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DESIGN AND CONSTRUCTION OF A FORKLIFT BASED CAR PARKING SYSTEM

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Abstract- *The conventional car parking system occupies more area in the parking space. The space utilization could be maximized and more vehicles could be parked by using a mechanical means by placing them in a vertically stacked position. The concept for the automated or semi-automated parking system is driven by two factors: a need for parking spaces and a scarcity of available land. In the long term, a car parking system is likely to be more cost effective when compared to traditional parking garages. It would be less expensive per parking slot, since it tends to require less building volume and less ground area than a conventional facility with the same capacity. In this paper a forklift based car parking system is introduced which would be less costly and easy to construct, install and control. A scale model with a ratio of 1:15 was developed. The said model was constructed and tested and its performance is found to be satisfactory.*

Keywords: *Car parking system, Forklift, Stacker, DPDT switch.*

1. INTRODUCTION

The conventional way of parking cars in garage or commercial parking areas is to place the vehicles horizontally. So for any limited area, there is a limitation of the number of vehicles to be parked in the specified area. In cities and metropolitan areas horizontal space is becoming scarce day by day. So, someone can think of parking vehicles in a vertically stacked condition. A mechanical car parking system may solve this problem of horizontally parking system. Mechanical car parking system is a group of self-acting or self-moving machines, things or parts that works together in a relation without attention to build up a place where vehicles can be left for a certain period of time.

As it is known that the land is becoming less and scarce because of urbanization in the cities but the human population is growing every day. This scenario is very obvious in modern developed and/or developing cities. Therefore, where land is very limited and spaces need to be saved in every aspect of life, building an automated or semi-automated parking system may be an option to get rid of this problem. It is designed to minimize the area and volume required for parking cars. Like a multi-storied parking garage, the parking system provides parking of cars on multiple levels to maximize the number of vehicles in the same parking spaces while minimizing land usage. On the other hand, once the vehicles are in the parking space of a multi-storied parking garage, they will slow down to search for an empty space. This slow moving will cause the traffic system a queue of cars in the line. Eventually, traffic jam will occur when the car park is crowded. Such a parking system may utilize a mechanical means to transport cars to and from parking spaces (rather than the driver) [1].

In order to eliminate much of the spaces wasted in a multi-storied parking garage, automated or semi-automated car parking system may be adapted. This system allows vertical space utilization thus less space is needed compared to the conventional car parking system because, in this type of parking system, the parking space can be more compacted by having vehicles parked nearer to each other and also less space is required for runways or paths in the parking space as vehicles are transferred to parking spaces using elevators and conveyers. Thus, optimization of the usages of space can be achieved [2].

In the automated or semi-automated parking system, the problem of traffic jam could be avoided because the parking spaces are located by using sensors. So, drivers do not need to search for the space one by one as they are notified by the system regarding where the empty parking space are located before the vehicle is transported to the desired parking space. In this way, a lot of time can be saved in the car park and vehicles are parked efficiently by the system. The automated parking system is relatively simple and convenient for storing vehicles in the shortest time [2].

While the development of the country and nation is growing in a quick pace, crime rates are also increasing daily. Therefore, security has become one of the main concerns in everyday life of the society. Car parking area is also one of the places where individuals are attacked by robbers frequently. Theft and robbery happen in car park because it is considered a relatively quiet place where not many people would be in the car parking area all the time. By having an automated car parking facility, safety for both the driver and vehicle is at less risk because the unauthorized person is not allowed to enter into the car parking area. The automated car parking can help in parking the vehicles without the driver going into the car parking area. In that way, security for individuals and vehicles are more guaranteed [2].

An automated or semi-automated car parking system uses a similar type of technology to that used for mechanical parcel handling and document retrieval. The driver leaves the car inside an entrance area and technology parks the vehicle at a designated area. Hydraulically or mechanically operated device can transport cars vertically (up or down) and horizontally (left and right) to a vacant parking space until the car is needed again. When the car is needed, the process is reversed and the vehicle lifts or transports the car back to the same area where the driver left it. In some cases, a turntable facility may be used to position the car so that the driver can conveniently drive away without the need to back up [1].
There are several advantages of employing a car parking system for urban planners, business owners and vehicle drivers. They offer convenience for vehicle users and efficient usage of space for urban-based companies. Automated or semi-automated car parking systems save time, money, space and often simplify the tedious task of parking. Automated system lifts/move the desired vehicle into safe and secure storage areas until they are needed further [2].

