

# AR in Data Centers

*VE450 Capstone Project Final Defense*

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Group 21

Instructor

Sponsor

Mentor

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vmware®



# Team Introduction



**Leader**

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Senior  
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**Member**

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Senior  
ECE



**Member**

**Liying Han**  
Senior  
ECE



**Member**

**Yaxin Chen**  
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ECE



**Member**

**Jinglei Xie**  
Senior  
ECE



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- Introduction
- Customer Requirements & Engineering Specifications
- Concept Generation & Selection
- Final Design Description
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# Maintenance & Audit in Data Center (DC)

**Maintenance & Audit  
are extremely important**

Ensure the normal work of

- Servers
- Devices
- Power & cooling system



google.com

# Problems & Needs

Problems with current systems to aid DC maintenance and audit work:

- Do not have software systems to **integrate** all necessary information
  - Assets
  - Power
  - Environment
- Lack **easy, vivid, and user-friendly** information access



[www.cisco.com](http://www.cisco.com)

# Problems & Needs

- Do not have software systems to **integrate** all necessary information



An integrated system that involves all the information together

- Lack **easy, vivid, and user-friendly** information ccess

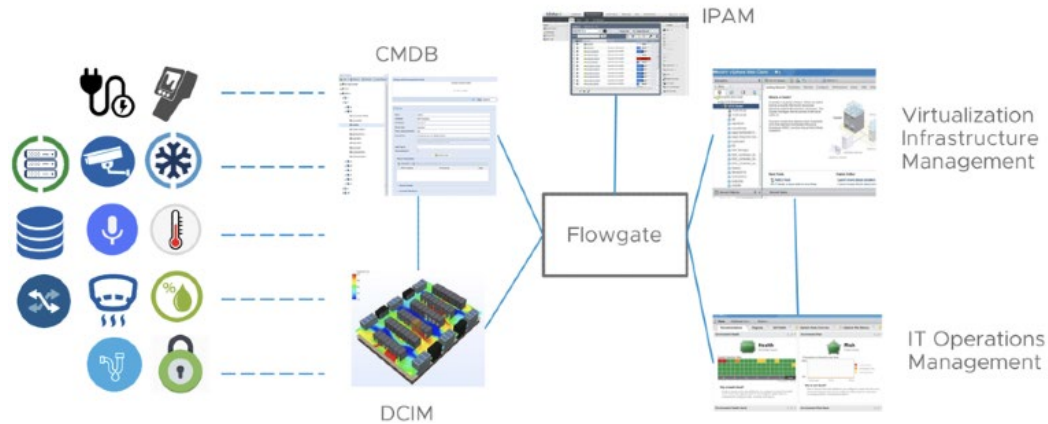


A more user-friendly tool to aid on-site maintenance and audit work



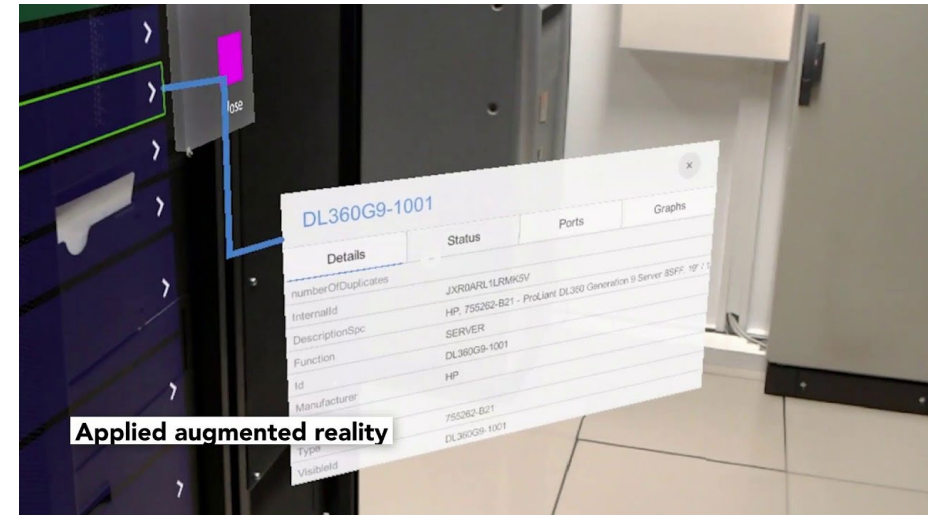
# Project Goal

[github.com/vmware/flowgate](https://github.com/vmware/flowgate)



➤ **Back-end: Flowgate**

[youtube.com/watch?v=1Pe028PjQhs](https://youtube.com/watch?v=1Pe028PjQhs)



