AR in Data Centers

VE450 Capstone Project Final Defense

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Team Introduction

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Maintenance & Audit in Data Center (DC)

Maintenance & Audit are extremely important

Ensure the normal work of

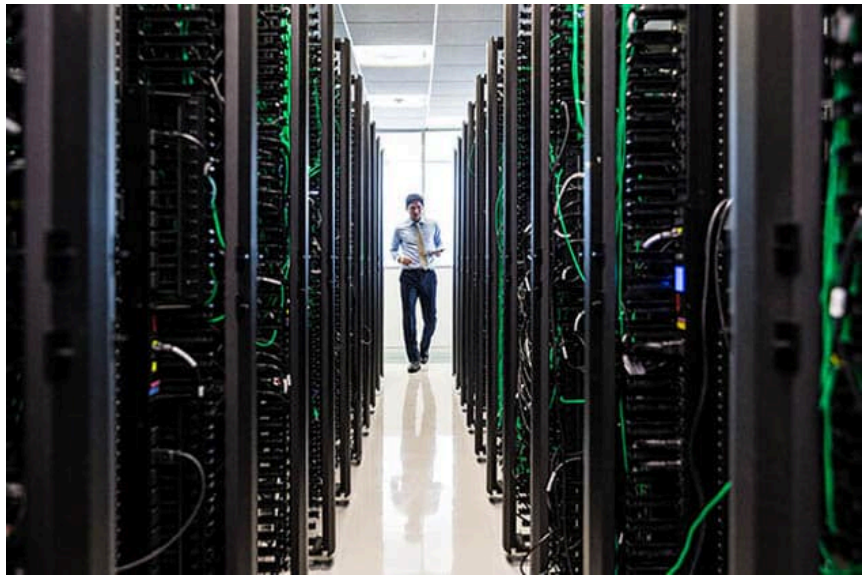
- Servers
- Devices
- Power & cooling system

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

Problems & Needs

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

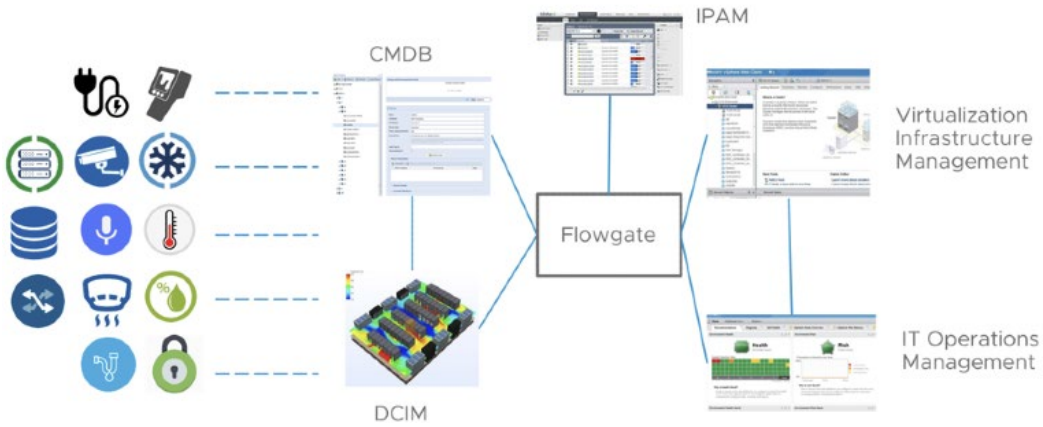
→ An integrated system that involves all the information together

