MAKEABILITY LAB

PAUL G. ALLEN SCHOOL
OF COMPUTER SCIENCE & ENGINEERING

RASSAR:

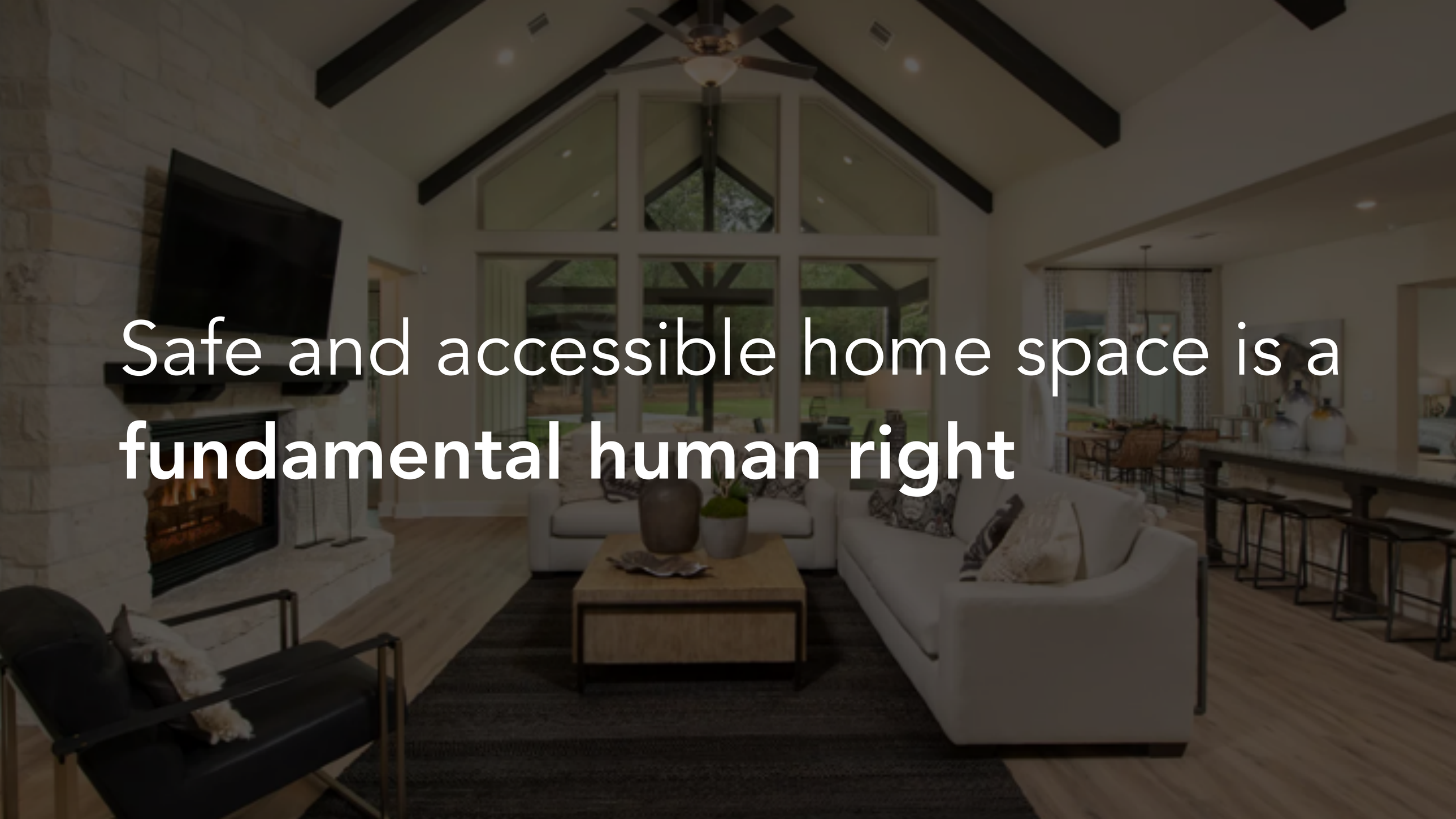
Room Accessibility and Safety Scan in Augmented Reality

