Knock Pattern Based Door Lock with Smart Phone Application

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Abstract: Current digital door locks have a risk of being broken because they are exposed outside and damaged by the electric shock. In order to increase safety, this work proposes an unexposed door lock, which removes the keypad in the outside. Instead of the keypad, it recognizes knock pattern. Users can setup the password using the knock pattern, and by knocking the same pattern, the door is open. The door lock can communicate with the smart phone application, also. Users can open the door by inputting the knock pattern to the smart phone, and it further increases safety because it removes the knocking sound and the possibility of being overheard.
[Ahreum Lee, Sujung Yu, Yoseop Kim, Ilhoon Shin. **Knock Pattern Based Door Lock with Smart Phone Application.** *Life Sci J* 2014;11(7):569-575]. (ISSN:1097-8135). http://www.lifesciencesite.com. 78

Keywords: Door lock**;** knock pattern; android application

1. Introduction

Because the current door locks are exposed outside, they have many risks of being broken. Even a little electronic power can make regular digital door locks open. For all of these reasons, removing outside device reduces the risk of damage and gives the security (Dave, 2012). This work proposes a knock pattern based door lock which is not exposed outside. Lastly in accordance with the age of smart ages, we make a smart phone application, and it can be used with door lock. An application has functions to control setting values and makes patterns and the passwords. The remainder of the paper is organized as follows: Section2 provides the work concept and principle of the door lock system using pattern of knocking. In Section 3 and Section 4, paper presents how to make hardware and firmware of the system. Section 5 explains application environment setting and composition of screen. Finally, In Section6, we suggest some applied flied and Section7 draws a conclusion.

2. Pattern Detection

The door lock using pattern of knocking uses time interval ratio between knock and knock as passwords (Figure 1). And this time interval ratio was stored in array and uses to compare with a existing knock array. For detailed studies of plant biodiversity and other vegetational parameters, selected sites were divided into three stands, viz., hill base, hill slop and hill top (HB, HS and HT, respectively).

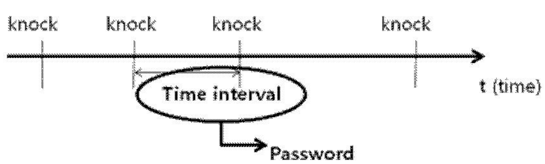


Figure 1. A time interval using as a password

To be specific, suppose that we beat a door four times. Each time and the time interval is 20ms, 40ms, and 60ms. The time interval goes through min-max normalization and stored in array. Our work focus on the time interval ratio, and we want that whether to knock quickly or slowly, if time interval ratios are same then system think same situation (password is same). Min-max normalization as :

V' = ((V - minV)/(maxV-minV)) * (newmaxV-newminV) + newminV

where, V means the arrangement of stored knock time intervals, and code set up newmaxV = 100 and newminV = 0. Thus, knock time intervals have values from 0 to 100 (Figure 2).

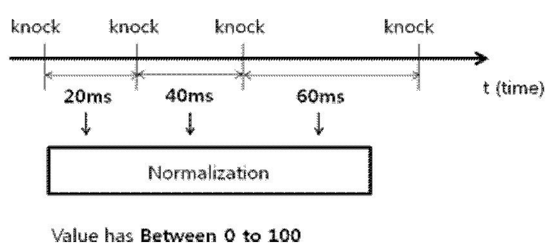


Figure 2. The normalization value

That 20ms, 40ms, and 60ms change values to 33, 67, and 100 after going through min-max normalization. Changed values store in array and then processing system compared with each entry in existing knock patterns. Existing knock pattern's initial value designates four knock at regular intervals. It can be changed from setting button. Compared values are used to judge whether unlock a door or not. First processing system checks each entry difference. *If each difference has error more than 5%, processing* system considers it not to correct passwords and doesn't unlock a door. If each difference has error below 5%, next we check if adding all differences has error more than 10%. When the value adding all differences also has error below 10%, system recognizes that password is correct (Figure 3). In examples, each one has 67%, 23%, and 0% error, so it will be filtered, and system thinks that user inputs wrong patterns.

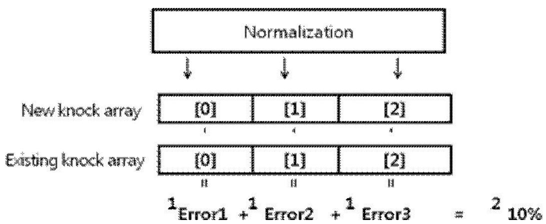


Figure 3. Error check for matching patterns

3. Hardware Design

Figure 4 shows overall system structure. The main processing system gets signals through sensor and smart phone application, and system processes to make suitable output. We use ATMEGA128 in main processor.