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

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

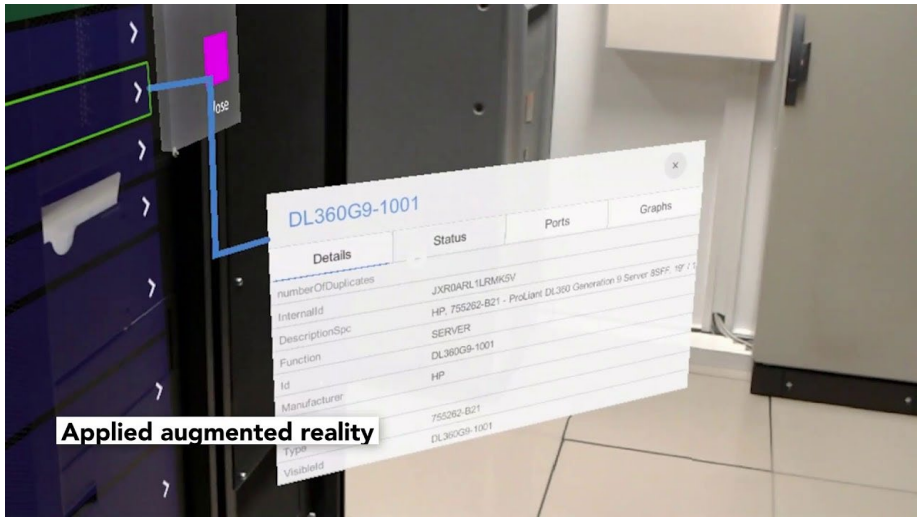
Project Goal

github.com/vmware/flowgate



➢ **Back-end: Flowgate**

youtube.com/watch?v=1Pe028PjQhs



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

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

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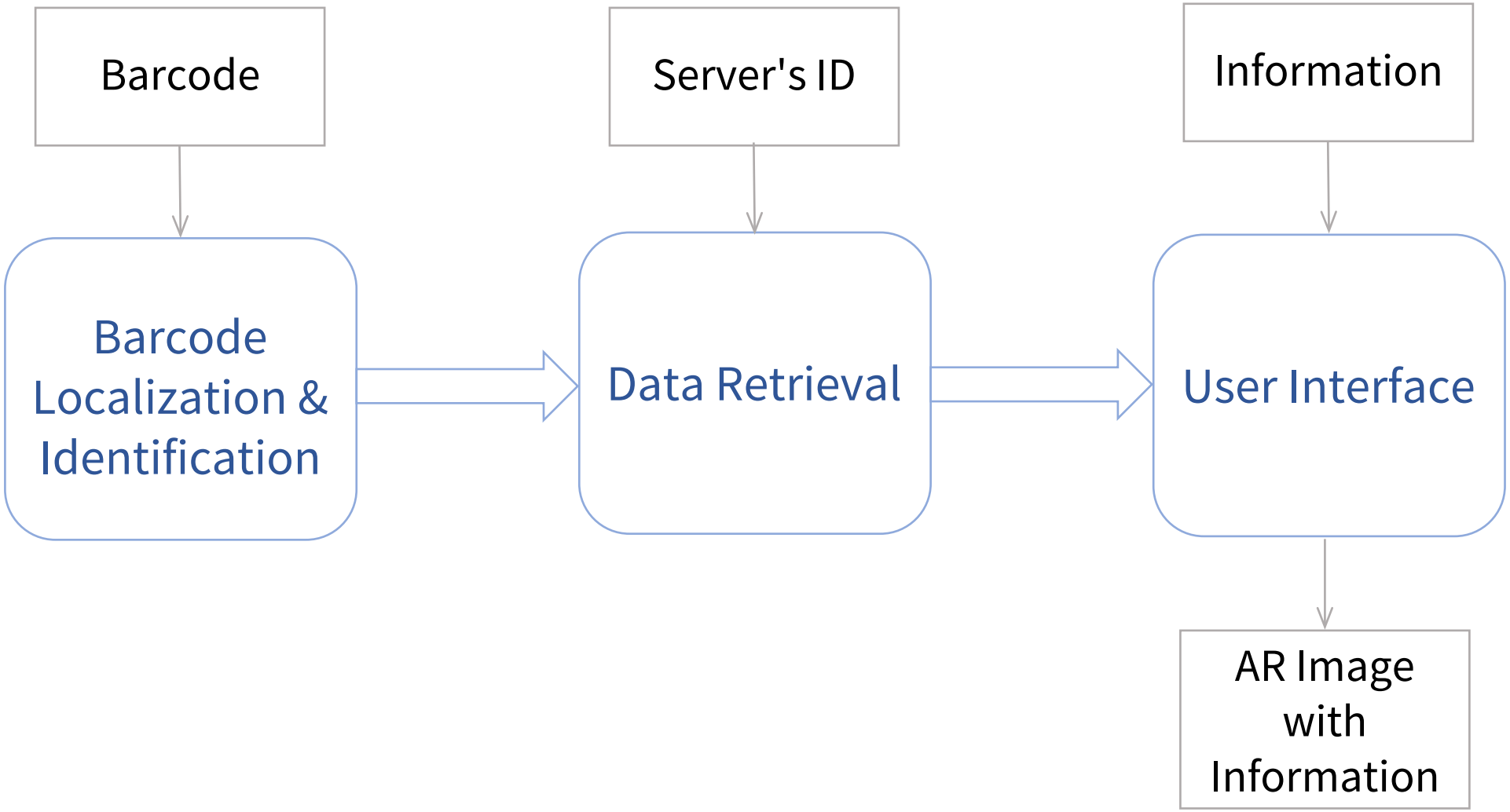
Concept Diagram



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
[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: >= 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