Xia Su, PhD Student, UW CSE

Han Zhang, Kaiming Cheng, Jaewook Lee, Qiaochu Liu, Wyatt Olson, Jon Forehlich

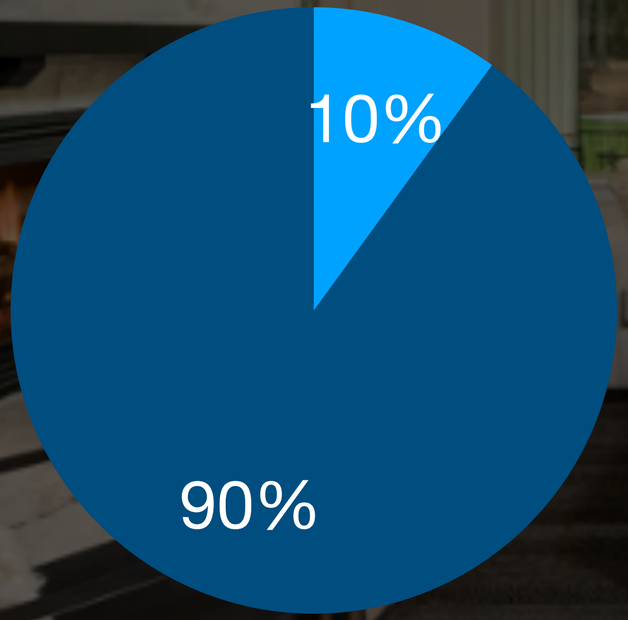
10:33
SOS
56
Finish
iRobot

Unreachable Space
Inaccessible Knob
Sharp Edges
Low Sofa
Throw Rug


Safe and accessible home space is a
fundamental human right

Most living spaces requires careful auditing and renovations to improve safety and accessibility.

Housing Units in US

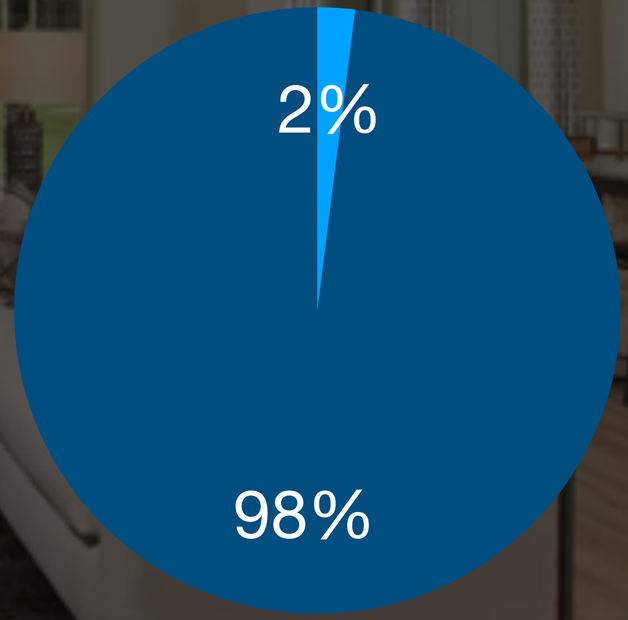


Accessible
Inaccessible

Stanley K. Smith, Stefan Rayer, and Eleanor A. Smith. 2008. Aging and Disability: Implications for the Housing Industry and Housing Policy in the United States. Journal of the American Planning Association 74, 3 (July 2008), 289– 306.

