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Vehicle Identification by OCR, RFID and Bluetooth for Toll Roads

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Abstract

Automatic payment in toll roads can improve the efficiency of the roads; however, errors in this payment can reduce the satisfaction of both the road users and the operators who will both have to waste time in order to sort out these mistakes. It is suggested to greatly minimize these mistakes by backup the recognition course of action of the license plates by using three different methods: RFID, Bluetooth and OCR in order to make recognition errors as seldom as possible.

Keywords: *Toll Road, RFID, Bluetooth, OCR*

1. Introduction

Toll roads are usually built in Build–Operate–Transfer (BOT) model, wherein a private commercial business obtains a concession from the government to finance, construct, operate, and collet money from the travelers in a road. This facilitates the road proponent to recover its investment, operating and maintenance expenses in the road [1].

The money collection from the drivers in the toll road can be automatically done by OCR systems which can recognize license plates [2], RFID devices that are installed in the vehicles [3] or Bluetooth equipment that communicates with the apparatus in the road entries [4].

Errors sometimes occur when a vehicle is not identified or when a vehicle is wrongly identified as another vehicle. In such cases the road operator will have a loss. In addition, if a wrong vehicle has been detected, an unhappy driver will be added to the case that will have a hassle in cancelling the wrong bill and a negative advertisement for the service of the toll road can be overstated.

In a few years the vehicles will be autonomous [5], so the need for an embedded system in the vehicle [6, 7] for automatic fee collection systems will be even more imperative. Some of the autonomous vehicles will be with neither a driver, nor a passenger, because they will drive alone to a parking lot [8, 9], so there will be no one to talk to and the only possible option will be an automatic fee collection system that will charge the fee.

In this paper we suggest to incorporate the 3 ways mentioned above *i.e.*, OCR system, RFID device and Bluetooth equipment as redundant tools in order to get the best results and to overcome mistakes.

Figure 1 shows an RFID tag on a vehicle. The RFID tag was circled and there is an enlargement of it in the right side of the picture.

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Figure 1. RFID Sticker on a Car

2. Implementation

Most of Intelligent Transportation Systems are implemented by state machines [10, 11]. We also used a state machine in order to implement the incorporate license plate recognition device.

RFID is the most efficient method in term of information transformation [12, 13, 14]. In addition, RFID is the most reliable method with an error bit rate of less than 0.001% [15]. Bluetooth has a higher error bit rate of 0.1% [16], whereas OCR has the highest error bit rate of 3.6% [17] because it is an intricate task to decode the information from a picture taken by a camera [18, 19,20].

Accordingly, we designed our state machine as described in Figure 2. We gave the RFID and the Bluetooth the first priority. Just if they do not agree, we will check the value of the OCR.