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

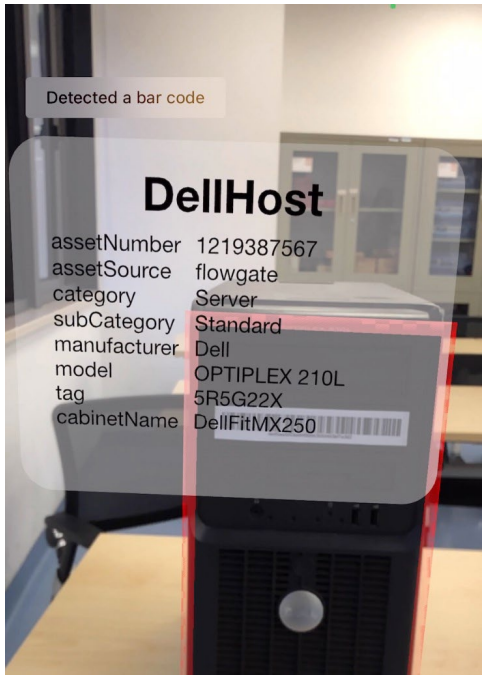
User Interface

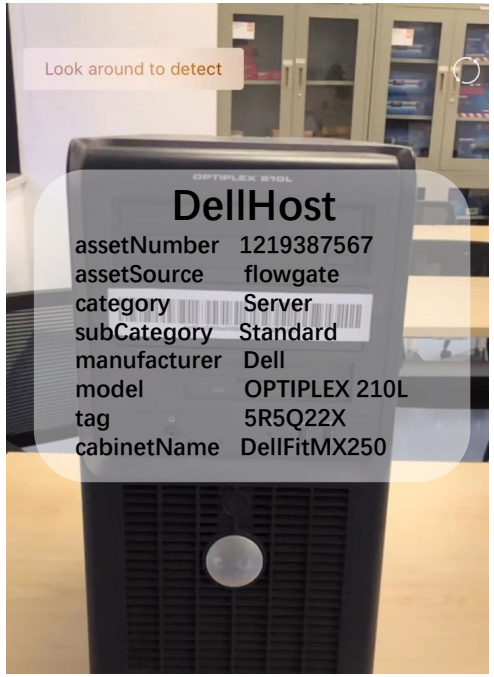
➢ User Interface

- 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