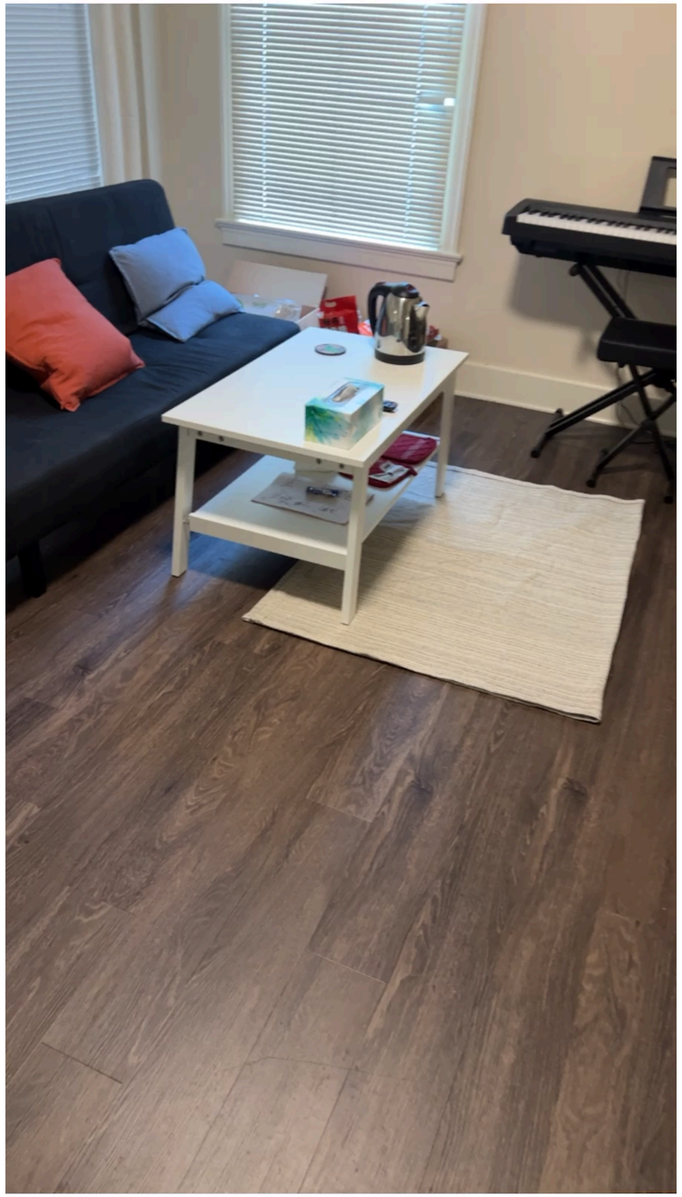
Steinfeld, E., Levine, D. R., & Shea, S. M. (1998). Home modifications and the fair housing law. *Technology and Disability*, *8*(1-2), 15-35.