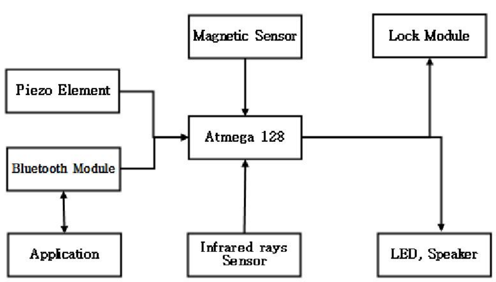


Figure 4. System Structure of Door Lock

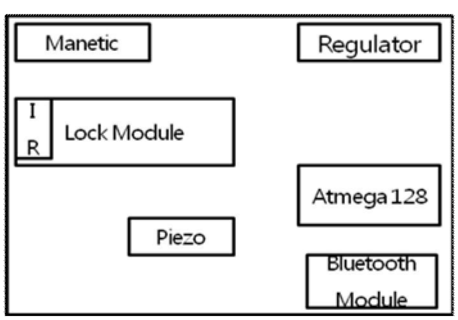


Figure 5. A electric component plan

An electric component plan is like as follows. Door lock is made of sensors (piezoelectric sensor, magnetic sensor, infrared light sensor), regulator, Bluetooth module, and lock module (Figure 5).

We use 'Piezoelectric sensor' to receive knock signals. Using piezoelectric sensor, a signal is proportional to knock sound and it was used to ADC input (Figure 6). ADC is abbreviation of analog digital convertor and has a function to change analog signal to digital signal.

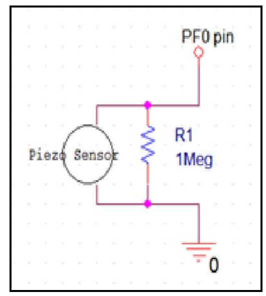


Figure 6. Piezoelectric sensor circuit

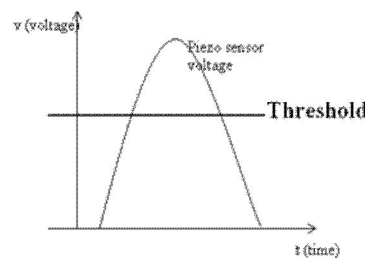


Figure 7. A piezoelectric sensor voltage

Piezoelectric sensor has a function to measure changes in pressure and vibration. When we beat a door, if the force is bigger, then it generates bigger vibration. If we get the signal, the sensor describes parabolas voltage like Figure 7. Many kinds of noise can be generated at the door. In order to separate noise from signals, we set up a certain level of threshold value. If signal exceeds threshold value, then the main processing system perceives it as knocking.

A magnetic sensor and an infrared sensor are used to check the situation of door and lock module. The situation means state of door is opened or closed, and state of lock module is locking or unlocking a door. Two kinds of sensor have the on-off character. So sensors are suitable for classifying states. We make our work to operate when door is closed and if the door is opened, lock module does not work and main processing device stands by. Classification of states makes system don't waste unnecessary source and so can save energy.

We use a magnetic sensor to check state of a door. When a magnetic sensor sticks to each other, a door is closed and a magnetic switch turns on. So voltage which input at PE7 pin becomes low. On the contrary to this, when a magnetic sensor falls to each other, a door is opened and a magnetic switch turns off. Therefore voltage which input at PE7 becomes high (Figure 8).

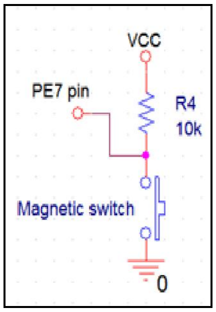


Figure 8. A magnetic sensor circuit

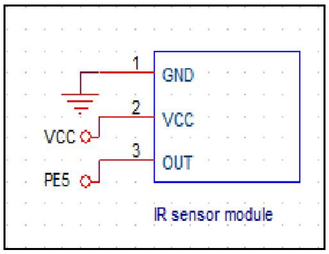


Figure 9. An infrared sensor circuit

We use an infrared sensor to check state of Lock a module. If an infrared sensor is aware of something within 10~12mm ahead, an infrared sensor module let high signals out and PE5 pin gets this signal as input (Figure 9).

To set the rated voltage at a Bluetooth module and ATMEGA128, we use a 5v regulator and a 3.3v regulator.

