Design & Fabrication of Rotary Automated Bicycle Parking System

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***Abstract*—Rotary Automated bicycle Parking System (R.A.P.S) is a smart and flexible parking system aimed to make maximum utilization of the available space. The parking system currently available does not efficiently make use of the available space and does not have adequate automation features. To overcome this, a smart and flexible system needs to be designed. The vertical rotary mechanism is favored over the horizontal setup as it requires lesser space and can accommodate more number of bicycles in one unit. This project aims to design and develop a rotary automated bicycle parking system with the use of a rotary mechanism. The system can hold a maximum of 12 bicycles at a time. It consists of 4 docking stations, supporting frame, drive mechanisms, PIN code Reader and PLC. The work space of the system is 4m in width, 4.8m in height and 4m in length. The system is fabricated using Mild Steel which is treated and powder coated to avoid corrosion. Using Mild steel reduces the cost factor and improves the overall strength of the structure .The rotary docking stations are rotated about a fixed axis and are driven by a motor of 31 HP. Each docking station has the 3 inbuilt cycle stands. A PLC and a PIN code reader are used to collect Input from the user and process the same information into memory locations of the cycles. When the user inputs his/her PIN code the PLC detects the empty docking station in the system and allots that space to the user. Now the user places his bicycle in the docking station. The system locates the specific memory location when the user inputs the same PIN code again and rotates the system based on the memory location to the exit point.**

***Index Terms*—rotary automated parking system, parking, retrieval, docking station, PIN code**

I. Introduction

The Rotary Automated Parking System (RAPS) belongs to the class of rotary smart parking systems [1]. The traditional parking systems such as multilevel or multi-storey parking systems (non-automated), robot parking systems, automated multilevel parking systems etc have been implemented on a huge scale [1]. But these systems have a major disadvantage of large space consumption which is successfully eliminated with the use of a rotary parking system. Moreover, the latter provides the added benefits of flexible operation without the need of an attendant and added security and least chances of bicycle damage [2]. Bicycle parking is an important part of a municipality's cycling infrastructure and as such is studied in the discipline of bicycle transportation engineering. A study has been made where a novel bicycle parking system based on IoT, which can record and process the all-around information of parking sites as well as the information of bicycles parking in the carport [3]. When bicycle parking facilities are scarce or inadequate, nearby trees or parking meters are often used instead. The rotary model is specifically designed to accommodate multiple bicycles in the horizontal space of 8. The structure can accommodate 12 bicycles in the space of 8 and can even be customized to hold a greater number depending upon the requirements of the user and can be efficiently put to use in much space crunched areas. In many urban housing societies, the parking space ratio is 1:1. The vehicles parked randomly, because the major problem faced in most of the metropolitan cities.

Mechanical parking equipment is also called docking stations. As compared to the existing parking arrangements, the most obvious advantage is maximum space utilization; it is safer and more convenient [4]. The RAPS is totally automated with the user being given a unique ID corresponding to the station being allocated to him/her. In one study, the control was obtained using a microcontroller arduino uno module that is able to control various types of electronics related equipment such as servo module, stepper motor, and some push button [5]. This kind of equipment is useful to solve the issue of limited parking space available in busy cities. So the task was to design mechanical equipment that can store 12 bicycles in one normal garage. It is called a rotary parking shaft. The idea is to park and move bicycles with no disturbance to the already parked bicycles in RAPS. All RAPS take advantage of a common concept to decrease the area of parking spaces - removing the rider from the bicycle before it is parked. With either fully automated or semi-automated RAPS, the bicycle is cycled up to an entry point to the RAPS and the rider exit the bicycle. The bicycle is then moved automatically or semi-automatically (with some attendant action required) to its parking space. With the elimination of ramps, driving lanes, pedestrians and the reduction in ceiling heights, the RAPS requires substantially less structural material than the multi-story parking garage. Many RAPS utilize a steel framework (some use thin concrete slabs) rather than the monolithic concrete design of the multi-story parking garage. Also, in future, solar panels can be

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used on the roof of the parking system to overcome electricity issues [6]. These factors contribute to an overall volume reduction and further space savings for the RAPS.

The objective of this system is to obtain,

- 3 Bicycles in each docking station.
- A total of 4 docking stations.
- An automatic retrieval position system for 12 bicycles.