Newly Built Private Homes in UK



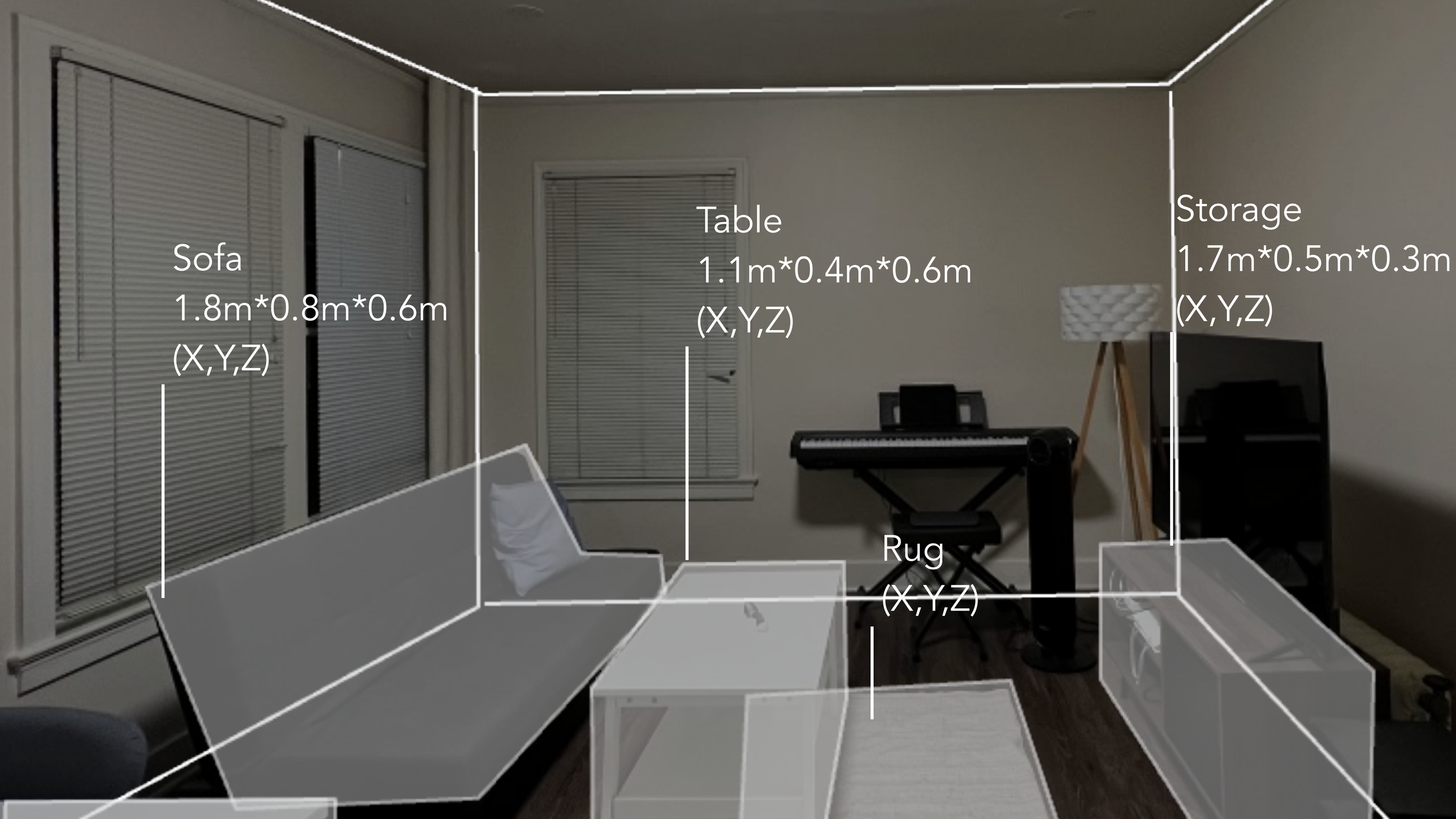
Accessible
Inaccessible to Wheelchair

Rob Imrie. 2003. Housing quality and the provision of accessible homes. Housing Studies 18, 3 (2003), 387–408.

