the parts description of the mechanical part of this robot.

i. *Base:* The base is made of aluminum alloy and iron plates. It consists of one aluminum plate on the upper side of the robot. That aluminum plate serves as the base for every companion system in the robot such as lifter mechanism and sensors. Mainly the motors are also attached on the sides of this aluminum plate. It has three parts, they joined to make the base. The other part of the base is the iron protector. This iron protector is attached with the main aluminum base to form the main body of the robot. Both merged and protect the motors attached to the body in between them. The fork lifter mechanism which will be discussed next is attached to the aluminum part of the base.

ii. *Fork lifter mechanism:* The Fork lifter mechanism consists of two forks. Forks are joined at rear end. They move vertically on a slider mechanism. This slider mechanism is supported by pairs of gears and chains. The fork lifter is operated by two simple DC gear motors. Why two DC gear motors to operate one mechanism? The answer is that the slider-chain mechanism with two motors is relatively easy to make than the one motor operating both sliders at the same time. Moreover, using two motors simultaneously ensures smoother movement than one motor for each. To

stop the fork lifter or to give a fixed upper limit an electric limit switch has been used. It has following parts:

i. *A fork*
ii. *Two chains*
iii. *Five pairs of idler pullies*
iv. *Two sliders*
v. *Two DC gear motors*
vi. *One roller limit switch*

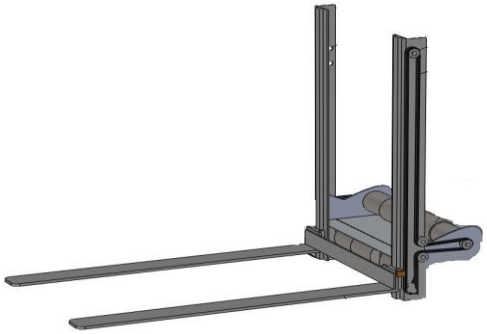

Fig 3. Lifter Mechanism

iii. *Tread:* The tank tread or caterpillar track or continuous track has been used in this robot. It is made of tough plastic material, black in color. It consists of small elements joined together to form the bigger structure. One link is formed when two hinges are placed together, and a plastic pin is inserted between them. The tread runs on gears. The gears are operated by the DC encoder motors. As the gears are moved by motors,they are just two in one side and have a lot of space between them. Two freely rotating aluminum rims on each side between the two gears are present for the better support of the continuous track. Also, to run the robot smoothly.

iv. *Gears:* There are two pairs of aluminum gears. These gears are connected with the DC encoder motors (discussed in next section). The tread runs on these gears. For further support, two pairs of free aluminum plate rims are freely connected.

v. *DC encoder gear motors:* To move the robot on the ground we are using four DC encoder gear motors. They are operated on 12-V each. They are hall effect sensor based encoded motors. The hall effect is change in voltage with respect to the change in magnetic field. This is used in positioning and direction finding. The motor torque is 8-kg.cm. The speed of each motor in revolution per minute is 200-rpm.

vi. *DC gear motors:* To operate the fork lifter, two simple DC gear motors have been used. The model is XD - 37 gb520 and it is usually used in home appliances. The motor is fully protected and enclosed. Motor torque is 1.96-Nm. It is divided into two parts; the one part is the motor and the second is gear box. It has a permanent magnet around the coil. The rotation per minute varies from 500 – 600 RPM. It draws 0.68-A current. The output power is 10-W as the operating voltage is 12/24-V. It is brush containing DC motor.

Fig 4. DC encoder gear motors
https://link.springer.com/chapter/10.1007/978-3-319-00557-7_25

vii. *Roller based limit switch:* An electromechanical roller-based limit switch has been used. In this switch, there is a roller acting as an actuator mechanically linked to a set of contacts. When the lifter end meets the roller, one electric contact breaks and other is made. This switching stops the fork.

b. *CAD model*

The CAD model of the robot is made on SOLID works. It is the completely described hardware model of the robot. Each part has been numbered and then described relative to its number in (Table I). It is done for comfort in reading. There are 11 hardware parts to show in this model. The body is made of Aluminum, so it is shown in grey color. The model is scaled and is shown in **(Fig 7).**

Table 1. Robot Parts Names

Fig 6. Roller limit switches
https://impremedia.net/arduino-motor-shield-rev-3/

Part Number	Part Name
1	Slider on which the fork moves [a]
2	Roller limit switch
3	Idler pullies
4	Lifter chain
5	DC gear motor to move lifter
6	Continuous track or tank tread
7	Gear attached to encoder DC motor
8	Base upper plate
9	Supporting free wheels
10	Lower plate holding DC encoder motors
11	Fork lifter

Components shown in model

4. ELECTRONICS AND ELECTRICAL STRUCTURE

In this section, the information related to the microcontrollers will be discussed. Microcontrollers control every movement of the robot. Coding is done in microcontrollers. Code is a set of commands in which the conditions to operate the sensors and actuators connected to the microcontroller will be defined.

a. Microcontroller

i. *ATmega2560:* This is Arduino Mega micro controller. The microcontroller has 54 digital I/O pins with 15 PWM outputs. The analog input pins are 16. The 2D dimensions are (101.54 × 53.3) mm. Its mass is 37-g. It has 13 built-in LEDs which blink according to the connections. Some of the other parameters are given in the table below.