➤ **Front-end: Augmented Reality (AR)**

**An AR app**  
for aiding on-site DC maintenance & audit

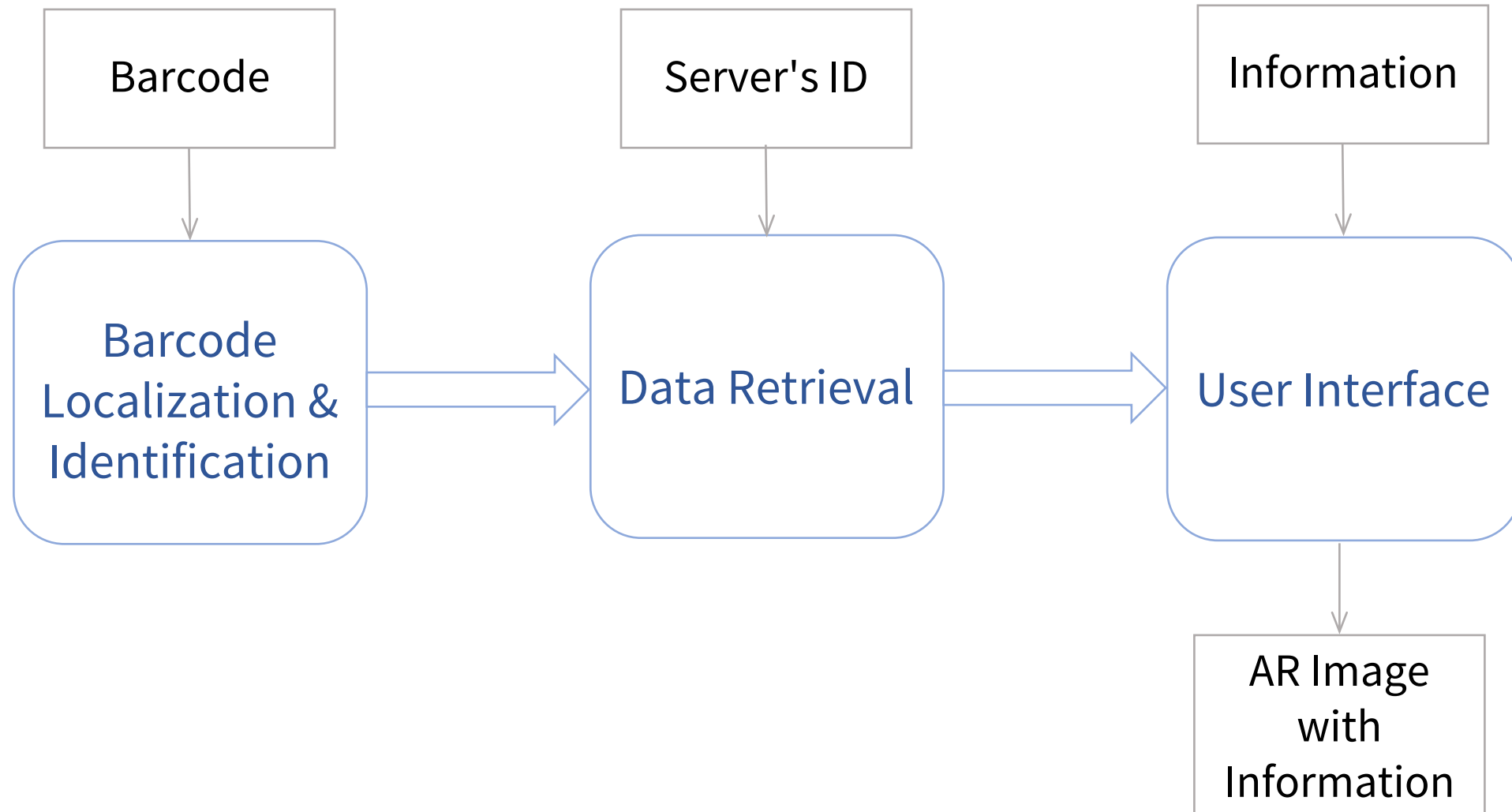




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# Concept Diagram



# Customer Requirements (CR)

**Short Reaction Time**

**Portability**

**Information Correctness**

**Comfortable Display**

# Customer Requirements (CR) & Engineering Specifications (ES)

## CR: Information Correctness

### ES:

- Barcode localization correctness: > 90% [1]
- Data retrieval accuracy: > 99% [2]

## CR: Comfortable Display

### ES:

- Frame rate: > 15 frames/s [3]
- Sensible temperature of device: < 40 °C [4]

[1] O. Oktay et al., "Stratified Decision Forests for Accurate Anatomical Landmark Localization in Cardiac Images," in IEEE Transactions on Medical Imaging, vol. 36, no. 1, pp. 332-342, Jan. 2017, doi: 10.1109/TMI.2016.2597270.

[2] [https://www.labce.com/spg650115\\_barcode\\_reading\\_and\\_accuracy.aspx](https://www.labce.com/spg650115_barcode_reading_and_accuracy.aspx)

[3] A. Craig. Augmented Reality Hardware, pp. 69-124. 2013.

[4] <https://support.apple.com/en-us/HT201678> & <https://support.google.com/pixelphone/answer/9134668?hl=en>



# Customer Requirements (CR) & Engineering Specifications (ES)

## CR: Short Reaction Time

### ES:

- Barcode localization & identification:  $< 0.55s$  [1]
- Database query complexity:  $O(\log(n))$
- AR image generation:  $< 0.1s$  [2]

## CR: Portable Device

### ES:

- Platform: Android 7.0+ / iOS 11.0+ [3]
- Light:  $\geq 40lx$  [4]
- Software package size:  $< 110MB$  for Android /  $< 940MB$  for iOS [5]

[1] E. Ohbuchi, H. Hanaizumi and L. A. Hock, "Barcode readers using the camera device in mobile phones," *2004 International Conference on Cyberworlds*, Tokyo, Japan, 2004, pp. 260-265, doi: 10.1109/CW.2004.23.

[2] A. Baek, K. Lee, and H. Choi, "CPU and GPU parallel processing for mobile Augmented Reality." 2013.

[3] <https://developers.google.com/ar/discover/supported-devices> & <https://developer.apple.com/documentation/arkit>

[4] L. Blom, "Impact of light on augmented reality." Diva Portal. 2018.

[5] <https://play.google.com/store/apps> & <https://www.apple.com/app-store>



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# Barcode Localization & Identification

## ➤ Barcode Localization & Identification

- Generated from ES & difficulty in implementation

## ➤ How to choose software development kit?



### ➤ ZXing [1]

- Open source
- Slow identification
- Low accuracy



### ➤ ML Kit

- Open source (Google)
- Moderate speed
- Moderate accuracy



### ➤ Scandit

- Close source
- Fast identification
- High accuracy

[1] [http://www.discoversdk.com/compare/scandit\\_-barcode-scanner-sdk-vs-zxing](http://www.discoversdk.com/compare/scandit_-barcode-scanner-sdk-vs-zxing)

# Concept Selection

Design criterion	Weight factor	Unit	ZXing			ML Kit			Scandit		
			Value	Score	Rating	Value	Score	Rating	Value	Score	Rating
Reaction time	0.17	Exp	Long	5	0.85	Fair	6	1.02	Short	8	1.36
Information correctness	0.5	Exp	Low	5	2.5	Fair	6	3	High	7	3.5
Implement. difficulty	0.17	Exp	High	4	0.68	Low	8	1.36	Low	8	1.36
Cost	0.17	\$	0	10	1.7	0	10	1.7	>100	2	0.34
			5.73			7.08			6.56		