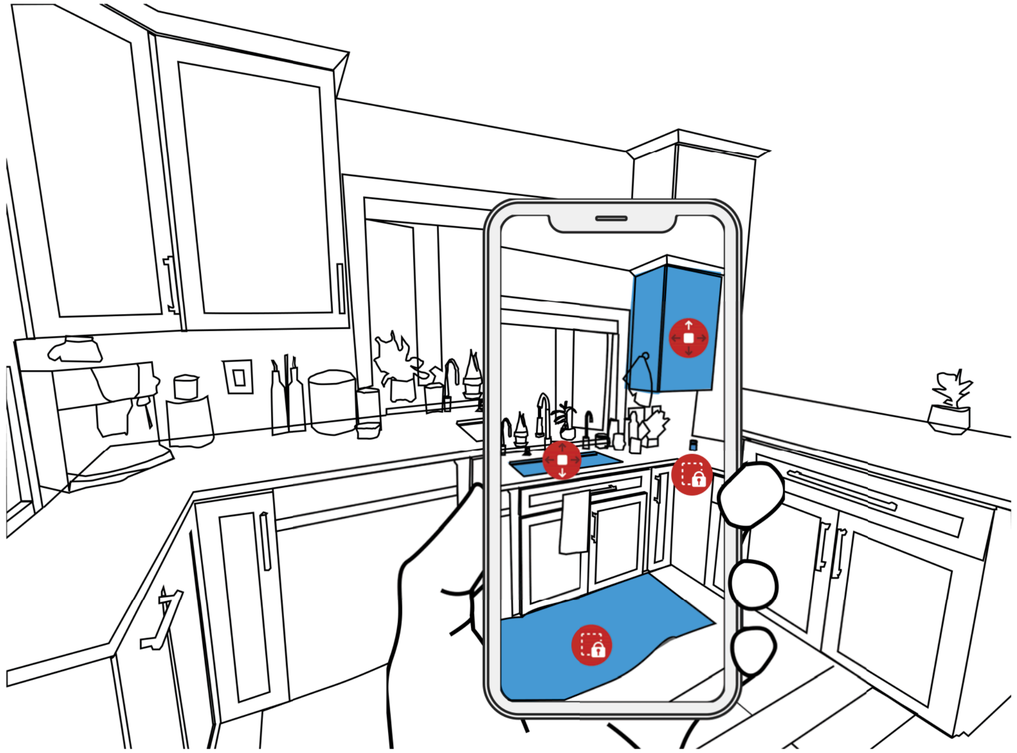


Elapsed 0.01283 seconds - 15.39 FPS

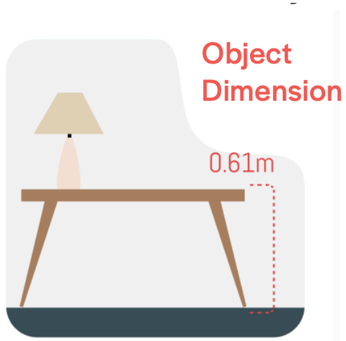
LiDAR

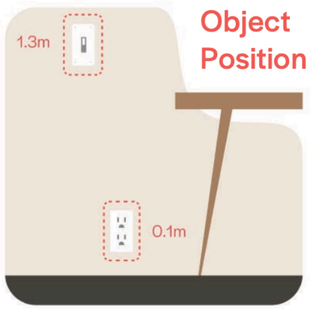

Sofa
1.8m*0.8m*0.6m
(X,Y,Z)
Table
1.1m*0.4m*0.6m
(X,Y,Z)
Storage
1.7m*0.5m*0.3m
(X,Y,Z)
Rug
(X,Y,Z)