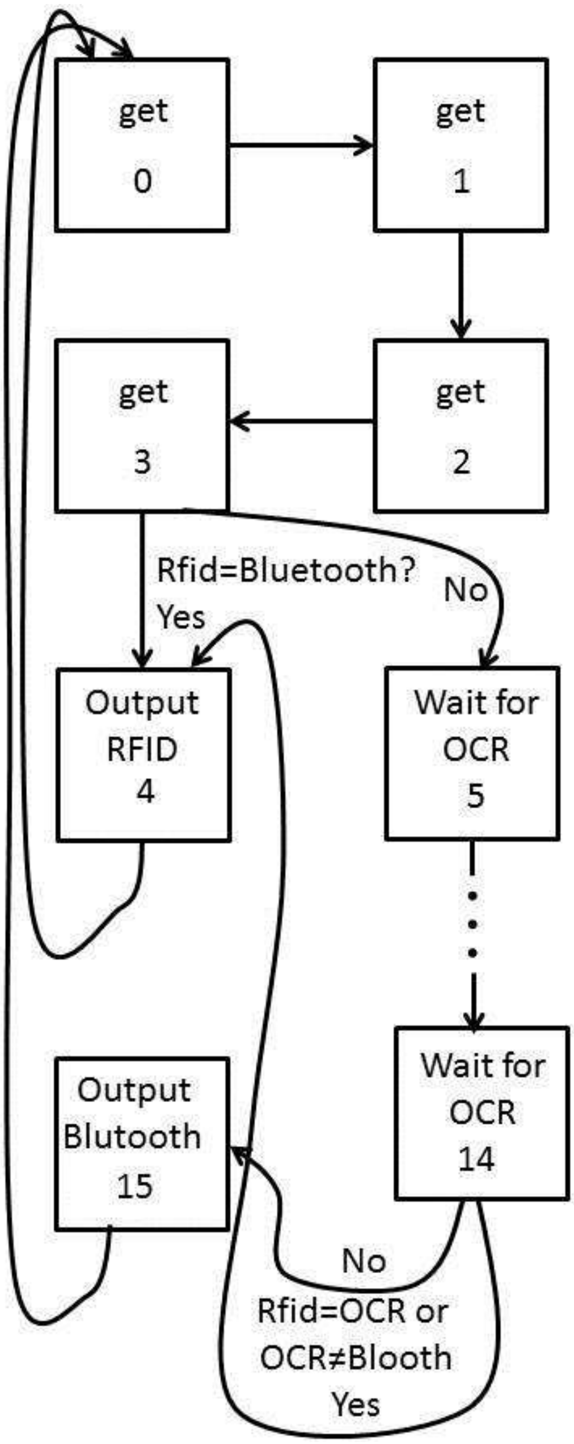

Figure 2. State Machine for the Combined System

The system works as follow: First it gets the value obtained by the RFID and the Bluetooth. Our clock pulse was 0.5MHz [21]; however, the Bluetooth could not provide the data in less than about 7.4µs, so we had to make 4 states of "get" in order to be sure that the data is obtained. It will give us a time of 8µs which is enough time to be sure that the Bluetooth data has been obtained. If a faster Bluetooth is available, the four states can be reduced into fewer states.

After obtaining the output of the Bluetooth and the output of the RFID, they will be compared using the comparator circuit described in Figure 3:

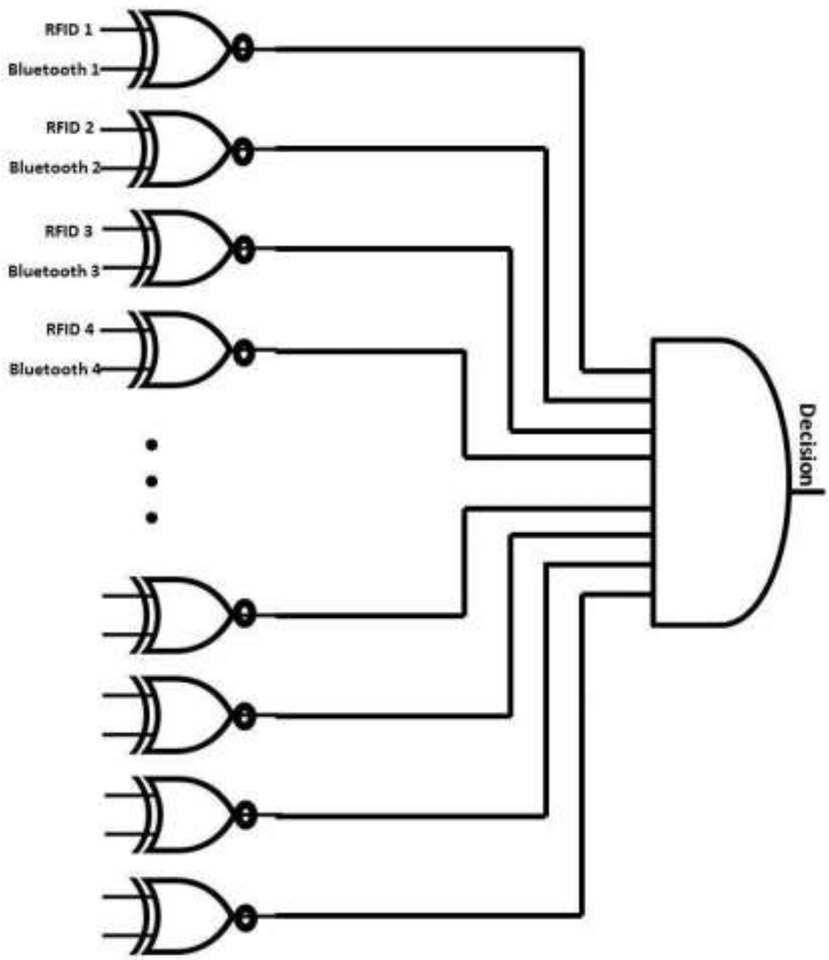

Figure 3. Comparator for RFID and Bluetooth

If the comparator decision is yes, it will denote that the RFID and the Bluetooth agree on the license plate number, this number can be accepted and it will be output as the correct number.

If the comparator decision is no, it will indicate that there is a problem in the RFID or the Bluetooth because they do not come to an agreement what the license plate number is. Then, we will take the OCR as the determining factor; however, the OCR takes more time, that is to say 27.6μs, so we will need 14 cycles; however, we can start always to read the OCR in the beginning when the RFID and the Bluetooth begin. If there is no need in the OCR, the OCR can be stopped, but if there is a need in the OCR result, we will have to wait just ten more cycles, because the first four cycles overlap the first four cycles of the Bluetooth and the RFID. The additional ten states are denoted as states 5 to 14 in Figure 2.

If all the devices can come to an agreement, *i.e.*, they produce three different values, the system will take the results of the RFID as this method is the most accurate as was mentioned above.

3. The Device Output

The device has several output bits – one bit for indication whether a decision what the license plate number is has been made or the decision has not been made yet. When this indication bit has a value of one, it will indicate that a decision has been made; whereas if this indication bit has a value of zero, it will indicate that no decision has been made yet.

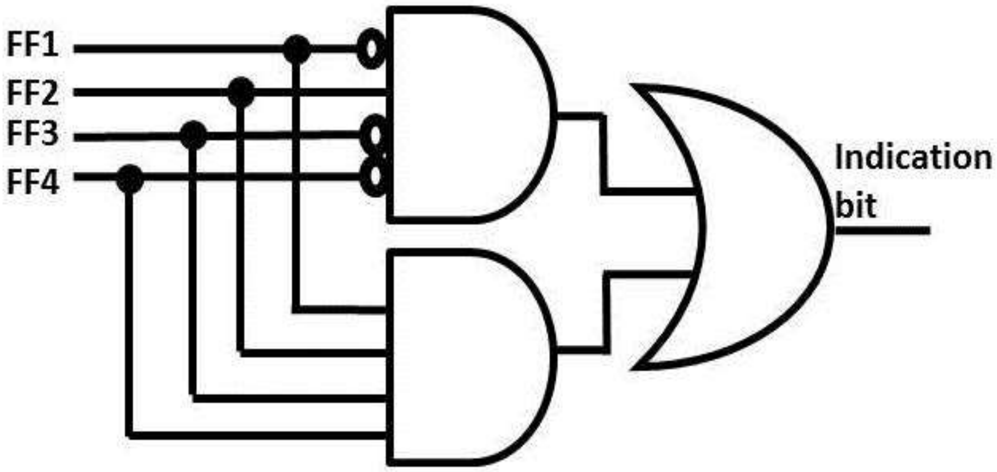

Figure 4. Implementation of the Indication Bit

The other bits are enable bits for the RFID output, the Bluetooth output and the OCR output. When the indication bit denotes that no decision has been made yet, all the enable bits will have a value of zero. When the indication bit changes its value to one, the chosen device will be enabled by setting its bit value to one, whereas the other enable bits will remain with the zero value.

The state machine has 16 states, so it should be implemented with 4 Flip-Flops. The indication bit is set to one just in state 4 and state 5 so the circuit for the indication bit should be implemented as described in Figure 4. In this Figure each one of the Flip-Flops is denoted as FF and it serial number.

There are enable bits actually just to the RFID and the Bluetooth. If the OCR value is equal to the RFID value, the RFID value will be taken. If the OCR value is equal to the Bluetooth value, the Bluetooth value will be taken. If the OCR value is not equal to both the RFID value and the Bluetooth value, the RFID value will be taken, so there is no need for enable bit to the OCR.