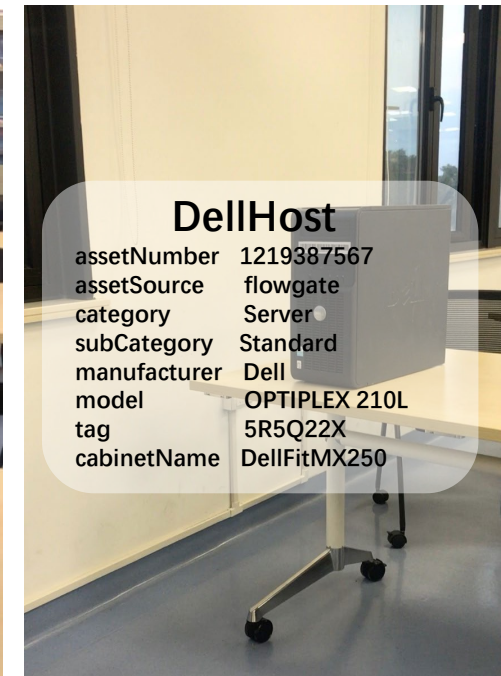
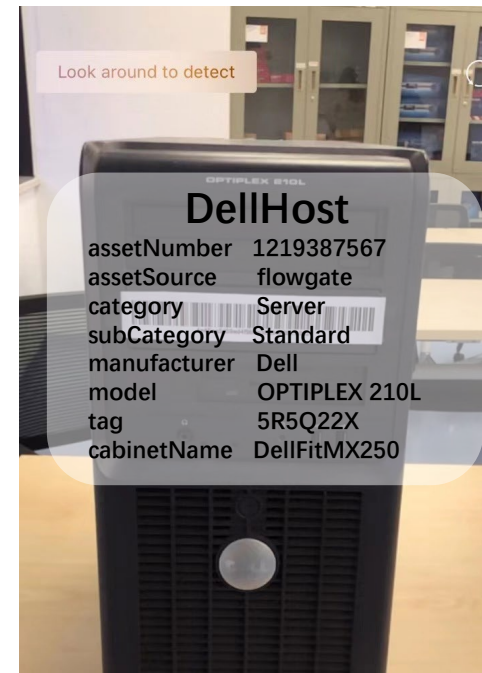
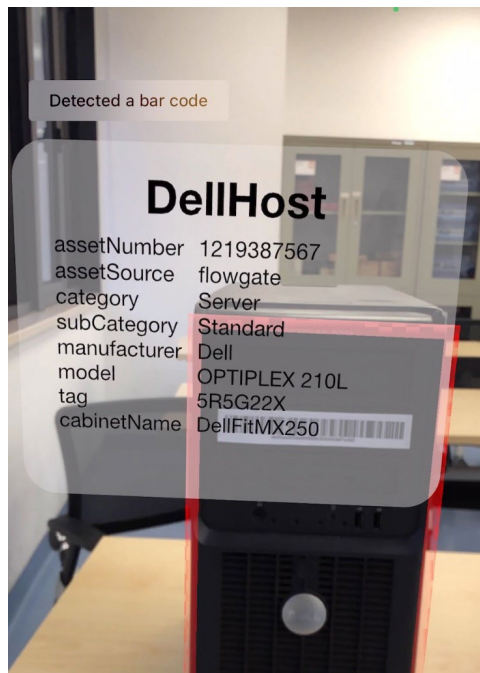
# User Interface

## ➤ User Interface

- Generated from CR & survey about existing similar softwares

## ➤ How to display information?

- Display in AR (3-D coordinate)
- Display on screen (2-D coordinate)



# Concept Selection

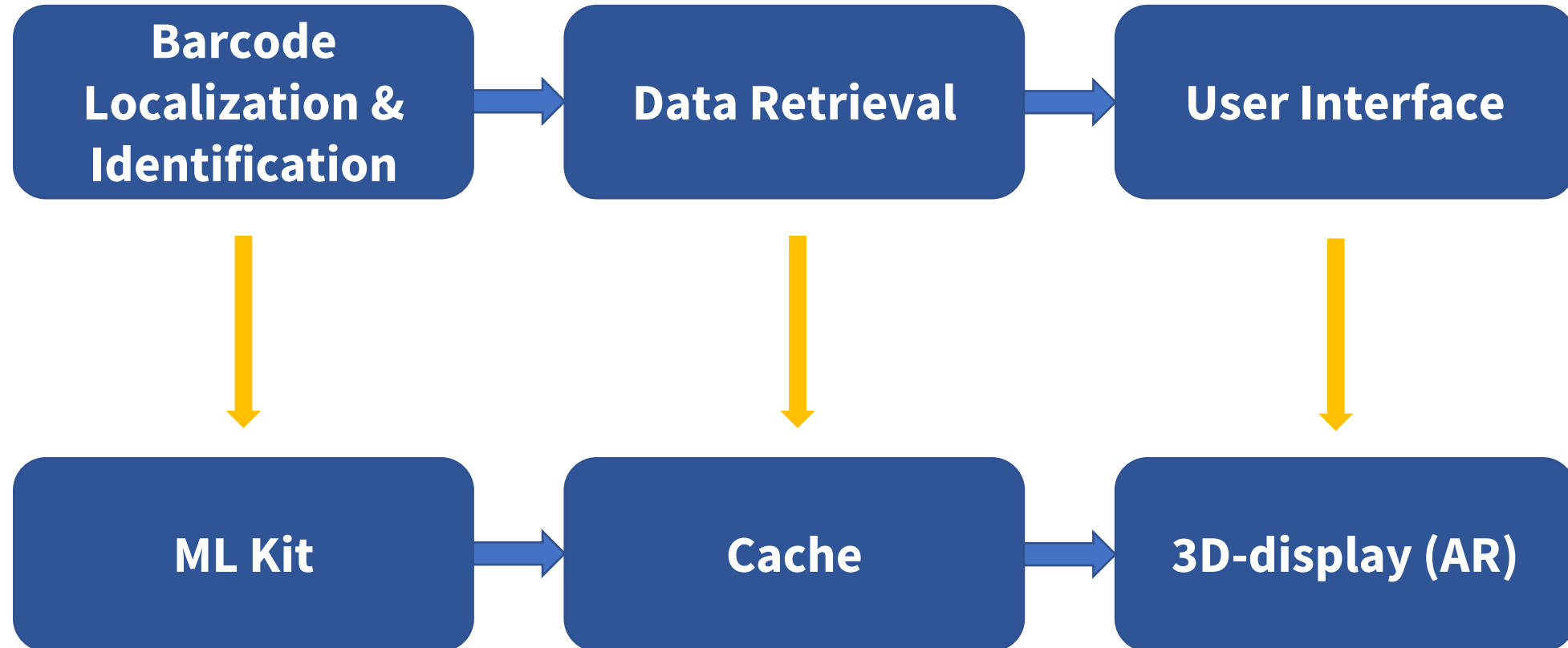
Design criterion	Weight factor	Unit	3-D display			2-D display		
			Value	Score	Rating	Value	Score	Rating
Read data	0.17	Exp	Fair	6	1.02	Clear	10	1.7
Select data	0.5	Exp	Easy	10	5	Difficult	7	3.5
Go to data	0.16	Exp	Fair	8	1.28	Easy	10	1.6
Implementation	0.17	Exp	Easy	8	1.36	Difficult	6	1.02
					8.66			7.82