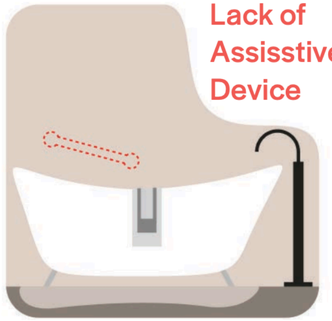
Scan



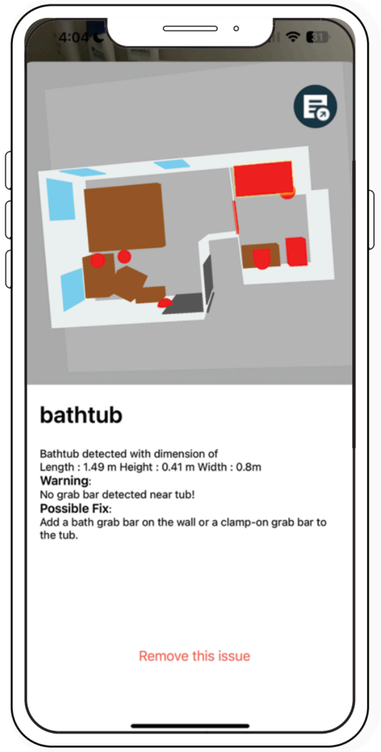
Detect

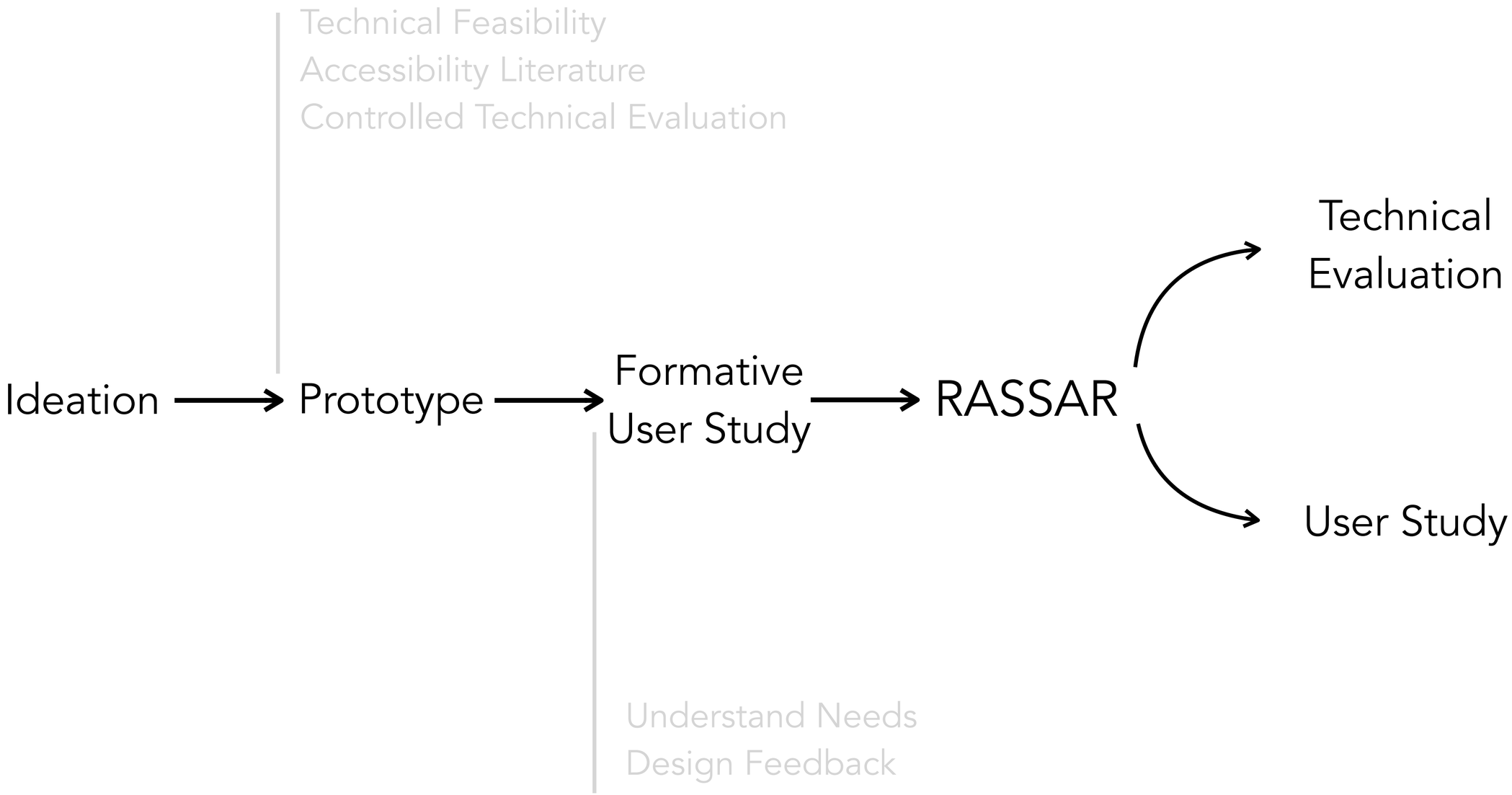


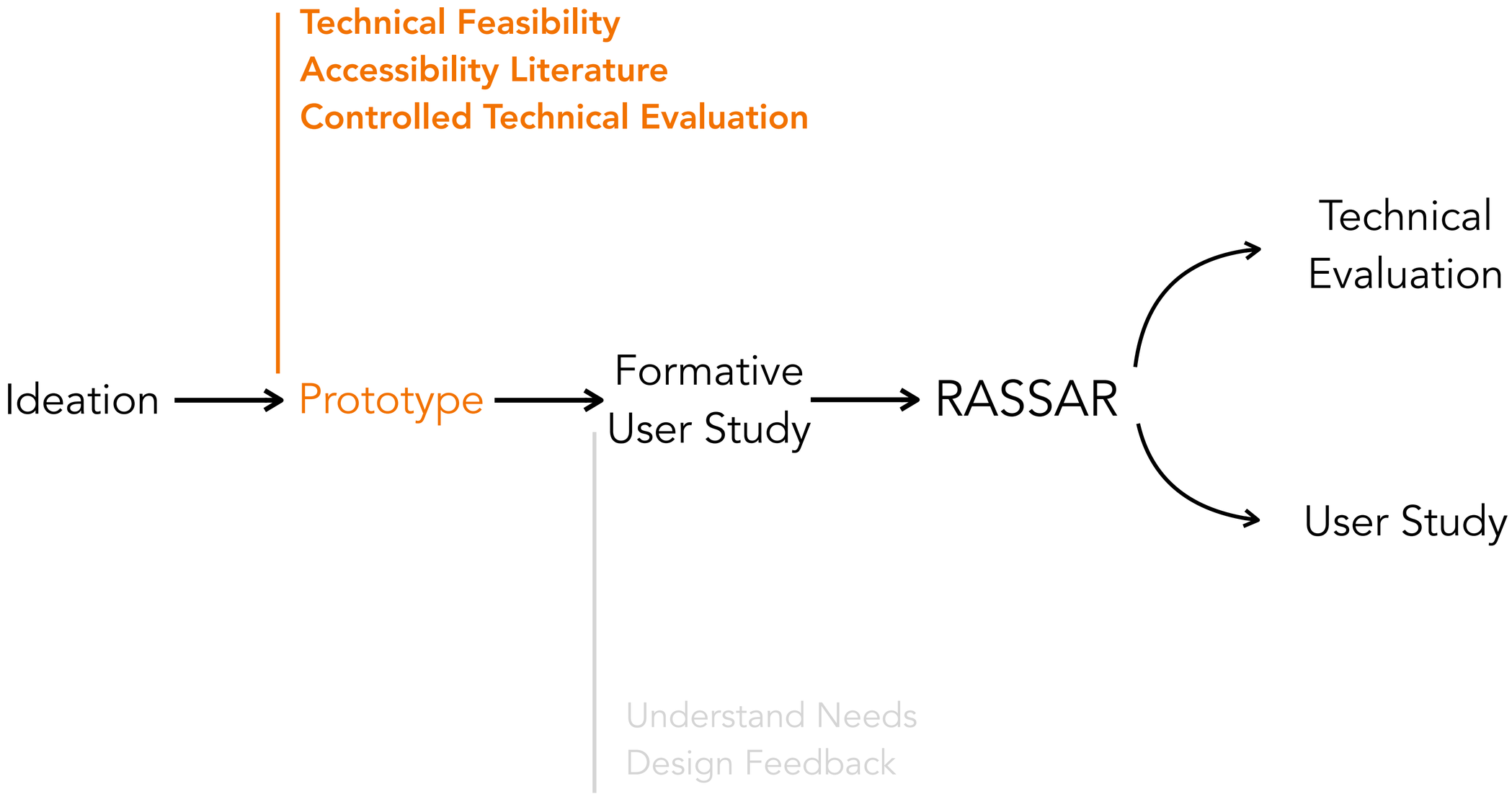




Summary




Technical Feasibility
Accessibility Literature
Controlled Technical Evaluation
