Authentication Mechanisms Using Raspberry Pi

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May 30, 2015

Outline

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  - Component failure results to contacting the manufacturing company, potentially resulting to replacing the entire unit.

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  - **Do-it-yourself**: The system can be replicated by assembling the components, and running our code. This is to improve overall transparency – users are more likely to trust a system if they know how exactly it was made.
  - **Open Source Code**: We have documented our code extensively so that users can easily modify or extend the system functionality. Hoepman and Jacobs[2] found that keeping the source open improves security, because all interested parties can test for vulnerabilities, and promptly fix them.

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- **Increased Flexibility**: Although our system supports multiple authentication methods, users do not have to buy a component they will not use. However, should the need arise, they can easily connect the said component later on. This is an advantage over propriety systems, which typically come as a package and can no longer be modified or extended.

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- **Can run on top of existing networks**: Our system uses plain local ethernet for communication between the server and the door controllers. This lessens the cost of hardware set-up and maintainance, and also makes the system more scalable because there is no hard limit on the number of controllable doors.

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- **Encrypted database and data transmission**: We have designed the system such that no sensitive information is transmitted in plaintext over the network. In the door controller, the data is hashed first before being sent to the server; while in the database, credentials are not stored in plaintext; Instead, they are hashed or symmetrically encrypted.

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- **Low Acquisition Cost**: The cost of a single access control device typically ranges from \$100 to \$350 (based on the prices listed at the online store BarcodesInc[3]). The combined cost of our system's components falls within the lower end of that range.

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- There are as many SpoonPis as there are doors to be secured, but only one ForkPi for the entire network.

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- There are no system-wide constraints with regards to the mechanism to be used. Each user can choose to authenticate using any combination they wish; SpoonPi can handle all five mechanisms by default.

Three Major Factors

Authentication is performed using various **factors**, which can be classified into three major types:

1. **Knowledge**: Something the entity knows (e.g. passwords)
2. **Biometrics**: Something the entity is (e.g. fingerprints)
3. **Possession**: Something the entity has (e.g. RFID tags)

Factor Strengths and Weaknesses

Each factor type has its own strengths and weaknesses, as illustrated in the following table. For consistency, each criterion is stated such that a Y is an advantage.

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[4] People can lose their fingerprints, but it is a much rarer event than losing keys or

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- **Inherence-based**: Fingerprint was chosen because it is the most prevalent and well-supported biometric.

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- This device can be either a computer or a microcontroller, and should preferably be cheap and small since one unit would have to be embedded on each door.
- The Raspberry Pi is an example of one such device. It is a credit-card sized computer that comes with pins that can be used to communicate with or provide power to peripherals.

Why Raspberry Pi (2 of 2)

- The Raspberry Pi model we used for development, Model B[4], is an outdated model that costs $35, uses an SD card for storage, and comes with 26 pins, 2 USB ports and 512 MB RAM.

[4] *Raspberry Pi 1 Model B+*. https://www.raspberrypi.org/products/model-b-plus/. Accessed: 2015-04-19.

[5] *Raspberry Pi 2 Model B*. . https://www.raspberrypi.org/products/raspberry-pi-2-model-b/. Accessed: 2015-04-19.

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- The Raspberry Pi model we used for development, Model B[4], is an outdated model that costs $35, uses an SD card for storage, and comes with 26 pins, 2 USB ports and 512 MB RAM.
- For the same price, one can buy the newer and better Raspberry Pi 2 Model B[5] instead, which uses a micro SD card for storage, comes with 40 pins, 4 USB ports and 1 GB RAM. Both models have an ethernet port and an HDMI port for video output.

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[4] *Raspberry Pi 1 Model B+*. https://www.raspberrypi.org/products/model-b-plus/. Accessed: 2015-04-19.

[5] *Raspberry Pi 2 Model B*. . https://www.raspberrypi.org/products/raspberry-pi-2-model-b/. Accessed: 2015-04-19.

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  - If there is a new user, one would have to manually add that user to each door, and the reverse if a user leaves permanently.