# Contents

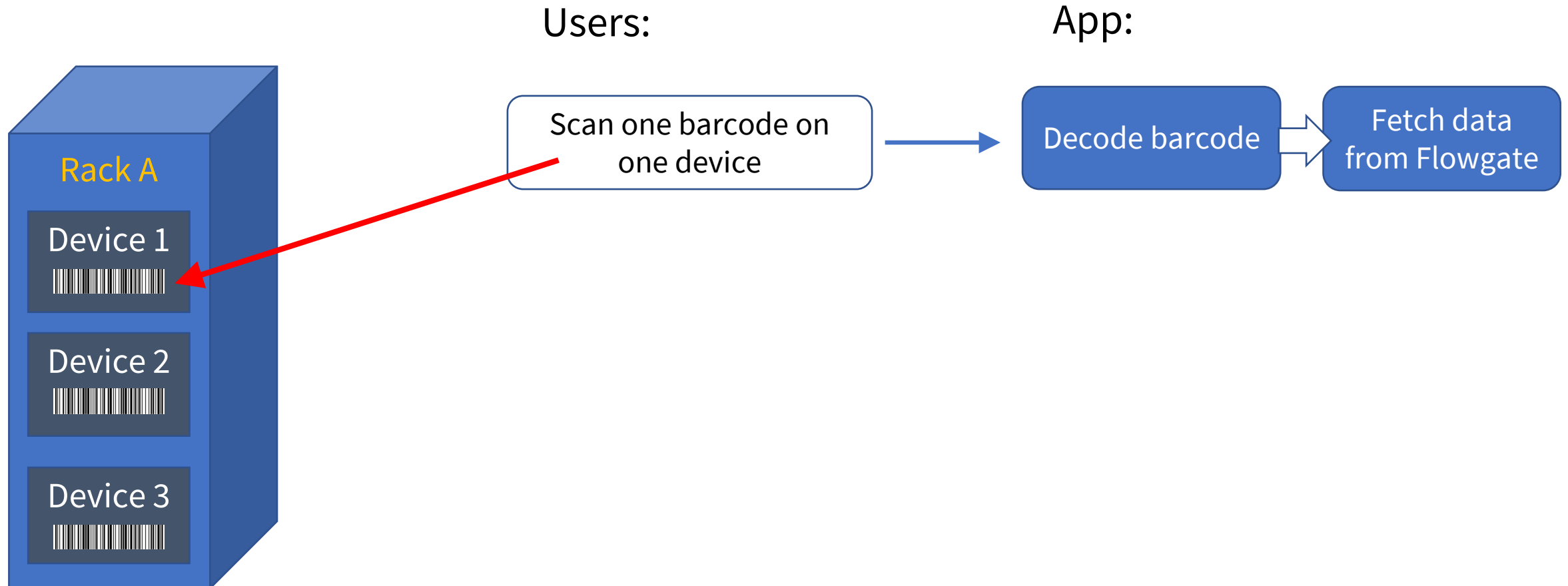
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# Final Design Components