Ideation
Prototype
Formative
User Study
RASSAR
Technical
Evaluation
User Study
Understand Needs
Design Feedback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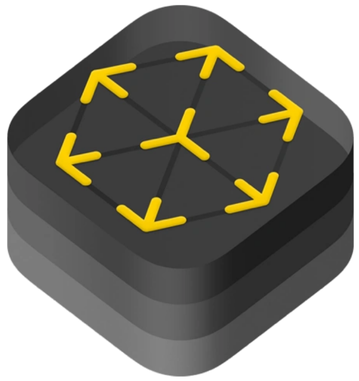
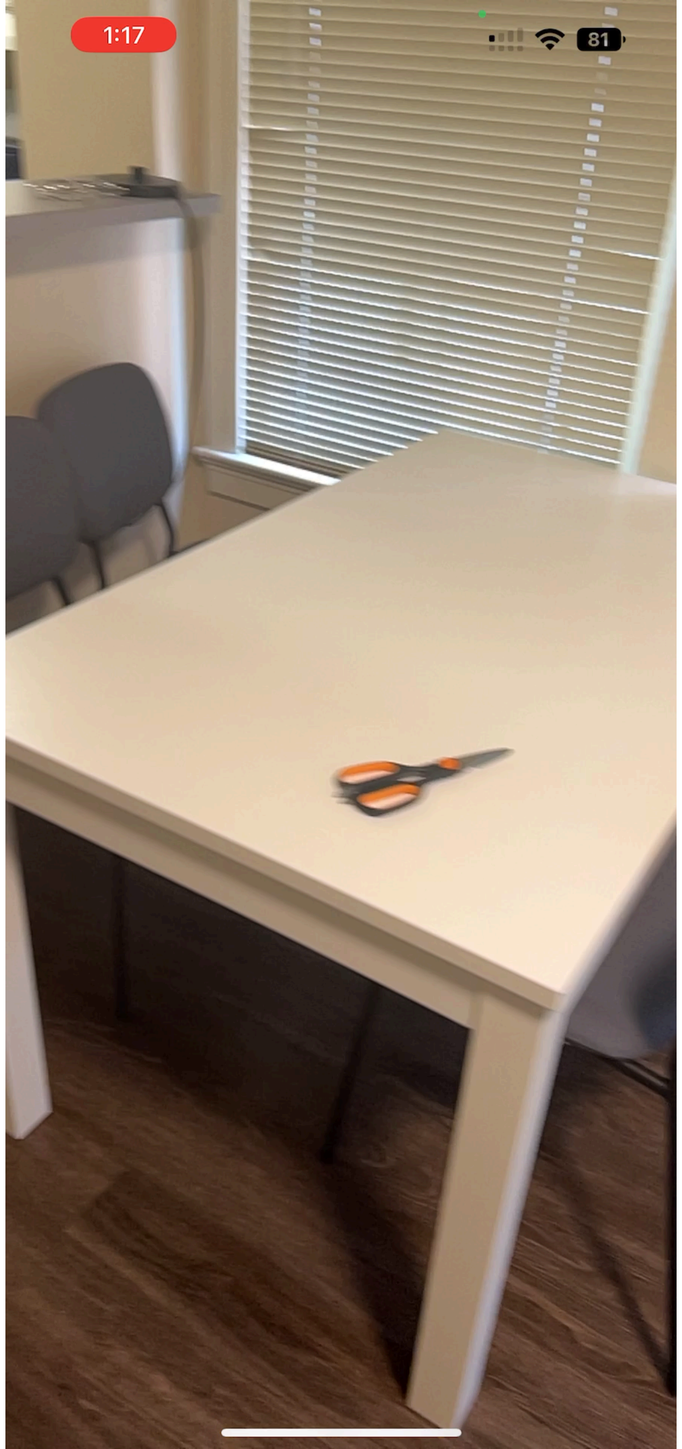
Prototype