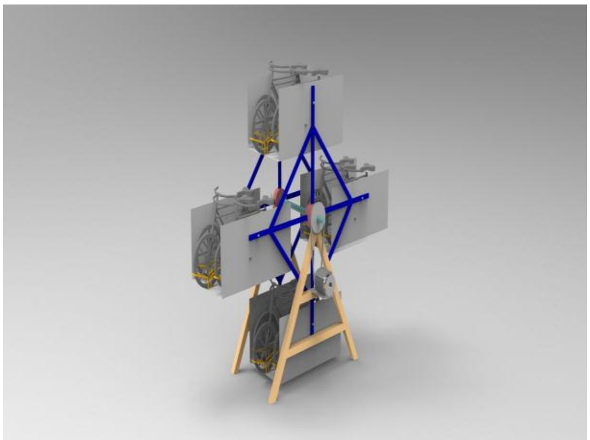

Figure 1. CAD model.

II. Fabrication And Assembly

A. Mechanical Components

The design is done considering the size constraints and provisions for all parts; therefore each dimension is carefully taken from part diagrams, and referred to the CAD model shown in Fig. 1, and fabricated accordingly. The fabrication started with the fabrication of the docking stations. The docking stations were fabricated using mild steel angles, and mild steel sheets. The supporting frames were welded at three positions for parking three bicycles.

At the same time the main shaft was machined to the required dimensions and two bearings were machined for the main shaft.

The main supporting structure was obtained by gas cutting an already available crane. The main shaft with the bearings was welded to the supporting structure including the discs which facilitated the connection of the mild steel flats to the docking stations.

The motor with the reduction gear box was mounted on the supporting structure along with the chain and sprocket assembly.

The final assembly was done and the electronics were integrated with the assembly as shown in Fig. 2. The operation of the system was verified and checked.

B. Connecting to the Electronics

The PLC is mounted next to the motor with the reduction gearbox mounting. Care is taken while fitting the PLC on to the support structure. Three connections are made from the PLC. One connection is given to the main power supply, the second connection is given to the motor, and the third is given to the four inductive proximity sensors that are placed to sense the required docking station. These connections are carefully given and soldered.

Figure 2. Assembled structure.

III. Operation

The rotary automated parking system is completely automated and is user friendly. The system can be accessed by anyone with ease and requires no prior knowledge to operate the system. The system stores address of each user's bicycle in the system in the form of unique 4-digit pin codes set by the user.

The rotary automated parking system consists of docking stations with 3 parking positions each.

The user first approaches the HMI (Human Machine Interface) and is now allowed two options to choose between i.e, Press F0 to park the bicycle and Press F1 to retrieve the bicycle.

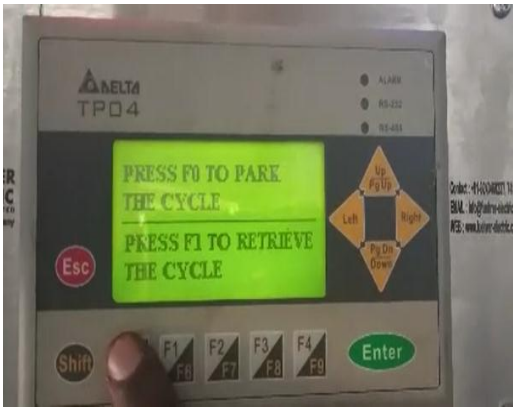

Figure 3. PLC entry.

If the user is going to park the bicycle he presses F0 as shown in Fig. 3, by doing so the Delta PLC then searches for closest empty positions in the parking system. Once the empty position is identified the Delta PLC sends a signal to the ABB AC type contactor. The contactor in turn sends a signal to actuate the motor. Once the required docking station is identified, Inductive sensors placed in the system with a sensing range of 8mm is used to identify if the required docking station is at the home position and sends a signal to the ABB contactor to stop the motor, the brakes on the motor help stop the station at the home position. Now the user can load his cycle onto the system as shown in Fig. 4, where he will place his bicycle front tires in the specially designed cycle stand and enters unique 4-digit pin code

Now when the user returns and wishes to retrieve his bicycle from the system, he first approaches the HMI where he will select the option to retrieve his bicycle, i.e, he selects the option ‘Press F1 to retrieve the bicycle’.

Further the HMI asks him in which position his bicycle his parked, once he enters the position correctly it will ask for the 4-digit unique pin set by the user. When the user then correctly enters the 4-digit pin a signal is sent to the PLC asking the PLC to locate the docking station which bears position to which the unique pin is assigned to. Once the station is located the PLC sends a signal to the ABB contactor to start the motor. The motor rotates and thereby drives the shaft as a result the docking stations are also under motion till the required station reaches the home position. The required docking station when it reaches the home position stops at that position as a result of the signal sent from Inductive sensor to the PLC requesting the PLC to stop the Contactor which thereby cuts the supply to the brake motor and brings the station to a halt via the brakes in the motor.