Using this controller, the DC motors and all the sensors except cameras are operated. PWM is used to control the speeds of DC motors. Also, the positioning sensors are attached to the Arduino. Due to less memory, Arduino cannot support cameras.

Table 2. Description of ATmega2560

Parameter	Value
Operating voltage	5 V
Input voltage	7 – 12 V
Flash memory	256 KB
Clock speed	16 MHz
EEPROM	4 KB
SRAM	8 KB

ii. *Raspberry pi 3:* This is a very modern microcontroller. In most of the projects related to robotics and specially with voice and image recognition, this microcontroller is being used from a decade. People prefer this because it has built-in functions and it has its own operating system. We can attach this microcontroller with any device from an LCD to speakers and keyboard. This microcontroller has an option of extendable memory. It has MicroSD format for loading the operating system, and storing the data transferred to it. The chip used in this controller is BroadcomBCM2835 SoC. It has 512MB memory. The memory card can extend the memory. The slot for memory card is SDIO. All the information regarding this microcontroller is given in **(Table 3).**

Fig.7. Raspberry pi 3

[https://www.pinterest.com/pin/320177854748885293/?lp=true

Table-3. Description OF Raspberry pi 3

Parameter	Value
CPU	700 MHz low power
Operating system	MicroSD card booting Linux OS
Power	Micro USB socket 5-V, 2-A
Ethernet	10/100 base T ethernet socket
Video output	HDMI (rev 1.3 & 1.4)
Audio output	3.5 mm jack, HDMI
Camera interface	15-pin MIPI CSI-2
Memory card slot	SDIO
Operating temperature	0 – 50 °C

b. Motor operation

It's a common observation that DC motors move in one

Fig. 8. ATmega2560

direction when attached to battery. If the polarity of battery is changed, driver spins to the other direction. The reason is the change in electrical polarity of the motor coil. It can be done manually to demonstrate the working of DC motor in school lab. But in a robot or any machinery where DC motor

is used, we cannot change this manually. So, we needed a circuit to do this in our machine automatically. Including the above-mentioned operation, we also need to control the motor speed according to the terrain.

i. *Motor driver L298:* To change the direction, speed, and fulfill the power needs of DC motors, a circuit named L298 motor driver is selected. It is a 12 V operated solenoid, relays, stepper, and DC motors controlling circuit. It is needed by DC gear motors to fulfill the current requirement according to the load and to change their direction. It also helps in changing speed of the motors. This is done by PWM control. There are some of the ratings of this circuit.

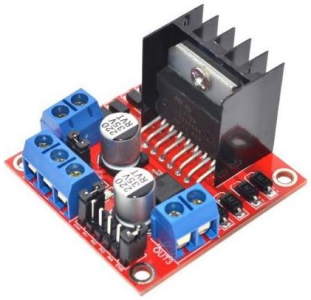

Fig.9.Motor driver L298
https://www.ebay.com/itm/Sky-Lipo-Battery-

Table-3. Description oF Motor Driver

Parameter	Value
Power supply	50 V
Logic supply voltage	7 V
Input and enable voltage	-0.3 to 7
	10/100 base Tethernet socket
Video output	HDMI (rev 1.3 & 1.4)
Audio output	3.5 mm jack, HDMI
Camea interface	15-pin MIPI CSI-2
Memory card slot	SDIO
Operating temperature	0 – 50 °C

c. Power Supply

In case of static machinery, switched power supply can be used. But in case of moving machinery like robots, an independent power source is needed. This independent power source is battery. Below is the description of battery and components supporting it.

i. *Lipo battery:* The battery used is 14 V and 1.2 A. It has one input port used to charge the battery through special Lipo battery charger. It has two output wires. The black wire is ground terminal. When fully charged, red wire has 14 V potential difference with ground in ideal conditions. Lipo is favorite among robotics makers due to its small size, high power and long battery timing. On the sticker of every lipo battery, the instructions and precautions are given. The most important are:

1. Temperature

Lipo battery has an operating temperature range. The temperature range is 0 to 50 degrees Celsius. In very cold

Fig.10.14V lipo battery
https://www.amazon.com/RioRand-3-01-0076-Converter-Module-1-23V-30V/dp/B008BHAOQO

environment, the battery drains faster. In high temperatures, a failure can happen caused by leakage. So, this shows that temperature is an important factor related to Lipo performance.