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  - The question is whether an access control system warrants more power on the hardware (Arduino) or the software (Pi) side. In our case, door controllers need to be able to communicate with the server over a network, in addition to their main function of controlling the door lock, so we find Raspberry Pi to be the more suitable platform.

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Outline

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- This can be done by lowering its cost while maintaining an acceptable level of security.

Outline

1. Introduction
2. Related Work
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4. Design and Architecture
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   - ForkPi
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5. Evaluation
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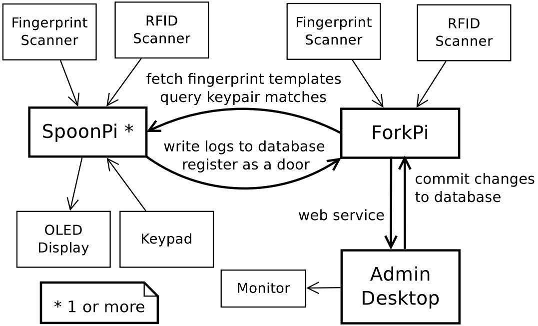

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- The web server has an underlying database run by PostgreSQL.
- Human administrators view ForkPi as a web server, while SpoonPis view ForkPi as a database server.

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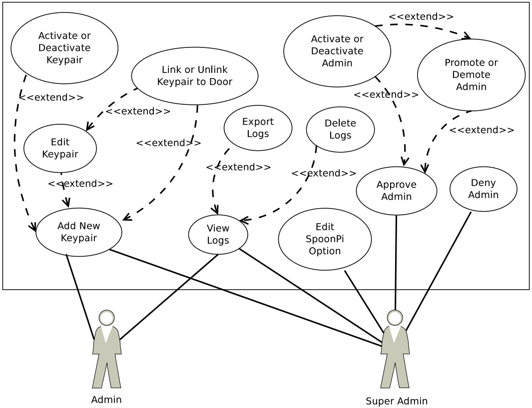
Use Case Diagram



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- New admin sign up requires the approval of another admin, and is a regular admin by default.
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- For fingerprint authentication, the verification is done at the SpoonPi side instead of the ForkPi side, because the matching is not a simple string comparison; fingerprint templates have to be uploaded to the scanner, where the actual matching takes place.

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SpoonPi Flowchart

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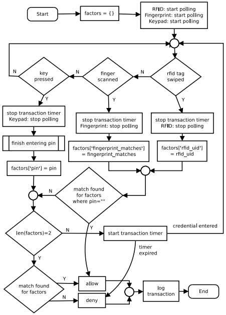

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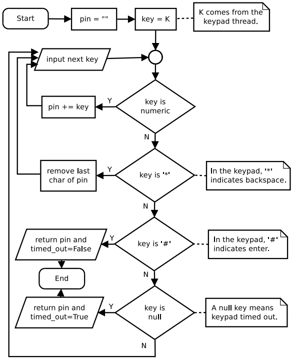

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Security Options (1 of 2)

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- **Max Transaction Time (seconds)**: This is the maximum amount of time between presenting two authentication tokens. The default value is 10 seconds.
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Outline

Security of the PIN Component (1 of 3)

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- If an attacker Oscar gets hold of an authorized RFID tag, he can gain access to a door if he guesses the corresponding PIN.
- However, a lockout functionality has been implemented for RFID authentication, so Oscar has to wait a long time between guesses.

Security of the PIN Component (2 of 3)

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- Plugging in those values, it would take, on average, 50694 hours, or about 5.78 years to crack. This makes brute force an impractical attack to use.

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- Hence, the user simply needs to go to the admin to get his keypair changed or deactivated.

Security of the RFID Component (2 of 2)

- Replication of an RFID tag can be performed by scanning its UID, and reprogramming another tag to have the same UID.

[17] *MiFare Classic (13.56MHz RFID/NFC) Card.* http://www.adafruit.com/product/359. Accessed: 2015-01-02.

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- MiFare in general is not known to be secure, as some attacks have been developed for it. De Koning Gans et al recommend that a more advanced RFID card technology with an open design architecture be used over MiFare[18].