According to the typical application presented datasheet (Freescale), we use a LM2575 regulator IC. This circuit is made up for regular 5v output (max 1.0A) (Figure 10).

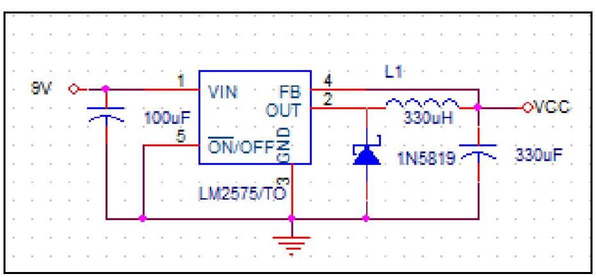


Figure 10. 9-5v Regulator circuit

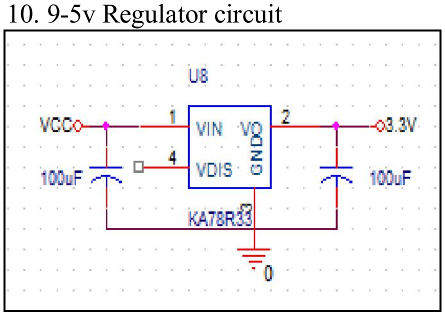


Figure 11. 9-3.3v Regulator circuit

According to the typical application presented datasheet (Freescale), we use a LM2575 regulator IC. This circuit is made up for regular 5v output (max 1.0A) (Figure 10).

According the typical application in datasheet (FAIRCHILD), we make a 3.3v regulator circuit (Figure 11) using KA78R33 regulator IC. 3.3v made this way is used for input of Bluetooth module.

Due to communication with smart phone application and main process system, we use a Bluetooth module. A Bluetooth module which we use is FB155BC made by Firm Tech firm. FB155BC provides 1:1 communication (it means we can use one smart phone to connect the door lock system at once) and communication speed become from 1200 to 230400bps. We use 9600bps communication speed setting basically.

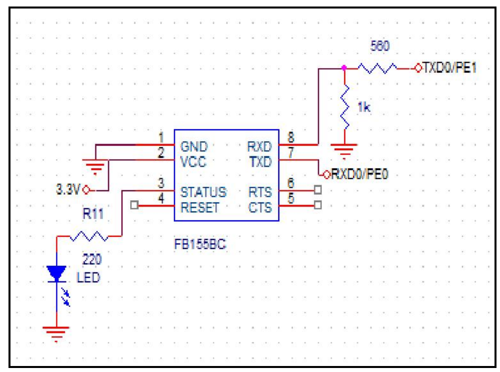


Figure 12. Bluetooth Module (FB155BC) circuit

RXD of a Bluetooth module (FB155BC) connects to TXD0 of ATmega128 and TXD of a Bluetooth module connects to RXD0 of ATmega128. It can make UART communication between ATmega128 and FB155BC. Because output of ATmega128 pin is 5v, we use voltage division circuit to step down voltage and apply 3.3v to RXD of Bluetooth module. LED circuit at the STATUS pin checks the state of Bluetooth module. When device asks for connecting, LED shows whether module can be connected with another device or not. (If connecting success, led turns off or if connecting is on standby, led blinks).

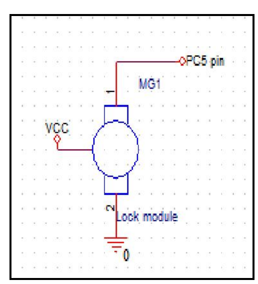
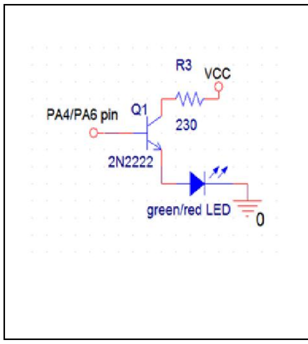


Figure 13. Lock Module circuit

Main processing system uses a PC5 pin signal to work a lock module. A PC5 pin usually keeps high voltage and a lock module doesn't work. When a lock module works, processing system sends falling edge signal to PC5 pin for 0.1 seconds (Figure 13).

Figure14 shows LED circuit. Using the formula (R=V/I), and considering a rated current of LED, 20mA based on the VCC 5V, we calculate resistance as R=5V/20mA=250ohm. Therefore we use 230ohom resistance in the light of brightness. Figure15 shows beep circuit. We control beep sound through BJT because ATmega128 output pin has small output current.