In the present work an attempt has been made to develop a model for a forklift based semi-automated car parking system. The system along with the forklift will travel on a designed track which accommodates the whole stack area. The forklift will lift the car and position it to the desired vacant space both in horizontal and vertical direction. The movement of the forklift stand and also the forklift will be controlled by gear motors. The main aim of this work is to design and construct the model of a forklift based car parking system.

2. LITERATURE REVIEW

Over the years, car parking systems and the accompanying technologies have been increased and diversified. Car parking systems are in use almost all around the world since the time cars were invented. In any area of developed country where there is a significant amount of traffic, there are car parking systems as shown in Fig 1 [3]. Car Parking systems were developed in the early 20th century in response to the need for storage space for vehicles.

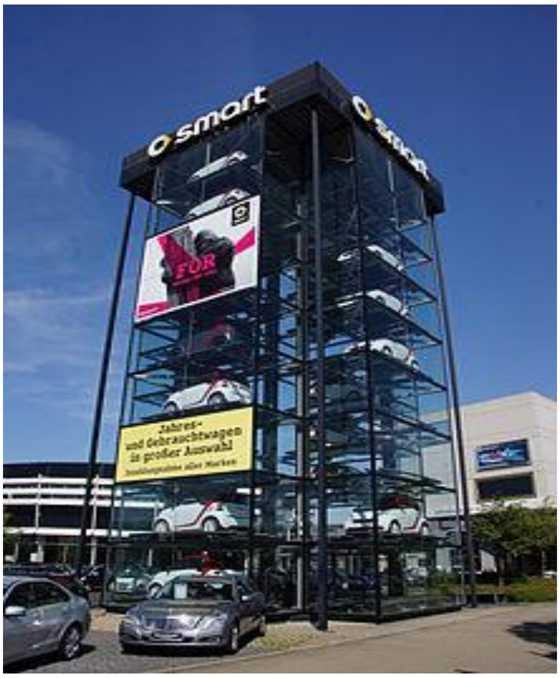

Fig 1: Modern Car Parking System.

In the 1920s, forerunners of automated parking systems appeared in United States in the cities like Los Angeles, Chicago and Cincinnati. Some of these multi-stored structures are still standing, and have been adapted for new uses. One of the Kent Automatic Parking Garages in New York (now known as the Sofia Apartments) is an Art Deco landmark that was converted into luxury condominiums in 1983. A system that is now found all over Japan the ‘ferris-wheel’. The paternoster system was created by the Westinghouse Corporation in 1923 and subsequently built in 1932 on Chicago’s Monroe Street. The Nash Motor Company created the first glass-enclosed version of this system for the Chicago Century of Progress Exhibition in 1933 and it was the precursor to a more recent version, the Smart Car Towers in Europe [2]. The first driverless parking garage opened in 1951 in Washington DC, but was replaced with office space due to increasing land values [4].

The ever-increasing scarcity of available urban land (urbanization) and increase of the number of cars in use (motorization) have combined with sustainability and other quality of life issues to renew interest in automated parking system (APS) as alternatives to multi-stored parking garages, on street parking and parking lots.

Currently the biggest automated parking system (APS) in Europe is in Arhus (Denmark) and provides 1000 parking spaces [5].

3. DESIGN OF THE SYSTEM

The CAD design and circuit diagram of the present project have been accomplished according to the design considerations, which have been assumed on the basis of the original dimension of commercial vehicles. But for financial limitations the model car parking system was constructed on a scale ratio of 1:15. Also, in the model design, movement in only one direction was chosen to reduce cost. But in the actual design, motion in two directions in horizontal plane was assumed.

3.1 CAD Design of the System

A CAD design of the proposed car parking system is shown in Fig 2. All the dimensions shown in the Fig. 2 are in meters.