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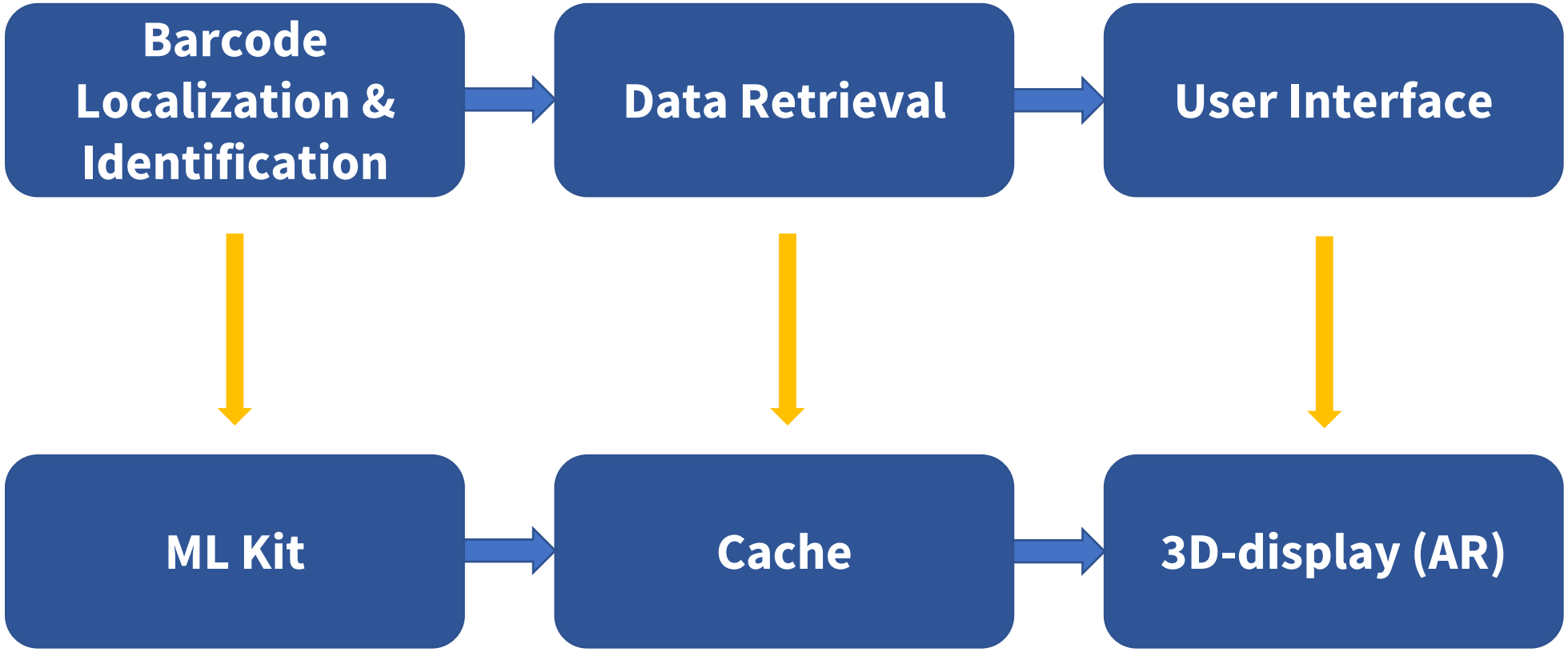
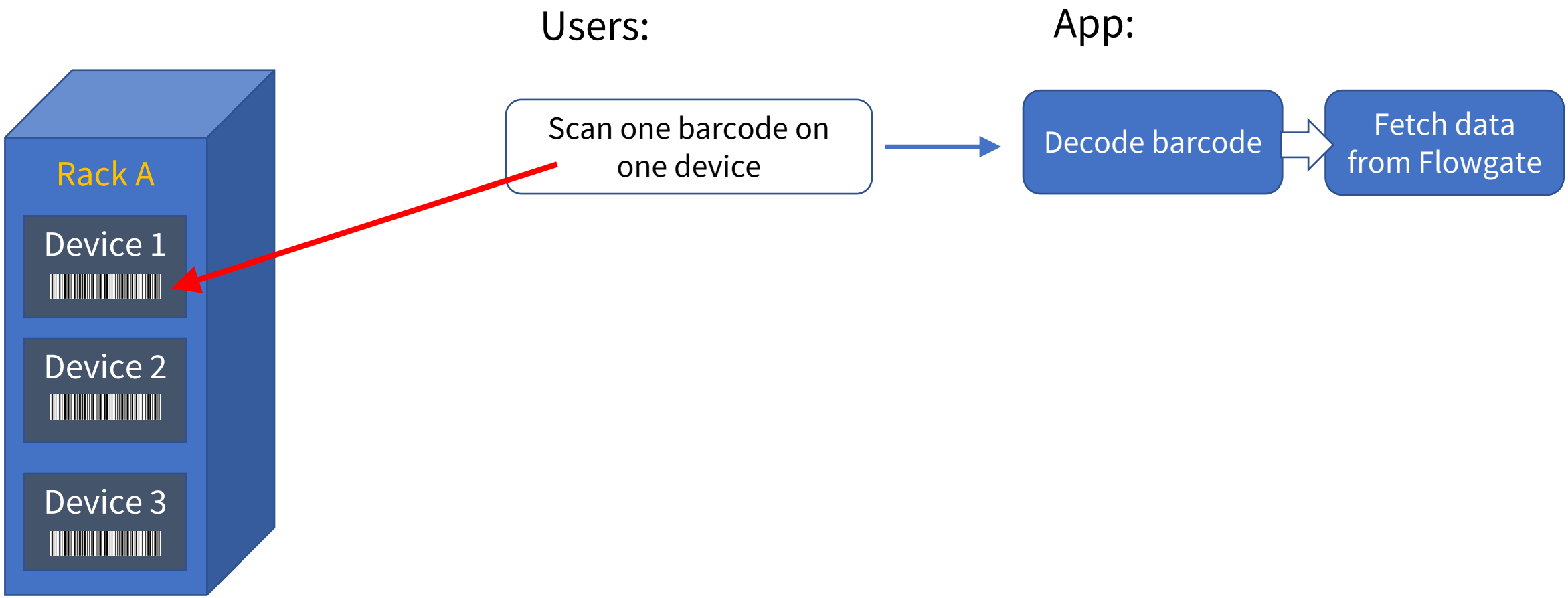
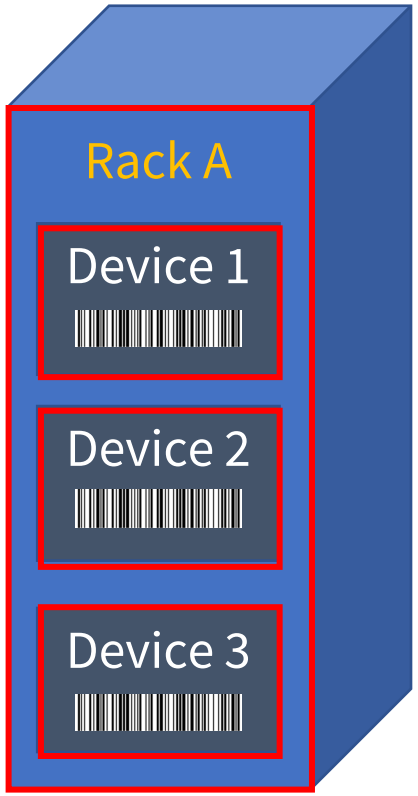
Final Design Components



Final Design Workflow



Final Design Workflow



Users:

App:

Scan one barcode on one device

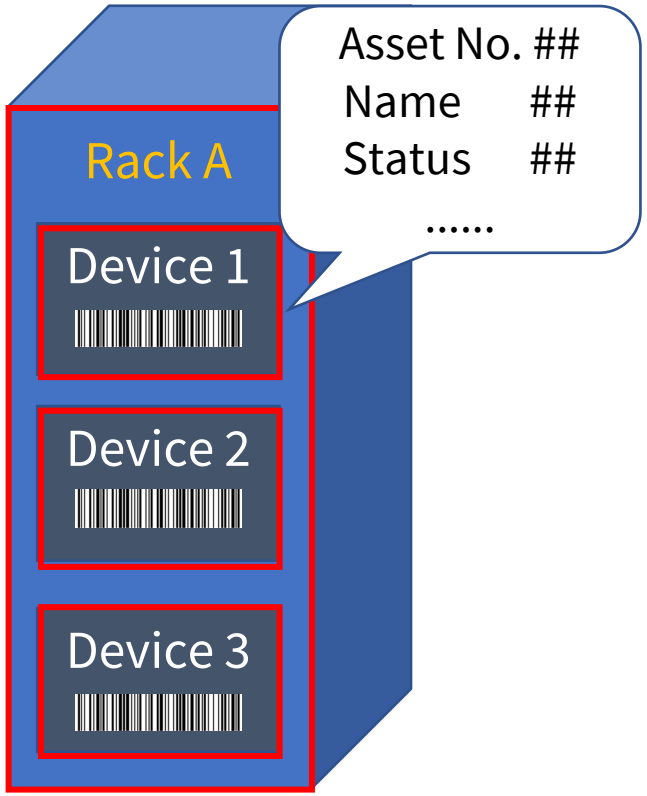
Step back

Decode barcode

Fetch data from Flowgate

Show location of rack & device

Final Design Workflow



Users:

App:

Scan one barcode on one device

Step back

Step closer

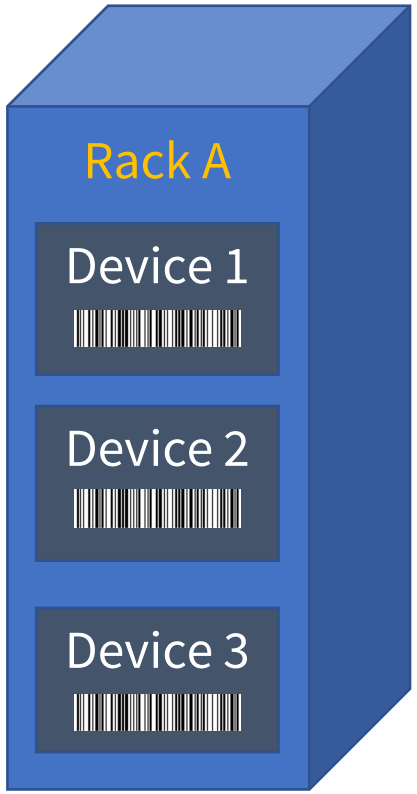
Decode barcode

Fetch data from Flowgate

Show location of rack & device

Show data of device

Final Design Workflow



Users:

App:

Scan one barcode on one device

Step back

Step closer

Maintain another device

Decode barcode

Fetch data from Flowgate

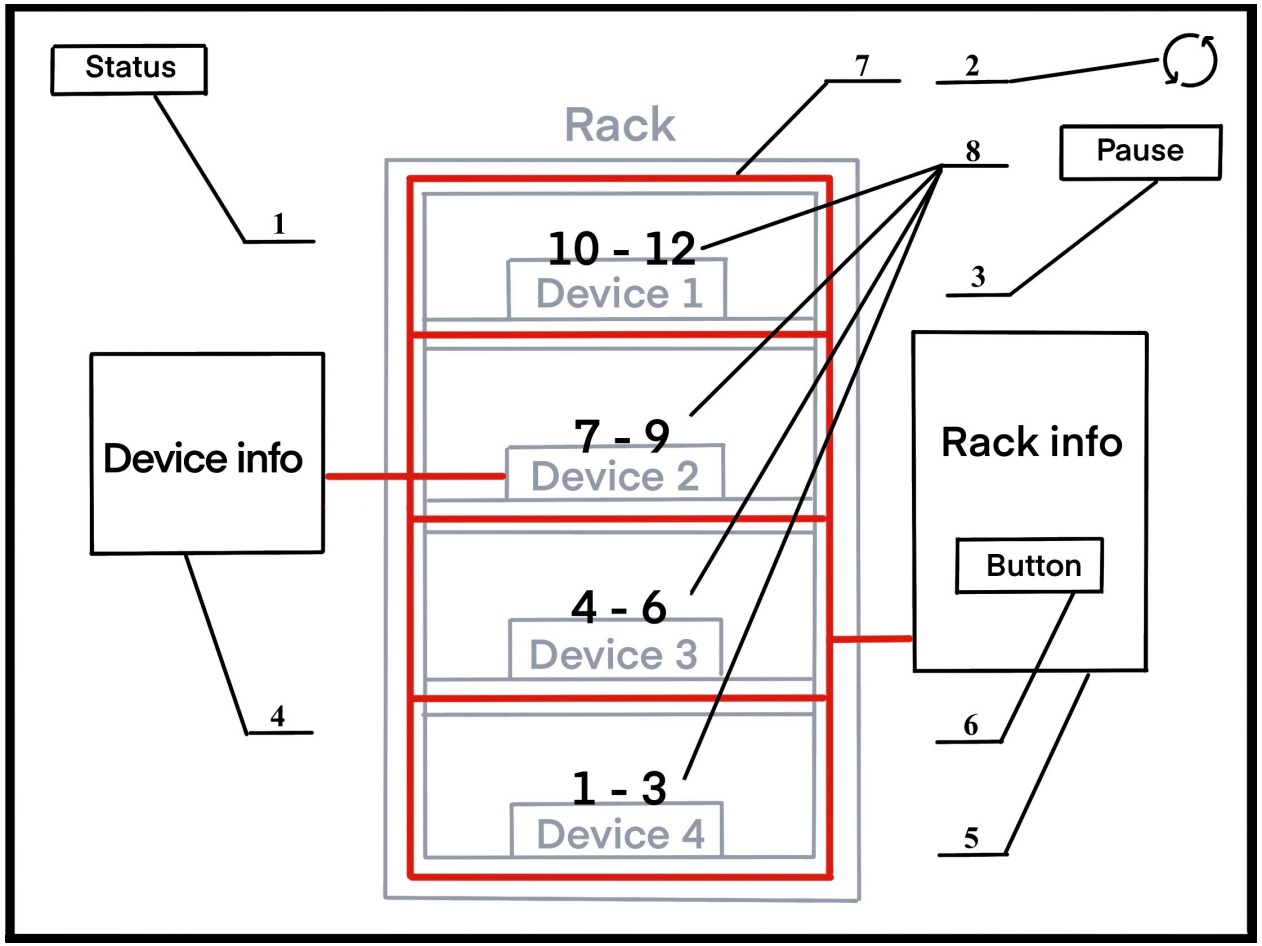
Show location of rack & device

Show data of device

Initialized

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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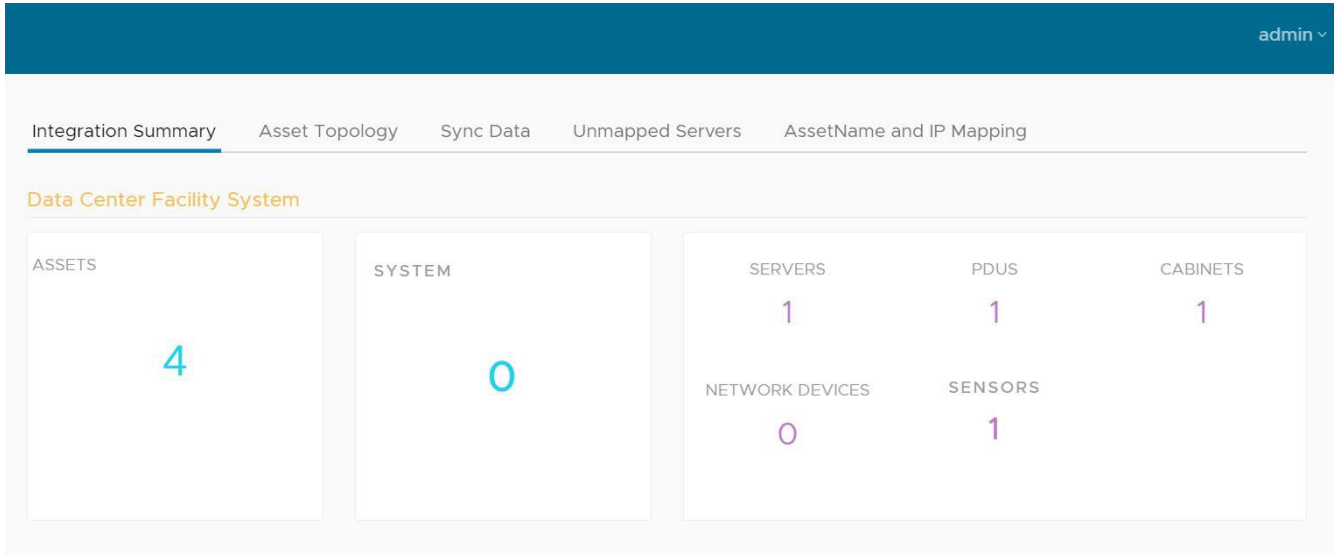
Steps of Implementation

Step 1
Configure back-end server

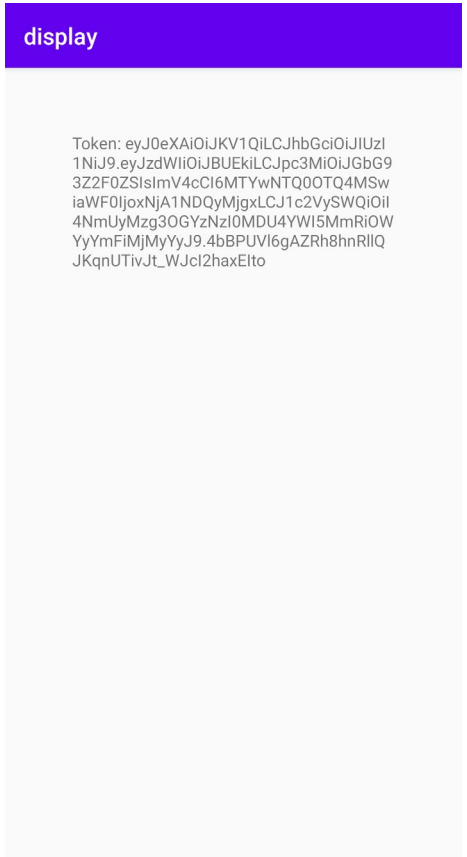
- Install flowgate server
- Create informations sets for data center assets