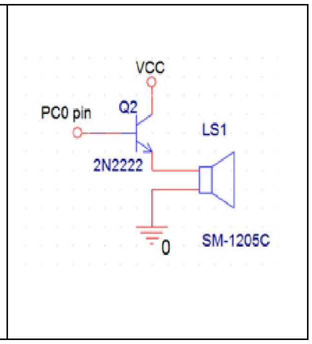


Figure 14. LED circuit Figure 15. BEEP circuit

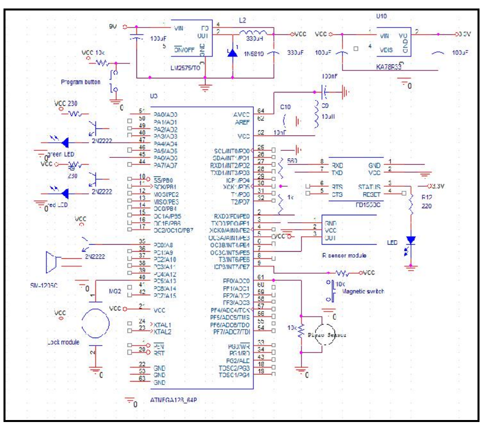


Figure 16. Whole circuit diagram

Figure 16 shows a whole circuit diagram and figure 17 shows a door lock prototype manufactured based on the circuit diagram.

Figure 17. Door Lock Prototype

4. Door Lock Firmware

In this session, we explain a firmware of the ATmega128. A flow chart of the firmware can be divided into two situations. One is the case of getting input through piezoelectric sensor and another is the case of getting input through application. When using the application, information system receives digital value, so information doesn't pass through ADC and directly go in input of processing system. Also it can't need to judge whether the information is noise or not. Therefore we use different input process of management about two situations. Not only input process but also handling after that is different in two cases. Therefore every code in ATmega128 treats two situations completely different part.

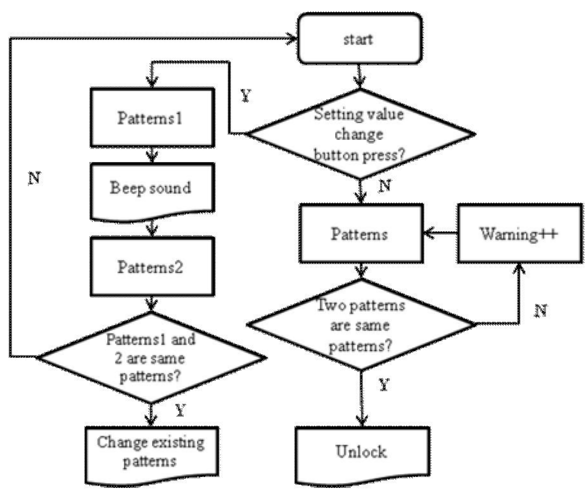


Figure 18. Flow chart in main processing system

Figure 18 shows the flow chart of the main processing system in the case of getting input through 'Piezoelectric sensor'. When the user starts knocking, the processor checks the setting button. If the button is not pressed, the processing system gets knock patterns and then it compares with existing pattern. If comparing results in an error smaller than standard.

Figure19 presents the smart phone application flow. In case that button is not pressed, we can open the door using passwords or touch patterns. A touch on the screen assumes the same role as a knock on a door. If the setting button is pressed, we can choose three cases. First we can change existing pattern like as getting input through 'Piezoelectric sensor'. New function is that we can change setting and change the password.

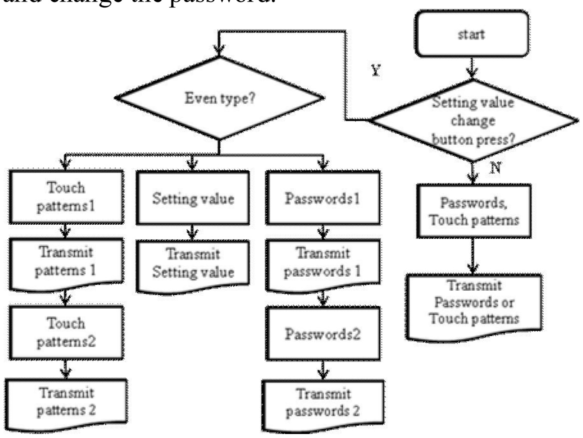


Figure 19. Flow chart in Application

Excluding first knock, all of the rest knocks is gotten in do-while statement in 'InputKnock (void)' function. When system judges that pattern is over, flow escapes the do-while loop. Observing a condition is as in the following. While ((now-startTime < knockComplete) && (currentKnock Number < maximumKnocks)) first, (now-startTime < knock Complete), while do-while repeats loop, now-startTime (knock interval time) is checked. If time of (Now-start Time) is over error then lock module unlock a door. (in code, the standard error is defined 10%) If the setting button is pressed and one knocks a pattern twice, the system compares equal degrees and change the passwords knockComplete (maximum allowed time between knock and knock), system judge that knock ends. KnockComplete time is setting 1.2second basically.