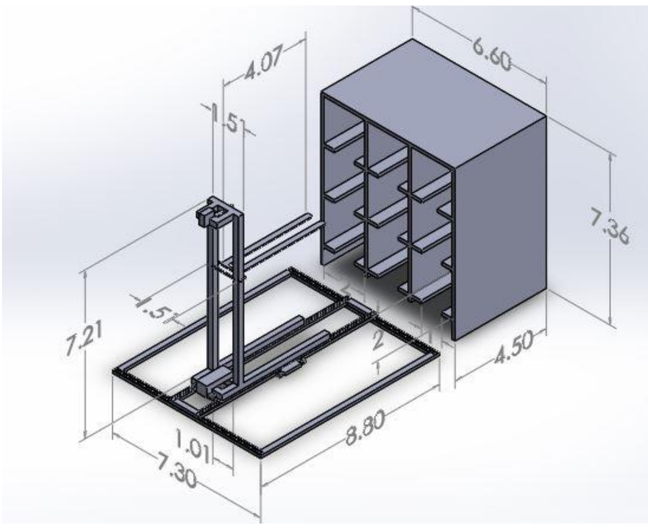

Fig. 2: CAD design of Proposed Car Parking Assembly

3.2 Circuit Design of the Model

A circuit diagram for the power supply to the model car parking system is shown in Fig 3. The major components are briefly described below.

- A dc power supply has been used as the power source for driving the motors.
- A power switch and two DPDT switches have been used to regulate the motors.
- The DPDT switch is used to invert the connection of the motors with the power switch to rotate the motor both in clockwise and counter-clockwise direction.
- Two dc gear motors have been used to facilitate the movement of the forklift.
- A complete gear mechanism has been used to reduce the rpm of the motors concerning about the safety of the storage and retrieval operations.

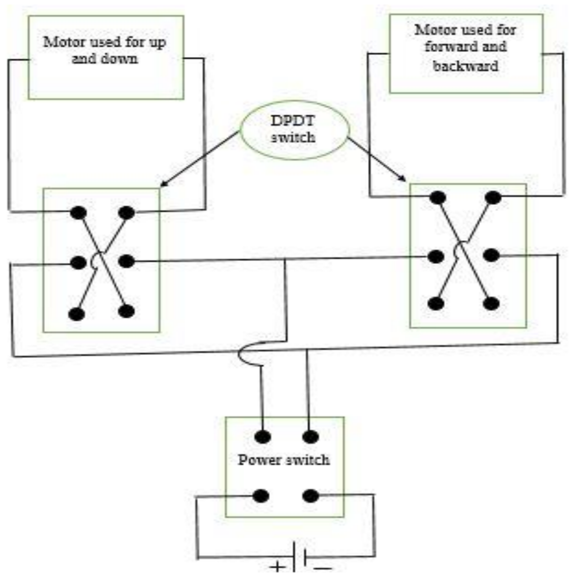

Fig. 3: Circuit design of Proposed Car Parking Assembly.

4. CONSTRUCTION OF THE MODEL

The scale model of the Forklift based car parking system as shown in Fig. 4 has been constructed. The construction considerations are as follows:

- 1:15 is taken as scale reduction ratio in all through the construction.
- Galvanized Iron flat bars and square bars are used as material of construction.
- In the model only two motions have been considered which are: Lifting up-down and moving forward-backward direction. The horizontal left-right motion was not considered because of cost limitation of the project.
- All the construction works have been conducted at the machine shop, welding shop and wood shop of KUET.
- The circuit of the model was constructed by purchasing the electronic components from the local markets.

After constructing the model car parking system, the model was tested to check whether it works properly or not.

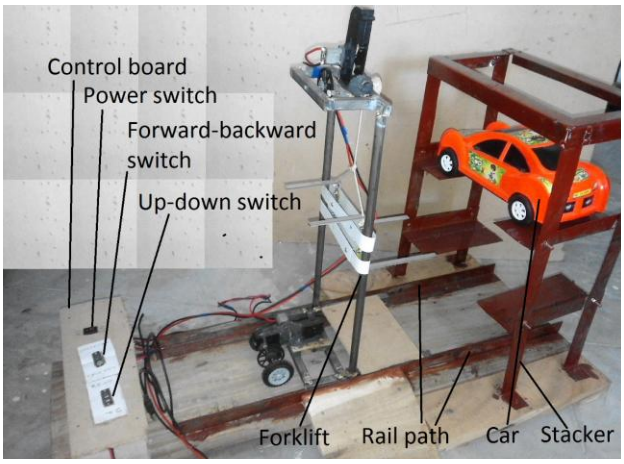

Fig. 4: Photographic view of Model Car Parking System

5. PERFORMANCE TEST

Performance test of the constructed Forklift based car parking system was carried out considering the following aspects.

- The estimation of the maximum load it carries.
- Average speed at which it can move in different directions.
- Time required for storing and retrieving operation.
- Area of the space in the stacker for each car.