The RFID enable bit implementation and the Bluetooth implementation are depicted in Figure 5. The RFID device is enabled only in state 4 and the Bluetooth device is enabled only in state 15.

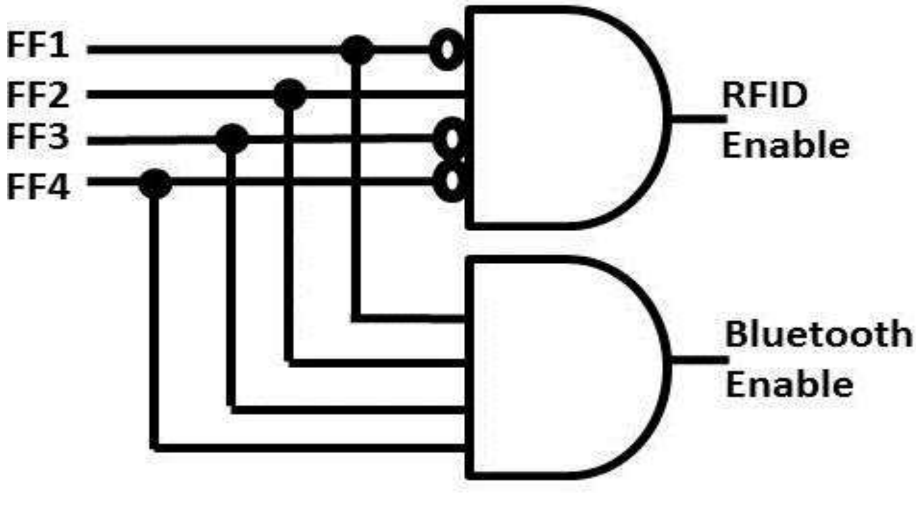

Figure 5. Implementation of the Enable Bits

4. The Next State Function

As was mentioned above, the system has 16 states, so it has 4 Flip-Flops. Accordingly, the system has 4 next state functions for each of the Flip-Flops in the system. We use Karnaugh maps [22,23] to find the simplest functions for implementing the next state circuits. We also assume for simplicity that the implementation uses Edge-Triggered D-Filp-Flops [24,25].

The most significantly bit is FF3. If the current state is from 7 to 13, the next FF3 will be 1. Also if the current state is 14 and Rfid≠OCR and OCR=Blooth, the next FF3 will be 1. This information is described in the Karnaugh map of Figure 6.