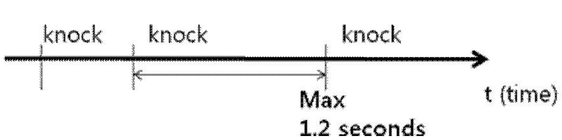


Figure 20. Max interval time between knock and knock

Second (currentKnockNumber < maximum Knocks), When processing system recognize knock, system increases currentKnockNumber value (this means current knock count) one by one. If current KnockNumber is over maximumKnock value (this variable means setting maximum count), system judges that user finishes knocking action. We set maximumKnocks value to 15 in the initial stages and this value can be changed to 5, 10, or 15 by using smart phone application. Input which exceeds maximum length of patterns (according to the setting, it can be 5, 10, or 15) become accepted new patterns. But, Only if system goes into 'KnockRead()' function at loop(while or do-while), each knock can be recognized. During flickering LED or operating lock, knock can be ignored.

In case of our work, between knock and knock interval time must be over 0.1seconds (100ms) at least. We make that system ignores second knock when knock interval time is below 0.1seconds.

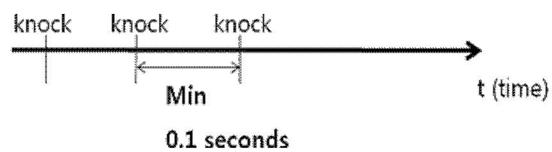


Figure 21. Min interval time between knock and knock

In the case of recognizing knock in 'InputKnock(void)' function, we make system doesn't get input during KnockFadeTime(100ms) to use '_delay_ms' function. The reason that we set the time to ignore knock is as in the following. In the case of not setting interval time between knock and knock, system can recognize knock signal twice. We conclude that this attributes to not problem of sensor but character of sound. Each sensor has difference to response of loudness level, but sound waves almost don't have difference. Knock is a kind of sound or vibration, and it is not in a moment. It maintains for a period of time. We need to time to fade way knock reverberation. Therefore we set interval time between knock and knock. Because we set 0.1 seconds as fading time, we do experiment to check knock speed that person make. the result is that it is complicated and almost impossible to beat the door below 0.1 second and we realize that it is pointless to just beating quickly because we think 'patterns' is a most important thing. If we get the input using another method, for example touch screen, we don't need to set up delay time for reverberation. Therefore in our work, we don't use delay time when system gets input.

5. Smartphone Application

FB155BC made by FirmTech firm support AT command, so we can control FB155BC using AT command (FirmTech). First connection mode becomes MODE4 and we change this mode to MODE2 for functions we want. MODE2 has functions to Standing by search (Inquiry Scan) or connect (Page Scan). If Master ask to connect, system check Pin code, and then if Pin code match up, connect will become success.

Table 1. FB155BC setting table

Item	Basic value	Change value
Device Name	FB155BC	GROUP1
Pin Code	btwin	0000
baud rate - data bit - parity bit - stop bit	9600-8-N-1	9600-8-N-1
ROLE	Slave	Slave
Connection Mode	MODE4 (AT command)	MODE2
Debug Char	0x02	0x02

Table 2. Transmit receive table

Application			ATmega128
Case connected with Bluetooth	U	⇨	Transmit current knock count and sensitivity
Case touch the screen	*	⇨	Accept the touch signal
In the case entered the password , transmit passwords like (1 2 3 4)	(	⇨	Start to accept touch signal
	)	⇨	Complete to accept touch signal
Show the message "The door is opened"	⇦	O	In case of door open
Show the message "The door is closed"	⇦	C	In case of door open
Show the message "Change the Pattern or Password or Setting"	⇦	P	In case of pressing setting button
Transmit setting character like & h m & (h : high, m : middle)	&	⇨	Starting or completing to change setting values
Show the message "Please enter your Pattern again"	⇦	M	In the case of changing passwords or knock pattern
Show the message "Fail change"	⇦	E	Fail to changing passwords/knock pattern/ setting values
Show the message "Success change"	⇦	S	When success changing passwords/knock pattern/ setting values
Display current knock count and sensitivity	⇦		

The application and main processing system use RS232 serial communication and ATmega128 and application send and receive appointed character for the according event as seen in table1. Finally if the main system or application gets the character, they output the appropriate result.