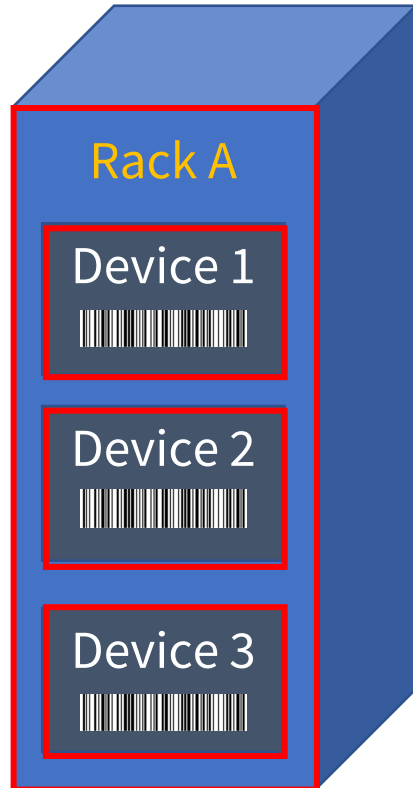




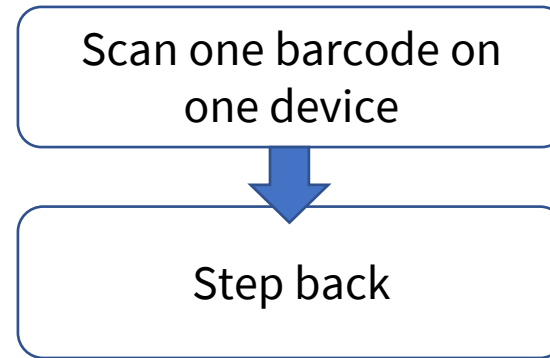
# Final Design Workflow



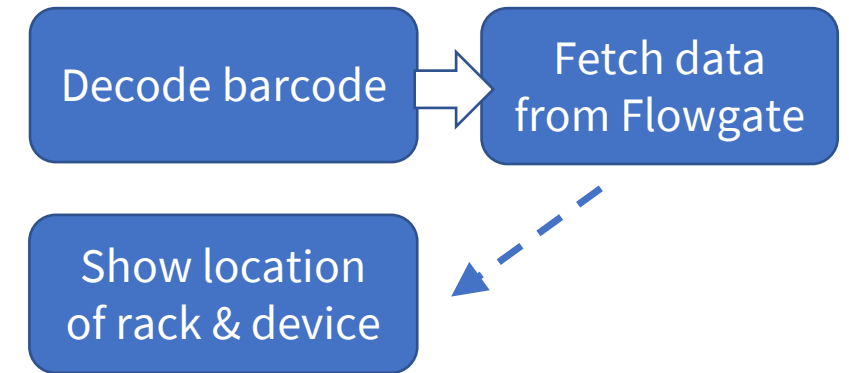
# Final Design Workflow



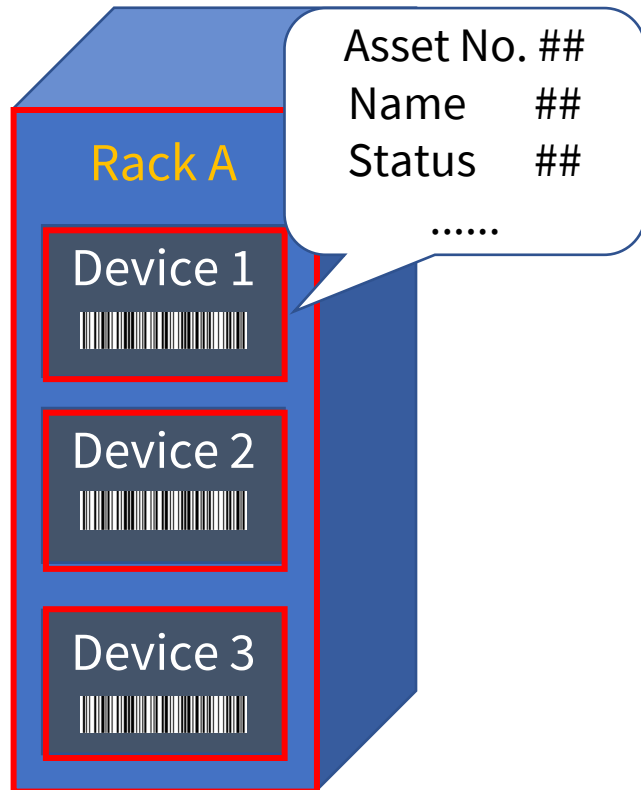
Users:



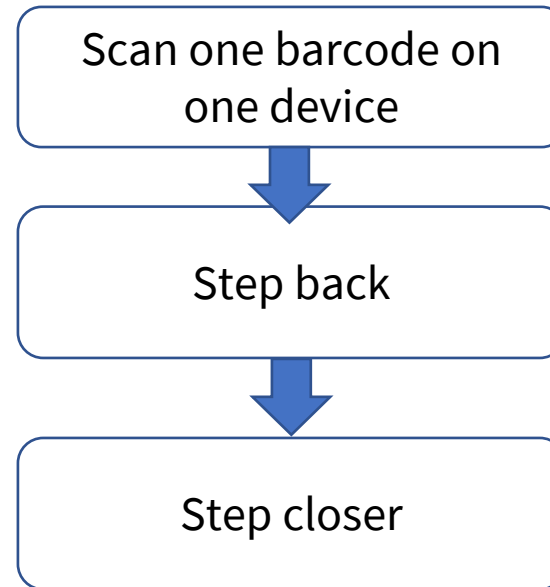
App:



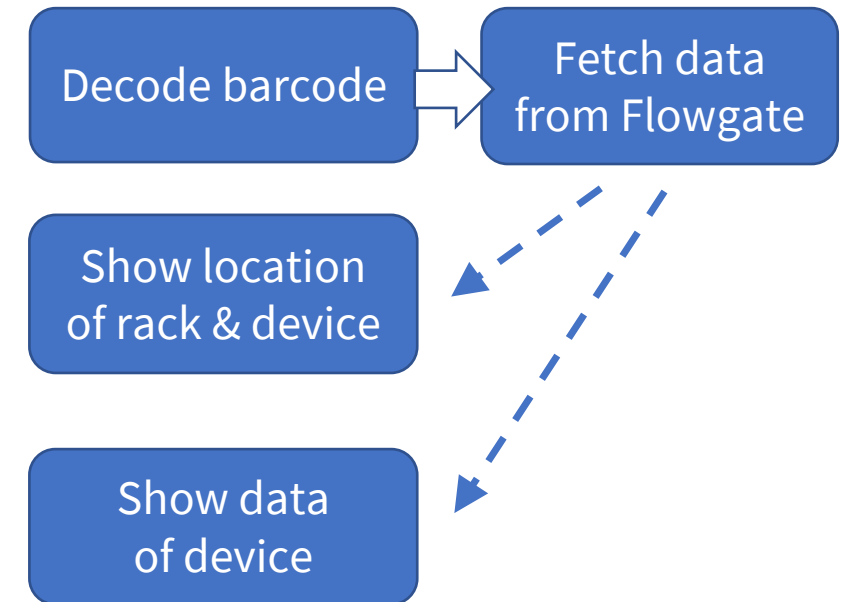
# Final Design Workflow



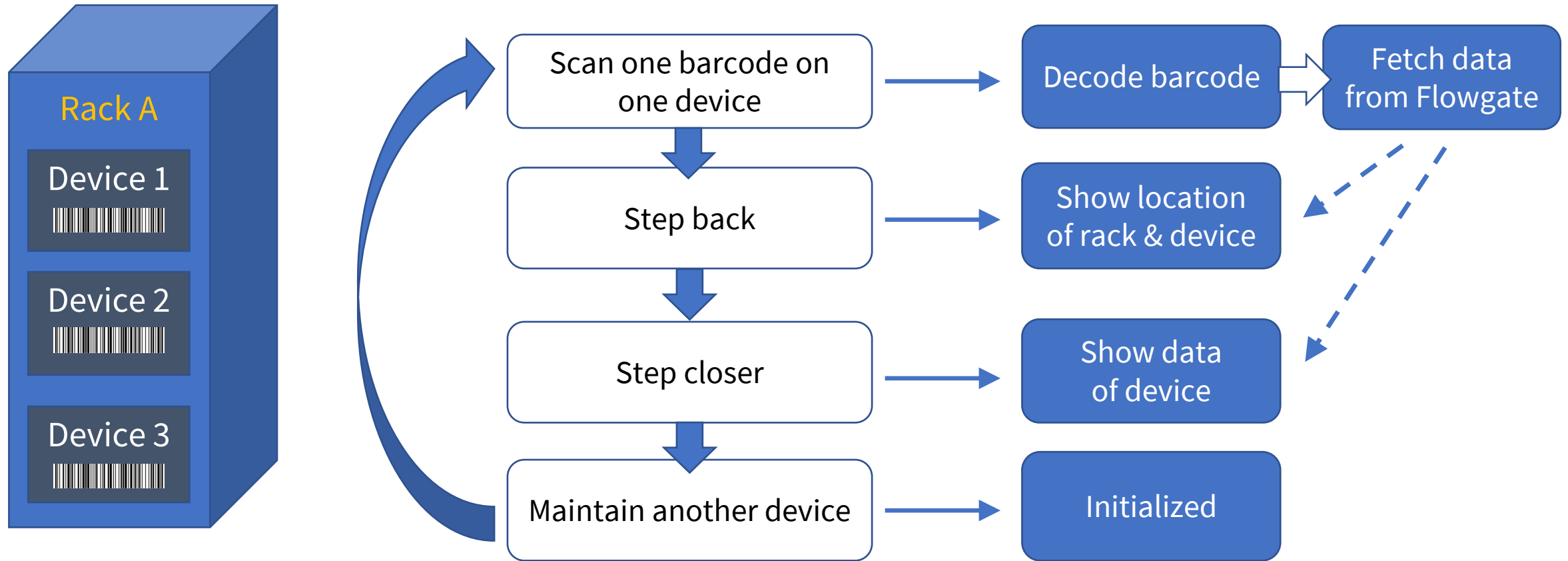
Users:



App:



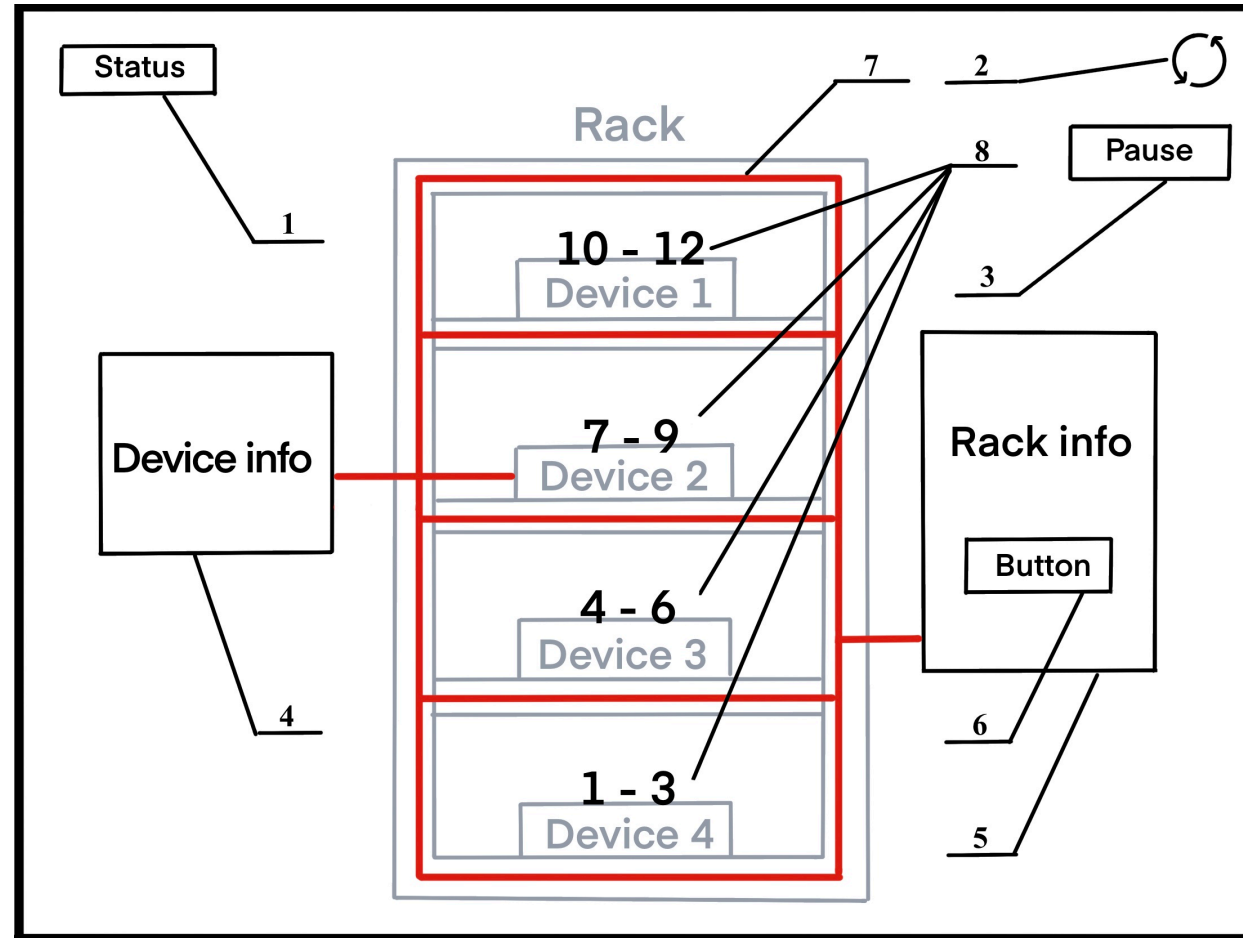
# Final Design Workflow





# User Interface Design

- 1) Display status of App
- 2) Reset
- 3) Pause
- 4) Show device info



- 5) Show rack info
- 6) Show temperature plot
- 7) Outline the rack with red
- 8) Show row number