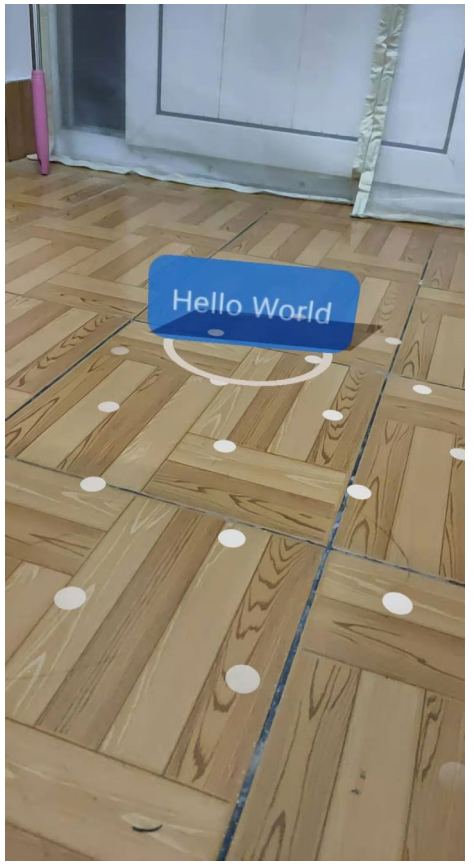


Steps of Implementation

Step 2
Realize subfunctions of front-end App

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

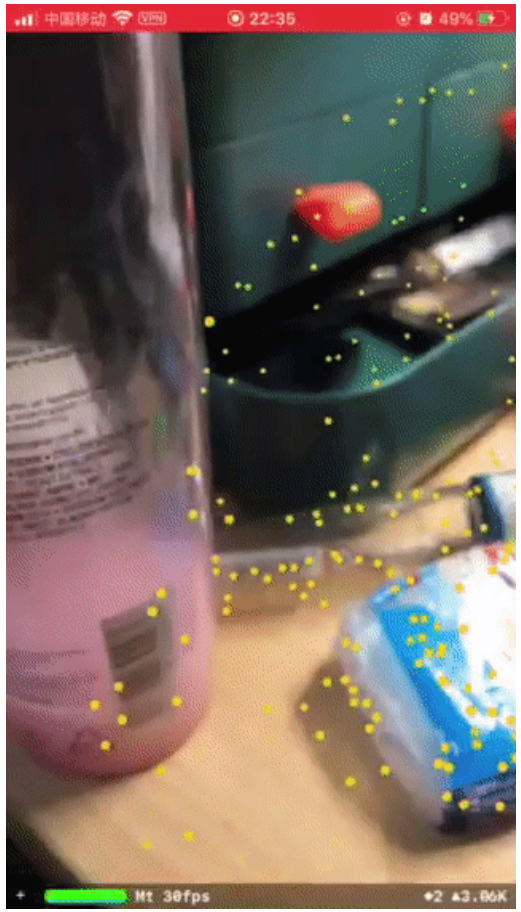




Steps of Implementation

Step 3
Integrate AR with bar code scanning

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



Steps of Implementation

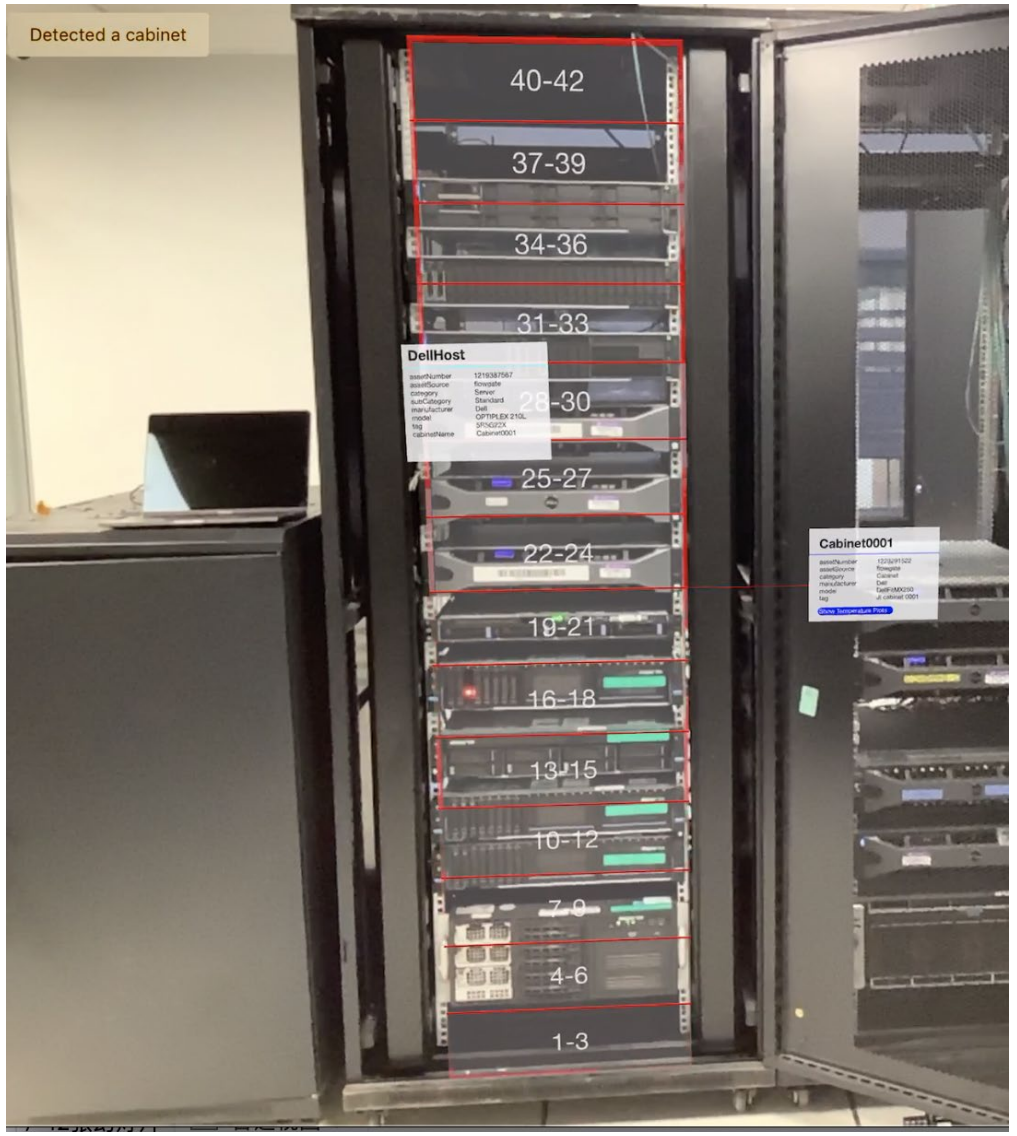
Step 4
Integrate AR, bar code scanning and data retrieval

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

Steps of Implementation

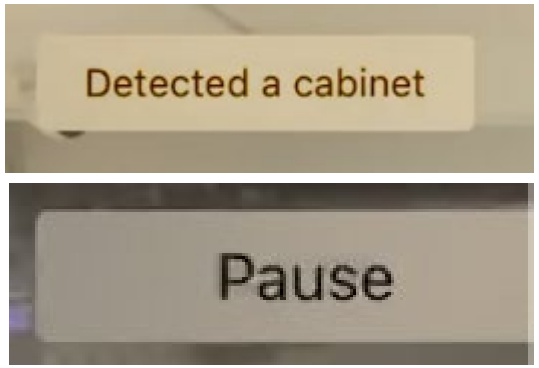
Step 5
Recognize racks / cabinets in AR