Smartphone application screen is composed of tapping patterns, entering the passwords, and changing the setting values like Figure 22. We make a function of change of setting values to compensate the defect due to knock sound. We can control door sensitivity and knock maximum number using setting area. Door sensitivity means the door area than can recognize knocking and loudness level that can distinguish whether the sound is knocking or noise.

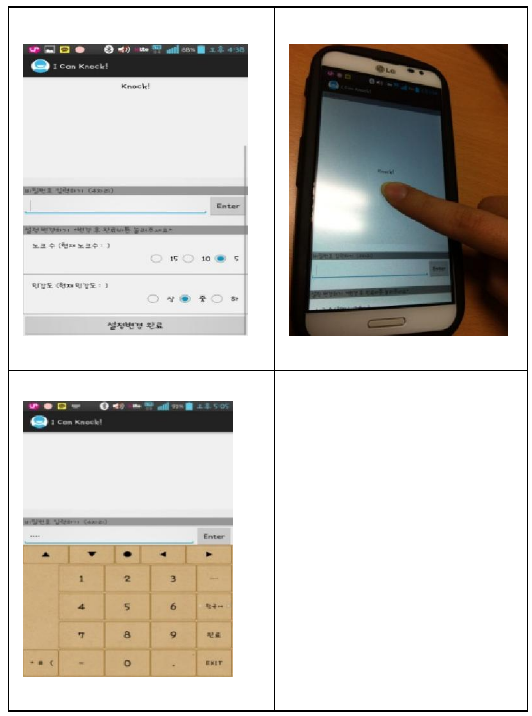


Figure 22. Smartphone application screen
(Above left : The entirely screen
Below left Area of entering password
Above right : Tapping the screen)

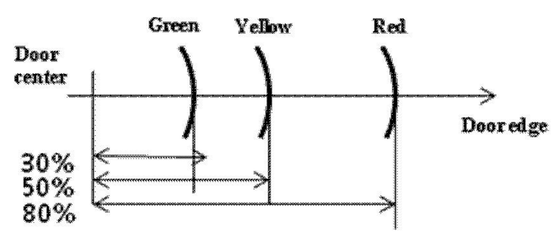


Figure 23. Sensitivity area on door

We set the sensitivity based on our test door. Changing the sensitivity setting in smart phone application from high to low, we check range of recognition and decide threshold. Threshold uses to decide whether knock or not. In the case of high sensitivity, system recognize knock in 80% area of door, and we mark red in this part. In the case of middle sensitivity, system recognize knock in 50% area of door, and we mark yellow. And lastly in the case of low sensitivity, system recognize knock in 30% area of door, and we mark green.

6. Applied Field

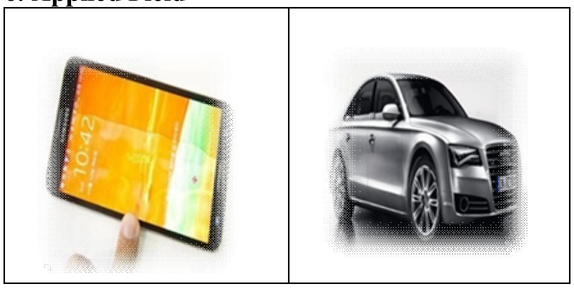


Figure 24. Applied filed
(left : Securing application
right : Door lock in car)

The basic idea using in our work can apply many fields. First, we can use securing application when we enter in smart phone main. We usually use pattern drawing in securing application, but this method remains fingerprint and so easily realize patterns. Our work just needs small tapping area. That means that user doesn't need to touch specific area. It will increase security and presents new form securing application. Second, we can use it in original door lock like our work. Lastly, we can use it as an emergency key in the case that you put the key inside of the car. Our work doesn't need to carry something and don't damage external appearance, so it is suitable for emergency key.

7. Conclusion

In this paper, door lock that recognizes a pattern of knocking and a smart phone application was presented. A door lock that uses pattern of knocking and, by extension, a smart phone application that can control setting values and function as knocking the door compensates for the defect of current door lock and presents a smart door lock alternative for the smart age.

Acknowledgements:

This study was supported by the Research Program funded by the Seoul National University of Science and Technology.

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