5.1 Maximum load Estimation

The maximum mass of the car, fork, forklift stand which can easily be lifted by the forklift have been measured by a digital weighing balance. These data are given in Table 1.

Table 1: Overall Maximum Load Estimation

Name of part	Mass m (kg)	Percentage of total mass (%)	Weight W (N)
Car	0.20	11.43	1.962
Fork	0.50	28.57	4.91
Forklift stand including two motors	1.05	60.00	10.3
Total =	1.75	100	17.17

5.2 Average Speed of the Forklift

To calculate the average speed of the Forklift, time was measured using a stopwatch for a certain movement. Then, dividing the distance by the time average speed of the Forklift was been calculated. The data were taken for both no load and loaded conditions. These data are given in Table 2 and Table 3.

Table 2: Average Speed at No load Condition

Operations	Distance S (cm)	Time t (s)	Average speed, (cm/s)
Lifting up	44	24.41	1.802
Falling down	44	24.39	1.804
Moving forward when the forks are on base.	17	6.95	2.452
Moving backward when the forks are on base.	17	8.07	2.107
Moving forward when the forks are on 0.1 m height from the base.	17	6.81	2.496
Moving backward when the forks are on 0.1 m height from the base.	17	8.23	2.065
Moving forward when the forks are on 0.26 m height from the base.	17	6.99	2.432
Moving backward when the forks are on 0.26 m height from the base.	17	7.82	2.174

Table 3: Average Speed at Loaded Condition

Operations	Distance s (cm)	Time t (s)	Average speed, (cm/s)
Lifting up	44	26.72	1.652
Falling down	44	22.94	1.918
Moving forward when the forks are on base.	14	6.11	2.292
Moving backward when the forks are on base.	14	6.82	2.053
Moving forward when the forks are on 0.1 m height from the base.	14	5.71	2.500
Moving backward when the forks are on 0.1 m height from the base.	14	7.14	1.961
Moving forward when the forks are on 0.26 m height from the base.	14	5.79	2.417
Moving backward when the forks are on 0.26 m height from the base.	14	6.35	2.205

5.3 Time Required for Storing and Retrieving

The time required for storing and retrieving operations is estimated using stopwatch. The data are shown in Table 4.

Table 4: Time Required for Storing-Retrieving Operations

Operation	Required time (s)
Storing the car on first floor	58.20
Retrieving the car from the first floor	55.35
Storing the car on second floor	72.79
Retrieving the car from second floor	63.83

5.4 Capacity of the Car Stacker

The length and height of each space have been measured by scale in meter. Then the area per space has been calculated by multiplying the length and height.

Table 5: Capacity of the Car Stacker

No. of parking space	Length of space of stacker, (m)	Height of space of stacker, (m)	Area per space (m^2)
2	0.335	0.16	0.0536

6. RESULT

From Table 2 and Table 3 it is observed that the lifting up operation takes more time than that taken in falling down operation in both cases of loaded and no-load condition. The reason is gravity is favoring while falling down operation but while lifting it works against gravity. In case of moving forward, it takes less time than that taken for moving in backward direction.

On the other hand, the relative time of moving forward while the load is on the base is more than that while the load is on 0.1 m height from the base. In this model parking system the approximate time required to store and retrieving in first and second floor are given in Table 4. The retrieving time is less than storing time. The reason might be that the car is first stored and then retrieved. So while storing, the forklift was first placed in position and then lifted and stored but in case of retrieving the forklift was already in the position and therefore it took less time. Besides, the overall capacity of the stacker can be observed from Table 5.

7. DISCUSSION

The results show that the model system works satisfactorily. The system although works for only vertical up-down and horizontal front-back direction, the horizontal left-right motion could also be obtained by modifying the circuit diagram. But because of cost limitation, only movement in one direction was tested. The variation in time for different operations might be because of the misalignment of the wheel attached to the motor which increases the tendency of increasing the friction as well as decreasing gripping capacity of the tire used in the wheel. Besides, a tilting effect on the forklift stand is induced due to gravity force which affects the movement of this forklift in the proper direction. Using lubricating oil this type of limitation could be reduced effectively in the prototype. Regular cleaning is mandatory to keep the car parking system in huge working capacity, especially with the problems imposed by weather.

8. ACKNOWLEDGEMENT

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[4] "64 years ago, the world's first driverless parking garage opened in DC".

[5] "Dokkl", Dokkle parking.