# Final Design v.s. Engineering Specifications

ES satisfied by concept selection:

- Platform: Android 7.0+ / iOS 11.0+
- Frame rate: > 15 frames/s
- Database query complexity:  $O(\log(n))$
- Software package size: < 110MB for Android / < 940MB for iOS

ES satisfied in theory, but need further tests:

- Sensible temperature of device: < 40 °C
- Barcode localization & identification: < 0.55s
- AR image generation: < 0.1s
- Barcode localization correctness: > 90%
- Data retrieval accuracy: > 99%



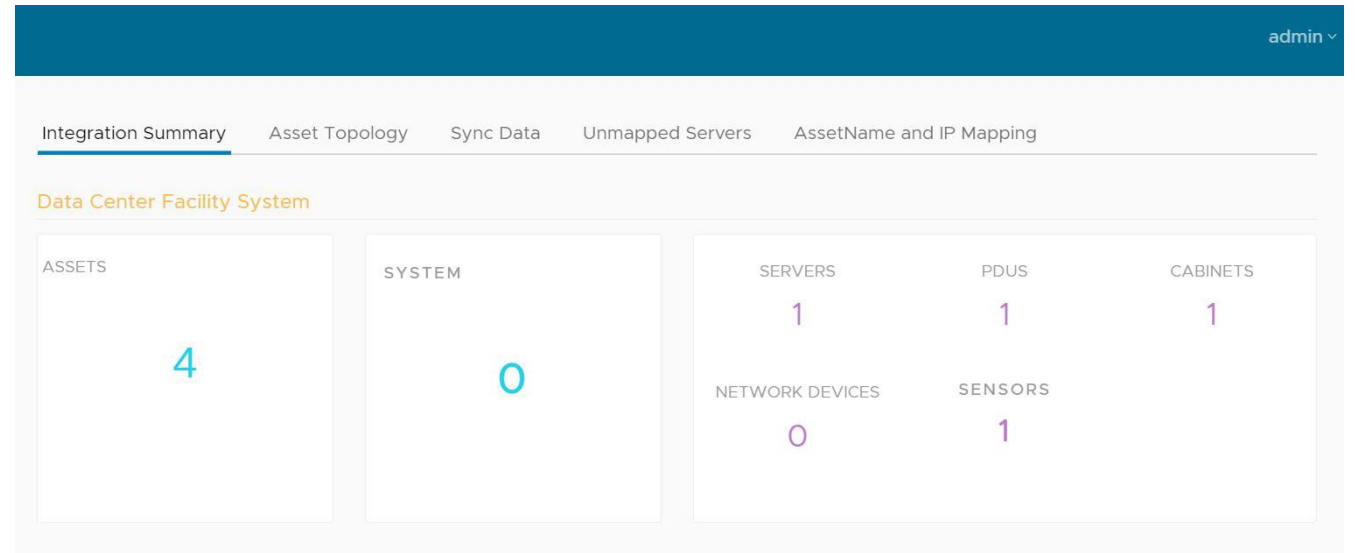
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# Steps of Implementation

## Step 1 Configure back-end server

- Install flowgate server
- Create informations sets for data center assets



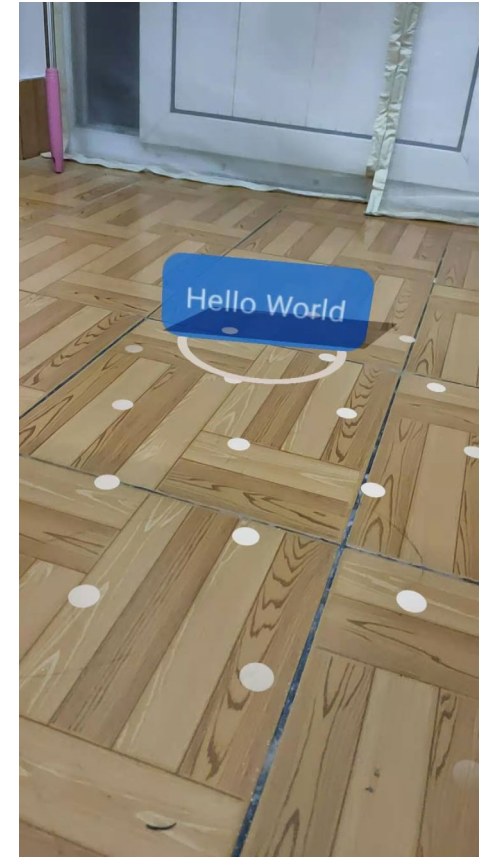
# Steps of Implementation

## Step 2 Realize subfunctions of front-end App

- Data retrieval (using API)
- Bar code scanning
- AR

display

```
Token: eyJ0eXAiOiJKV1QiLCJhbGciOiJIUzI1NiJ9.eyJzdWUiOiJBUEkiLCJpc3MiOiJGbG93Z2F0ZSIsImV4cCI6MTYwNTQ0OTQ4MSwiaWF0IjoxNjA1NDQyMjg5LjE2VjSWQ0iil4NmUyMzg3OGYzNzI0MDU4YWI5MmRiOWYyYmFIMjMyYyJ9.4bBPUVl6gAZRh8hnRlIQJKqnUTivJt_WJcl2haxElto
```