Figure 4. Loading and unloading bicycle.

The user can now safely unload his Bicycle. Once the user has un-loaded the bicycle the Pin code set by the user is automatically deleted making way for a new user to set another pin for the same position as shown in Fig. 4.

IV. Results

A. Comparison of Actual Rpm to Theoretical Rpm Calculation of Theoretical RPM

The 1hp brake motor runs at 1440rpm which has to further reduce to less than 1rpm. This reduction in obtained by mounting the motor to a reduction gearbox with reduction gear ratio of 800. Further the rpm is reduced by installing two sprockets with different number of teeth.

Motor rpm = 1440rpm

Reduced rpm at the reduction gearbox end = $\frac{1440}{800}$ = 1.8rpm

Number of teeth on the large sprocket, Z1 = 50 teeth

Number of teeth on the small sprocket, Z2 = 18 teeth

Reduced rpm = $1.8 \times \frac{Z2}{Z1}$ = 0.648 rpm

Therefore, theoretical rpm = 0.648 rpm

Actual rpm = 0.9 rpm

Deviation = Theoretical rpm – actual rpm = -0.252

Percentage error = $\frac{\text{Actual}-\text{Theoretical}}{\text{Theoretical}} \times 100$

$$= \frac{0.252}{0.648} \times 100 = 38.8\%$$

The deviation in the rpm can be attributed to the faster disengagement on the slack side of the chain, uneven grinding of teeth in the sprocket, less effective reduction gearbox and other external factors.

B. Inclination and Deviation of Docking Station

Theoretically, when the docking station is positioned at the ground platform, there should not be any inclination or deviation from the centre of the platform. However, it is observed that there are minute deviations and inclination under different loading conditions. The inclinations were measured using a magnetic angle measuring device and the deviation was measure using standard scale. These conditions are discussed below.

Fig. 5, 6, 7, 8 and 9 shows different conditions at which the deviations and inclinations are measured.

1) Empty docking station

Figure 5. Empty docking station.

TABLE I. Observations for Empty Docking Station

Parameter	Measurement	Deviation
Inclination	5^0	5^0
Deviation	1.8 cm	1.8 cm

Table I, gives the information that there is an inclination of 5^0 with respect to the horizontal as there is slight imbalance due to the welding of two locking frames on one side to one locking frame on the other. The docking station stops at 1.8 cm away from the centre of the platform due to the delay of the contactor to stop the motor at the exact time the sensor senses the docking station and inertia.

2) Docking station with one bicycle on either of the sides

Figure 6. Docking Station with one bicycle on side.

TABLE II. OBSERVATIONS FOR DOCKING STATION WITH ONE BICYCLE ON ONE SIDE

Parameter	Measurement	Deviation
Inclination	4^0	4^0
Deviation	1.5 cm	1.5 cm

Table II, gives the information that there is an inclination of 4^0 with respect to the horizontal. The imbalance caused by the empty docking station is slightly cancelled out by one cycle being parked as it adds a weight to the other end of the station. The docking station stops at 1.5 cm away from the centre of the platform due to the delay of the contactor to stop the motor at the exact time the sensor senses the docking station and inertia.

3) Docking station with one bicycle on the middle

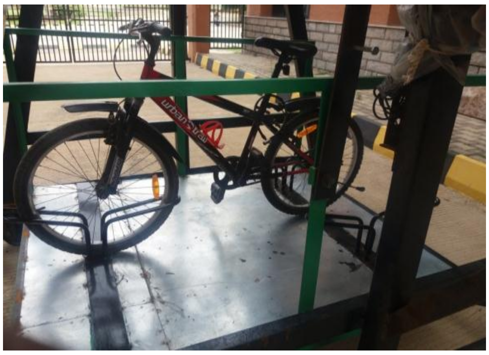

Figure 7. Docking Station with one bicycle in the middle.

TABLE III. OBSERVATIONS FOR DOCKING STATION WITH ONE BICYCLE IN THE MIDDLE

Parameter	Measurement	Deviation
Inclination	3^0	3^0
Deviation	1.7 cm	1.7 cm

Table III, gives the information that there is an inclination of 3^0 with respect to the horizontal. The inclination is lesser than the previous condition as the bicycle is parked in the middle and this balances the docking station. The docking station stops at 1.7 cm away from the centre of the platform due to the delay of the contactor to stop the motor at the exact time the sensor senses the docking station and inertia. It deviates slightly more than the previous condition as the overall weight of the docking station is concentrated towards the centre of mass.