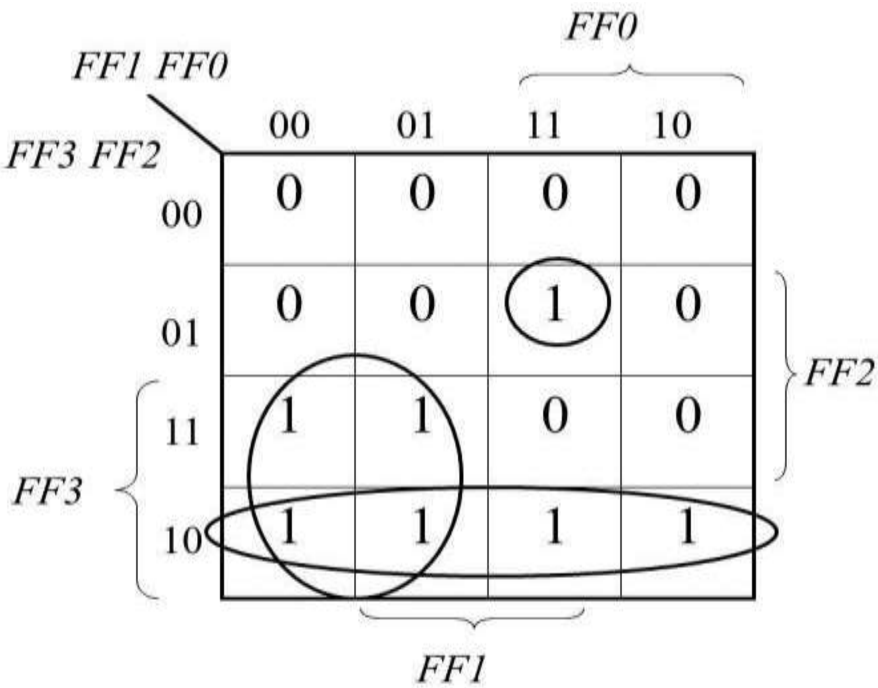

Figure 6. Implementation of Next FF3

According to Figure 6 and according to the condition that if the current state is 14 and Rfid≠OCR and OCR=Blooth (denoted as condition A), the next FF3 will be 1, the next state function of FF3 is:

NextFF3=FF3·FF1'+FF3·FF2'+FF3'·FF2·FF1·FF0+(condition A)

The next state of FF2 has a value of 1 if the current state is 3,5,6,11,12,13,14. Accordingly the Karnaugh map of the next state function of FF2 is described in Figure 7. And the function that is represented by this figure is:

NextFF2=FF2'·FF1·FF0+FF3·FF2·FF1'+FF2·FF1'·FF0+FF2·FF1·FF0'

It should be noted that the comparators which compare the values of the RFID value, the Bluetooth value and the OCR value do not affect the NextFF2 function. These comparators are the only input to state machine, but they have influence only on the next state function of FF3, FF1 and FF0.

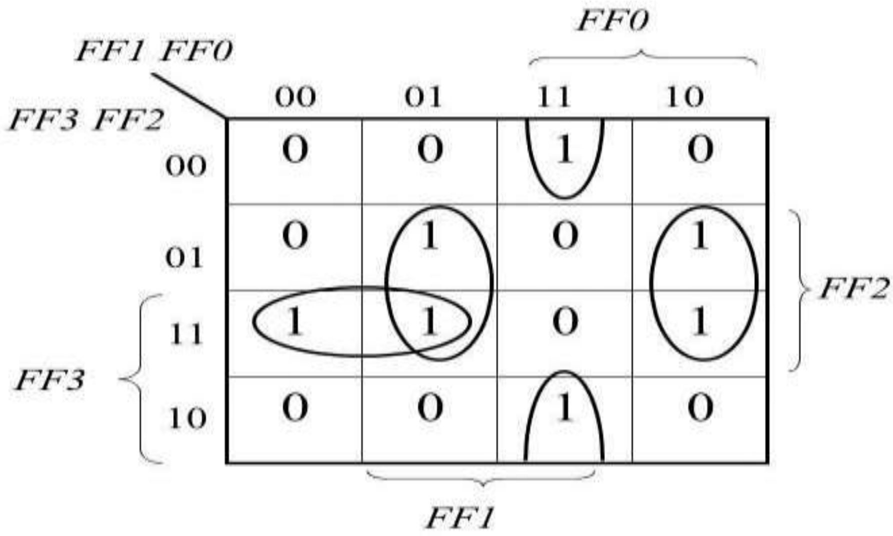

Figure 7. Implementation of Next FF2

NextFF1 is described in Figure 8. NextFF1 will have a value of 1 if the current state is 1,2,5,6,9,10,13 or the condition that if the current state is 14 and Rfid≠OCR and OCR=Blooth (denoted as condition A).

Therefore, according to the Karnaugh map of Figure 8 and condition A, the function of NextFF1 is:

NextFF1=FF1'·FF0+FF3'·FF1·FF0+FF2'·FF1·FF0+(condition A)

The last one is NextFF0 which will have a 1 value if the current state is 0,2,6,8,10,12. Also, if the current state is 14 and Rfid≠OCR and OCR=Blooth (denoted as condition A), NextFF0 will be 1 and in addition, if the current state is 3 and Rfid≠Bluetooth (denoted as condition B), NextFF0 will be 1. Subsequently, the function of NextFF0 according to these conditions and according to the Karnaugh map of Figure 9 is:

NextFF0=FF2'·FF0'+FF3·FF1'FF0'+FF3'·FF1·FF0'+(condition A)+(condition B)