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

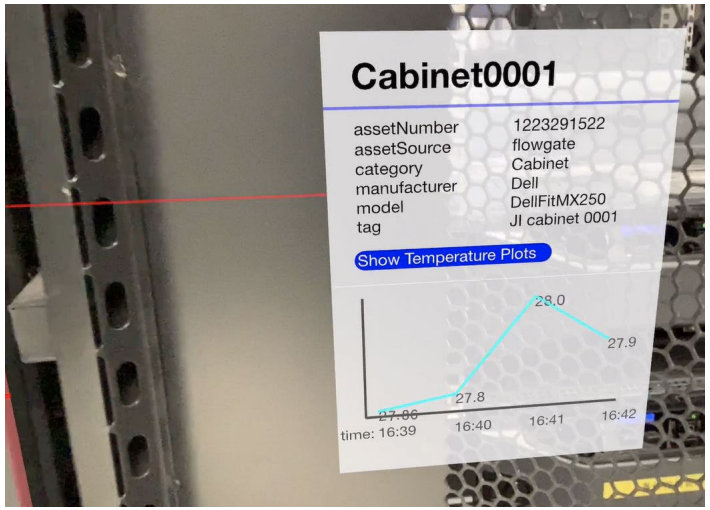


Steps of Implementation

Step 6
Improve UX



- Pause button
- Status window
- Show temperature plot



Contents

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

- X Unsatifsy 1 ES: barcode identification time
- X Unable to strictly align the information with the plane of the device
- X 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

Contents

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
- **IT support**
  - Bin Zhu, Yunlong Cai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Q & A