4) Docking station with two bicycles

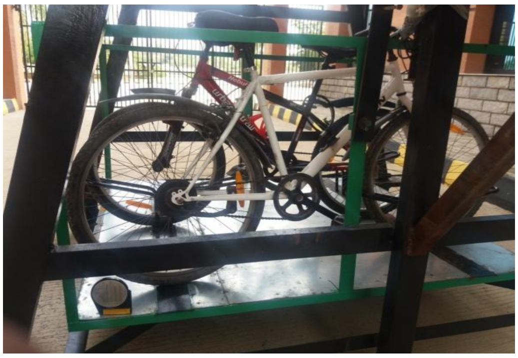

Figure 8. Docking station with two bicycles.

TABLE IV. OBSERVATIONS FOR DOCKING STATION WITH TWO BICYCLES

Parameter	Measurement	Deviation
Inclination	1.5^0	1.5^0
Deviation	1.3 cm	1.3 cm

Table IV, gives the information that there is an inclination of 1.5^0 with respect to the horizontal. This condition is has balanced condition as the inclination is close to 0^0. The docking station stops at 1.3 cm away from the centre of the platform which is the least measured deviation due to balanced condition.

5) Docking station with three bicycles

Figure 9. Docking Station with three bicycles.

TABLE V. OBSERVATIONS FOR DOCKING STATION WITH THREE BICYCLES

Parameter	Measurement	Deviation
Inclination	1^0	-1^0
Deviation	2.6 cm	2.6 cm

Table V, gives the information that there is an inclination of 1^0 with respect to the horizontal. This condition is the most imbalanced condition as the inclination is closest to 0^0. The docking station has the most deviation at 2.6 cm away from the centre of the platform which is due to the addition of three bicycles which increases the overall weight of the platform.

C. Uncertainty Analysis

The uncertainty in the project can be the repeatability of the system to run at constant rpm. In this analysis, the time required to complete one complete revolution for dry run and loaded conditions are calculated for measuring uncertainty. The time taken to complete one revolution is calculated in different loading conditions and standard deviations are calculated. Fig. 10, plots a graph where it is observed that the longest mean time is obtained in the balanced condition while the shortest time is obtained in the unbalanced condition. Fig. 11, is a standard error graph that shows the different conditions have different variations in the time taken for completing one complete rotation. The most deviation is obtained for the empty station condition.

- Empty docking station

  Sample Mean

  $X_{,} = \frac{55+54+55+55+56+54+54+54+55+56}{10} = 54.8$ s

  Standard Deviation,

  $u(X)=\frac{1}{10\times(10-1)}\times(0.2^2+0.8^2+0.2^2+0.2^2+1.2^2+0.8^2+0.8^2+0.8^2+0.2^2+1.2^2)^{1/2} = 0.788$

- Balanced Condition

  There are two loading conditions either balanced or unbalanced. When there are equal number of bicycles parked in each docking station then the condition is balanced.

  Sample Mean,

  $X_{,} = \frac{55+55+55+55+56+55+56+56+55+56}{10} = 55.4$ s

  Standard Deviation,

  $u(X)= \frac{1}{10\times(10-1)}\times(0.4^2+0.4^2+0.4^2+0.4^2+0.6^2+0.4^2+0.6^2+0.6^2+0.4^2+0.6^2)^{1/2}= 0.5163$

- Unbalanced Condition

  When there are unequal number of bicycles parked in different docking stations then the condition is unbalanced.

  Sample Mean,

  $X_{,} = \frac{54+54+53+54+54+54+53+53+54+54}{10} = 53.7$ s

  Standard Deviation,

  $u(X)=\frac{1}{10\times(10-1)}\times(0.3^2+0.3^2+0.7^2+0.3^2+0.3^2+0.3^2+0.7^2+0.7^2+0.3^2+0.3^2)^{1/2}=0.4830$

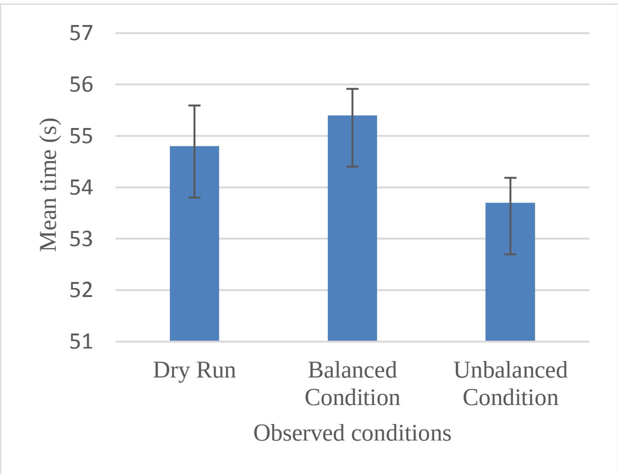

Figure 10. Time taken for one complete rotation under different conditions.