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[18] Gerhard de Koning Gans, Jaap-Henk Hoepman, and Flavio D Garcia. "A practical

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- While a false negative (denying a user that is supposed to be authorized) might cause some minor inconvenience on the part of the user, a false positive (allowing a user that is not supposed to be authorized) is potentially devastating.
- However, an attacker cannot rely solely on chance in order to generate a false positive, since that probability is infinitesimally small (less than 0.00001% in our case).

Security of the Fingerprint Component (2 of 2)

- What the attacker can do is to make a clone of the registered fingerprint. This can be done by pressing the finger against various materials such as silicone or gelatin, in order to make a mold.

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- However, this attack relies on the attacker obtaining an accurate mold of the finger, which usually requires the cooperation and consent of the authorized user.

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Security Against Passive Attacks (1 of 2)

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- Hence, our system is secure against such attacks for both communication lines.
- **Communication between SpoonPi and ForkPi**: When a PIN is entered or an RFID UID is scanned, SpoonPi never queries for matches in plaintext. These two fields are hashed first using SHA-1, so Eve cannot retrieve their original values.

Security Against Passive Attacks (2 of 2)

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  - The same goes for when the admin adds a new keypair; the new keypair's credentials might be exposed to Eve. The impact is lessened in a system with multiple doors, since it would become more difficult for Eve to determine which door(s) a keypair is linked to.

Security Against Active Attacks (1 of 3)

- Let us assume that a malicious attacker, Mallory, is actively trying to break into the security of the system, either by targeting a single computer, or by pretending to be a certain computer to another computer.

Security Against Active Attacks (2 of 3)

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  - If Mallory was able to guess the username and password of the PostgreSQL database, she would gain access to it.
  - However, she will not be able to retrieve the PIN and RFID UID in plaintext, since they are encrypted in 128-bit AES.
  - Gaining access to the database can still potentially damage the system because Mallory can delete all the tables and rows. This is a severe attack on the system, so it is highly recommended to have a strong username and password for PostgreSQL.

Security Against Active Attacks (3 of 3)

- **Man In The Middle Attack**:

[20] M. Krochmal S. Cheshire. *Multicast DNS - RFC 6762.* Feb. 2013.

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  - All computers in the local network refer to ForkPi using `forkpi.local`

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  - These numbers are assigned according to the order of start-up. Hence, provided that the ForkPi unit is started before Mallory's computer, `forkpi.local` will refer to the real ForkPi unit. Therefore, it will be hard for Mallory to pass off her own computer as the ForkPi unit.

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Usability (1 of 4)

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I thought the prototype was too complicated.	7	2	0	0	0
When I was using the prototype, I always knew what I was expected to do.	0	0	0	4	5
I thought the prototype was efficient.	0	0	0	4	5
I would be happy to use the prototype again.	0	0	0	2	7
I found the prototype confusing to use.	6	3	0	0	0
The prototype was friendly.	0	0	0	4	5
I felt under stress when using the prototype.	7	2	0	0	0
I felt this prototype was secure.	0	0	0	4	5
The prototype has a nice user interface	0	0	0	3	6
This prototype has potential.	0	0	0	1	8
I found the prototype frustrating to use.	7	1	1	0	0
I enjoyed using the prototype.	0	0	0	4	5
I felt flustered when using the prototype.	7	0	2	0	0
I think the prototype needs a lot of improvement.	1	6	1	1	0
I had to enter too many details during the prototype.	3	5	1	0	0
I felt the prototype was easy to use.	0	0	0	3	6
I felt that the prototype was reliable.	0	0	1	3	5
I had to concentrate hard to use the prototype.	3	5	1	0	0
I did not feel in control when using the prototype.	4	4	1	0	0
I would use this prototype in my house.	0	1	2	1	5

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Usability (2 of 4)

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- There was a total of nine respondents from different walks of life:
  - Four of the respondents were female, while five were male.
  - Four of the respondents were within the 18 to 25 age range, the other four were within the 26 to 40 age range, and the remaining respondent was aged 68.