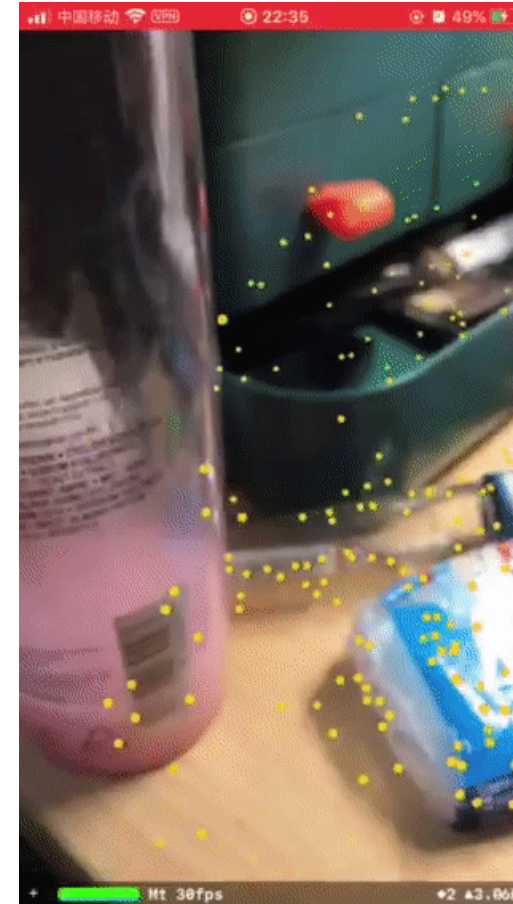




# Steps of Implementation

## Step 3 Integrate AR with bar code scanning

- Scan the bar code and place the readings onto a 3D window



# Steps of Implementation

## Step 4 Integrate AR, bar code scanning and data retrieval

- Scan the bar code, retrieve corresponding data from the backend server, and display the information onto a 3D window



# Steps of Implementation

## Step 5 Recognize racks / cabinets in AR

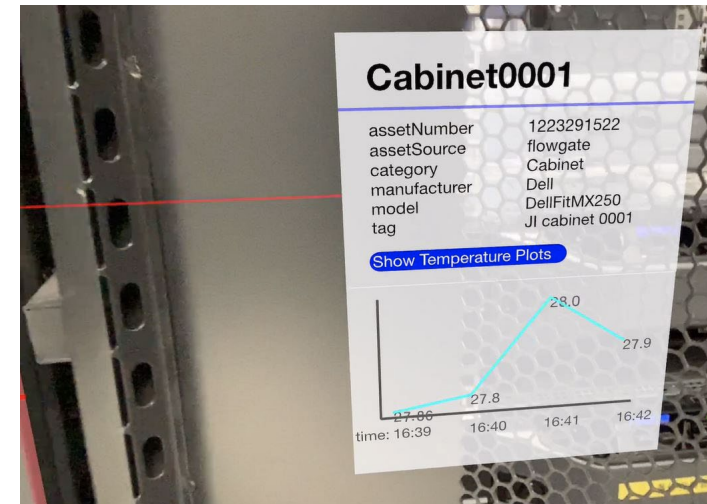
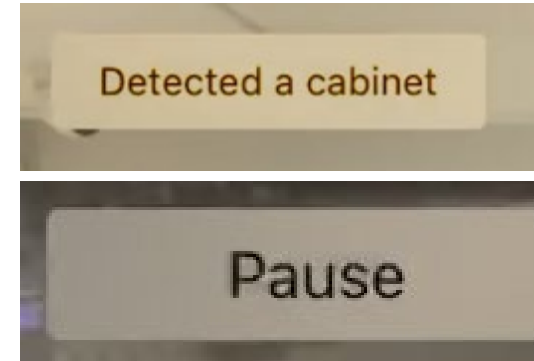
- Recognize a rack / cabinet, mark it with a blue rectangle and display its corresponding information in the AR interface



# Steps of Implementation

## Step 6 Improve UX

- Pause button
- Status window
- Show temperature plot





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# Design of Experiments

## ➤ Repeated trials to calculate success rate

- Object localization correctness
- Data retrieval accuracy

## ➤ Repeated trials to calculate average time

- Object localization time
- Barcode identification time
- Database query time
- AR image generation time

## ➤ Sampling to find the mean value

- Frame rate
- Device temperature in operation

## ➤ Direct reading

- Size of software package



# Test Results

	Test results	Expected results
Barcode identification time	≈ 0.85s	< 0.5s
Object localization time	≈ 0.23s	< 0.5s
Object localization correctness	≈ 98%	> 90%
AR image generation	< 0.1s	< 0.1s
Data retrieval accuracy	100%	> 99%
Database query time	≈ 0.89s	< 1s
Frame rate	≈ 60 fps	> 15 fps
Device temperature	≈ 39.5 °C	< 40 °C
Size of software package	≈ 16 MB	< 110 MB

# Strengths & Weaknesses

## Strengths

- ✓ Meet CR & most of ES
- ✓ Provide vivid information access with AR
  - Mark the structure of racks
  - "Freeze" function

## Weaknesses

- × Dissatisfy 1 ES: barcode identification time
- × Unable to strictly align the information with the plane of the device
- × Fail to identify various racks

# Future Development

## ➤ **Fix the weaknesses**

- Accelerate barcode identification ← Image recognition algorithms
- Alignment ← Display information based on relative position
- Identify various racks ← Machine learning

## ➤ **Add more features**

- Support a power saving mode
- Integrate QR code identification



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# Conclusions

## ➤ Objective

- To develop an app that can display information in AR to aid data center maintenance

## ➤ Design solution & outcomes

- Barcode identification → data retrieval → AR image
- Short reaction time, information correctness, comfortable display, and portable device.

## ➤ Achievements & lessons

- AR-based apps on both Android and iOS platforms
- Cooperation in software development



# Acknowledgements



## ➤ Sponsor

- Gavin Lu, VMware

## ➤ Mentor

- Yixing Jia, VMware



## ➤ Instructor

- Mingjian Li

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- Bin Zhu, Yunlong Cai





**Joint Institute**

**Q & A**