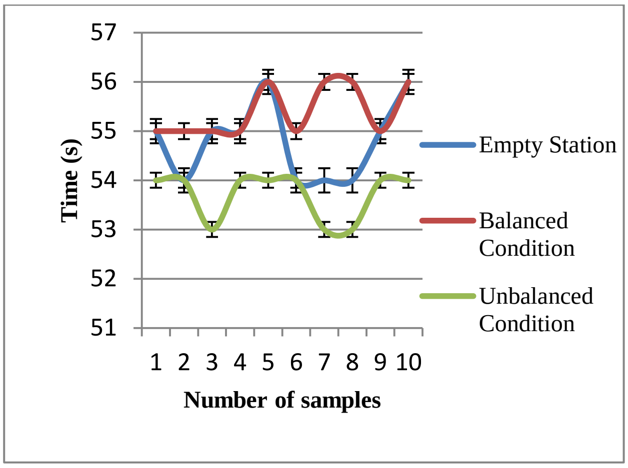

Figure 11. Standard error graph.

D. *Space Reduction*

Figure 12. Horizontal parking of bicycles.

The Fig. 12, shows the horizontal space consumed in the college parking lot for parking 12 bicycles.

The space consumed by 12 bicycles when parked adjacent to each other = 7.32 m

The horizontal space consumed by the fabricated parking system = 5 m

Percentage of horizontal space reduced = $\frac{7.32-5}{7.32} \times 100$ = 31.69 %

E. *Waiting Time*

The waiting time for either parking or retrieval varies due to the different positioning of the docking station.

Shortest waiting time for a docking station to be positioned at the ground platform = 15 s

Longest waiting time for a docking station to be positioned at the ground platform = 56 s

Average waiting time for parking or retrieval = $\frac{15+56}{2}$ = 35.5 s

V. Conclusion

With the increasing of the bicycle number in universities, the effective management of bicycles becomes a significant and challenging problem. To solve the problem, using the PLC, we design and implement an intelligent bicycle parking system. This project introduces the architecture and modules of the system, and presents the methodology of system implementation.Automatic Bicycle parking has been designed and fabricated for Space optimisation and Secured docking. The same can be improvised for bikes.

The design for the system is analyzed using the components available in the market which when used can perform the necessary function of storage and retrieval of bicycle.

The fabricated parking system has the following features

- The parking system is capable of parking 12 bicycles.
- The parking system takes up a horizontal space of 5m which is 2.32m lesser than the space consumed by bicycles parked horizontally handlebar to handlebar.
- The parking system allocates unique PIN code to the respective users for their bicycles for easier and safer docking of their bicycles.
- Integrated with PLC controlled parking assistance for better precision and repeatability.
- Inductive Proximity Sensors is used for accurate docking.
- The system is a portable system that is easy to set up or remove.
- Simple and speedy bicycle storage entry or exit.
- Running cost is inexpensive and economical.

VI. Future Scope

The rotary automated bicycle parking system was developed to facilitate bicycle parking in reduced space. There are areas in which this system can be further improved. Few are listed below

- The parking system currently has a capacity of parking 12 bicycles. By increasing the width of the docking stations, this capacity can be increased greatly.
- The PIN code is unique to each position in the docking station. This can be further used to develop an automatic locking mechanism that locks the wheel of the bicycle when parked and unlocks when the bicycle is being retrieved.
- The design and development of a ratchet and pawl mechanism for the prevention of disengagement of the teeth between chain and sprocket to efficiently arrest any sudden fall of the docking station due to weight imbalance.
- The current system uses PIN code as the unique identification. The identification can be further improved to bar code or QR code or Biometrics.
- Superior materials such as composites can be used to further increase the strength to weight ratio for the mechanical components of the system.
- This parking system can be used as a proof of concept for the design and development of an automated rotary bike parking system as the motorcycle users in the country has always been on the rise and there are no efficient parking facilities in public spaces such as malls, metro stations, etc.
- Further design optimisations can lead to better space reduction.

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