Usability 3 of 4)

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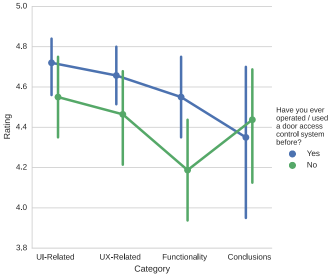

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- An exception, however, occurs with questions pertaining to drawing conclusions from the system (e.g. "The prototype has potential."), where the respondents with no experience ranked the system more favorably.
- Overall, the respondents rated the system positively, commenting that the system shows promise and has a lot of potential, especially compared to products that are currently in the market.

Cost-Effectiveness (1 of 3)

- In this section, we list all the hardware components we used for the system, along with their respective prices.

[21] *Amazon.com: Online Shopping for Electronics, Apparel, Computers, Books, DVDs & more*. http://www.amazon.com/. Accessed: 2015-05-28.

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- We also compare the total price of our system against similar commercial products that are for sale on Amazon.

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Cost-Effectiveness (2 of 3)

- In determining the price ranges, we took a look at the price filters on Amazon, and for each price range, we multiplied the number of items by the maximum amount in that range. (e.g.: For the $200 and above price, we set the price to $250.)

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- In determining the lower end of the range, we set the count of the most expensive group to 0, and took the mean price. For the higher end, we set the count of the least expensive group to 0, and took the mean price.

Cost-Effectiveness

	Component	Cost: Project	Cost: Commercial
Base	Raspberry Pi Model B	$35	$35
	OLED Display	$17.50	$10 - $20
	Raspberry Pi Cobbler Breakout	$6.50	$6 - $11
PIN	Keypad	$3.95	$2.5 - $7
RFID	Reader	$39.95	$30 - $80
	MiFare Classic 13.56MHz Card x1	$2.50	$0.5 - $1.5
	Total (Base+RFID+PIN)	$102.9	$80 - $140
Fingerprint	Scanner	$49.95	$40 - $90
	Total (Base+Fingerprint+PIN)	$110.4	$100 - $170
	Total (All Components)	$152.85	$140 - $200

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    - Potentially useful as extra features.

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- In the code, however, we have created a dummy door lock class which we give instructions to, like `lock` or `unlock`, so that future researchers will have less trouble implementing the real door lock class.

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- An exit button needs to be connected to the door lock, in order to temporarily unlock it when it is pressed.
- This can be implemented using pure hardware wiring; it does not necessarily have to pass through the SpoonPi unit.

Power Supply

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- Such a power supply would enable SpoonPi to function even after a power outage, and determine when to release all door locks and shut down.
- Another potential improvement for the system is the use of Power Over Ethernet (PoE), so that only one cord needs to be attached to each Raspberry Pi unit. With this, we can provide power and transmit data over the same wire.

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- This can be done in the form of a LED light that is only on when it is connected to ForkPi.

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- Instead of querying the ForkPi database for every transaction, it would be better for the SpoonPi to maintain its own copy of authorized keypairs, so that it can function after a network failure.
- This can be implemented as a cached database copy, which is periodically updated whenever SpoonPi is connected to ForkPi.

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- Each ForkPi must be able to stand on its own without the help of KnifePi, so that KnifePi does not become a single point of failure.
- ForkPi units can be connected to different networks, as long as KnifePi can reach all of them. For example, one ForkPi can be dedicated to each floor, and one KnifePi for the entire building.

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- However, there is no easy way to back-up keypairs to a file such that they can be restored later if the need arises.
- Theoretically, this can be done by dumping the PostgreSQL database and restoring it, but we want to be able to do this inside the web app for convenience.

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- For example, students should only be allowed into classrooms when they have a class at that time.

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- The hardware components, like the Pi controller or the door knob, can also be checked for damage, since an intruder may try physically breaking the system in order to get in by force.

Conclusion(1 of 2)

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- Since all the system components can be easily bought from online stores, and we made the code open source, any user that wants to try out the system can build the system for themselves.
- While the door lock has not yet been integrated into the system, all other major functions are already in place, like determining whether to allow a user based on their input credentials, managing user permissions, and viewing and exporting logs.

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- When we presented the system, it was well-received, whether the person had prior experience with similar systems or not.
- We have shown that the system is both acceptably secure, and easy to understand and operate, while still costing less than most commercial products currently available in the market.