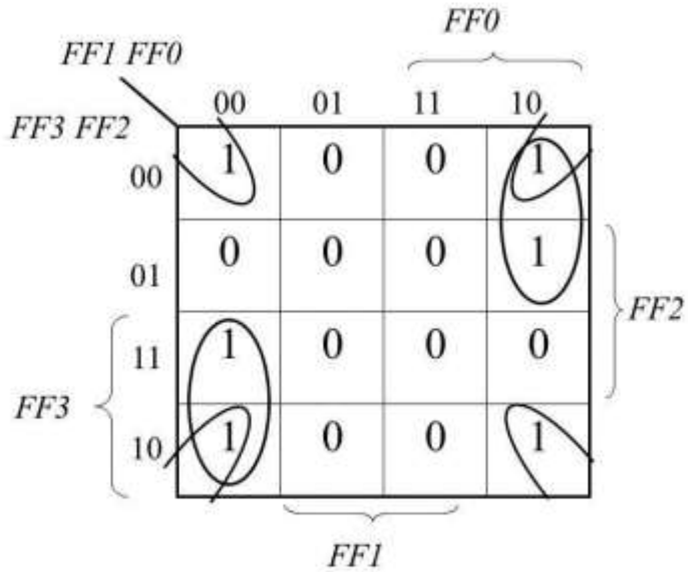

Figure 8. Implementation of Next FF1

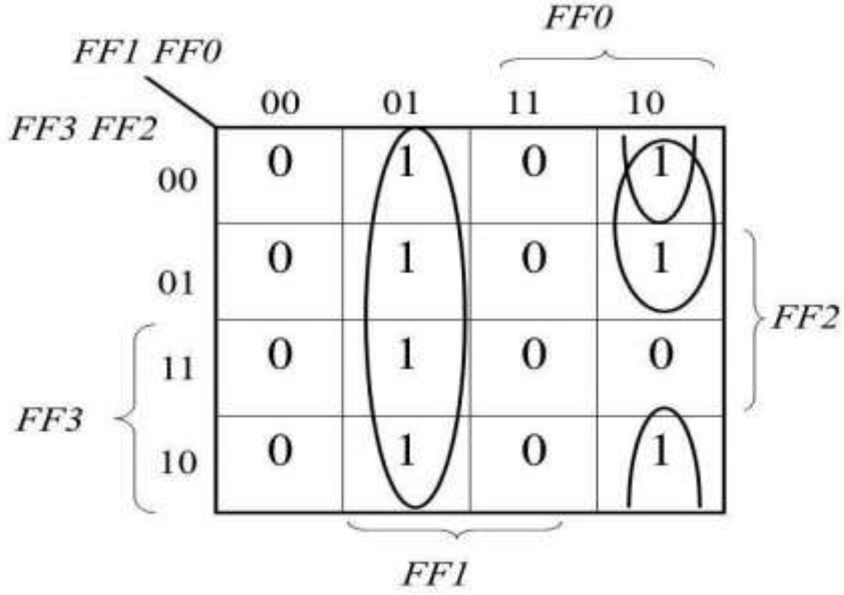

Figure 9. Implementation of Next FF0

6. Conclusions

One of the most common areas where Build–Operate–Transfer (BOT) model is carried out is Toll Roads [26, 27, 28]. Our system can help toll road proponents working out more efficient automatic fee collection system. Usually, in new contracts of toll roads, the government requests Intelligent Transportation Systems like collision detection systems [29, 30], so in general toll roads on average have a better safety standard [31]. In addition, toll roads save money of the government budget, because the construction expenses are financed by a private entity. The saved money of the budget can be allocated for alternative projects and other purposes as been done in many countries [32].

The suggested incorporated system can be implemented in a dedicated chip [33] or in a remote manner [34] and can have many benefits for many objectives like better traffic flow [35, 36, 37] or carbon emissions mitigation [38].

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Dr. Wiseman is an international expert who has reviewed and evaluated several large projects of the European Union, Israel Science Foundation, Marie Skłodowska-Curie actions in Ireland, Ministry of Education and Science of Kazakhstan. His papers have been published in many venues around the world.