Charging

Lipo battery cannot be charged without a specified charger. It is a balance charger. If direct charging methods are used, they can be unsecure and lessen the battery life.

ii. *Buck converter:* It is DC-DC converter circuit. It converts high voltage to safe level voltage to supply to components. The input voltage is 4.5-V to 8-V (DC). The current supply capability is 0 to 1.6-A. The switching frequency is 1.25 MHz 'Buck' means to act against. Buck converter got its name because it always acts against its input voltage. So, whenever certain input voltage is applied to the buck converter to supply it further to the components, it cuts voltage into different levels and supply it to the components. The circuit is used for following purposes:

I. To keep sensors and other electronics safe from short circuiting
II. To supply the minimum operational voltage to the sensors.
III. It saves the power.

IV. It converts high DC voltage to the low DC voltage, in a very efficient way.
V. It helps in increasing battery timing.

d. Ultrasonic sensor

The robot should move smoothly without striking any hurdle in its way. The Ultrasonic sensor detects the obstacle and robot continues moving by avoiding hurdles. For this purpose, we are using HC-SR04 ultrasonic sensor. It has 4 pins. Two of which are for power supply. The central two pins are echo and trig pins. The trig pin sends the pulse to detect the obstacle. When the ultrasonic waves strike the obstacle, it comes back to the sensor. The echo sends the signal back if an obstacle is found. If no obstacle is found, then it does not send signal back. So, the robot continues moving in its path. In this any unwanted damage to the robot can be avoided.

Here are some advantages of HC-SR04 ultrasonic sensor.

I. It is simple to use.
II. It has less number of pins.
III. The voltage requirement is low (5V).
IV. Size of the sensor is small.

e. Camera

The camera used in the robot has the following parameters:

Fig. 12. HC-SR04 ultrasonic sensor

Fig.11. Buck converter

Table 4.Camera Specification

Parameters	Values
Image detail	5 MP
Operating voltage	5 V
Cable connection	USB cable
Input	To raspberry pi 3
Movaeble	*No*

Fig. 13. Camera

4. ACKNOWLEDGMENT

The work presented in this paper was partial fulfilment of the requirement for the degree of Bachelor of Engineering in Mechatronics & Control Engineering, UET, Lahore.

REFERENCES:

Garcia, J. M., Equipment Co Of America, (1981). Drum lifter for fork lift truck. U.S. Patent 4, 072, 220Pp.
https://en.wikipedia.org/wiki/Automated_guided_vehicle

Gilbert, S., Les Equipements Industriels, (1994). Caterpillar track attachment. U.S. Patent 5,343,960.
https://www.ebay.com/itm/DC-12V-320rpm-Encode-Gear-Reducer-Motor-Electric-Gear-Box-Motor-/172311971286

Gonçalves J., J. Lima P. J. Costa A. P. Moreira (2013) Modeling and Simulation of the EMG30 Geared Motor with Encoder Resorting to SimTwo: The Official Robot@Factory Simulator. In: Azevedo A. (eds) Advances in Sustainable and Competitive Manufacturing Systems. Lecture Notes in Mechanical Engineering. Springer, Heidelberg

https://link.springer.com/chapter/10.1007/978-3-319-00557-7_25
https://www.indiamart.com/proddetail/micro-limit-switch-roller-18012534612.html
https://impremedia.net/arduino-motor-shield-rev-3/
https://www.bestmediabuy.nl/raspberry-pi-3b

https://www.pinterest.com/pin/320177854748885293/?lp=true
https://www.ebay.com/itm/Sky-Lipo-Battery-4400mAh-18-5V-40C-USED-/232613212118
https://www.amazon.com/RioRand-3-01-0076-Converter-Module-1-23V-30V/dp/B008BHAOQO
https://www.evakw.com/en/line-proximity/56-ultrasonic-sensor-hc-sr04.html

Kooi, H. and S. Meijer, (1985). Selectiebedrijf Kooi Beheer BV and Machine En Constructiewerkplaats Meijer, Fork lifter comprising a slidable fork. U.S. Patent 4,498,837.

Koren, Y. and Y. Koren, (1985). Robotics for engineers (Vol. 168). New York McGraw-Hill.

Miyazaki, A., N. Ono, H. Shimizu, H. Sueshige, K. Miyahara, T. Otsuki, and H. Kanke, Honda Motor Co Ltd, (2001). Motor-assisted single-wheel cart. U.S. Patent 6, 173,799.

Pires, J. N. and S. Paulo, (2005), Complete robotic inspection line using PC-based control, supervision and parameterization software. Robotics and Computer-Integrated Manufacturing, 21(1),11-17.