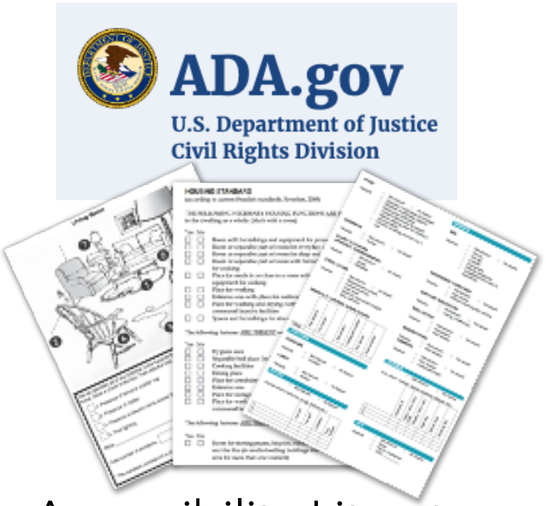


ARKit

RoomPlan

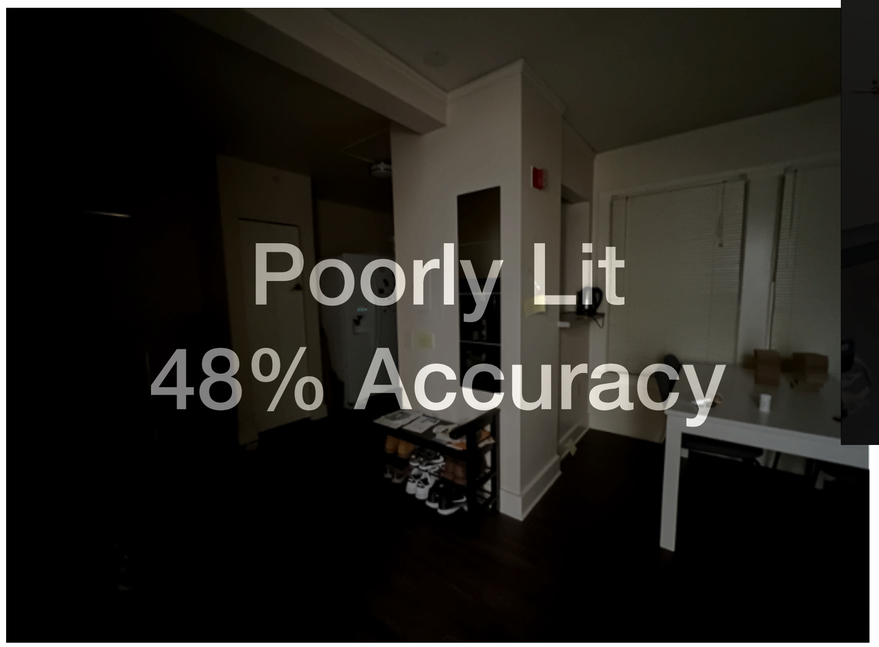


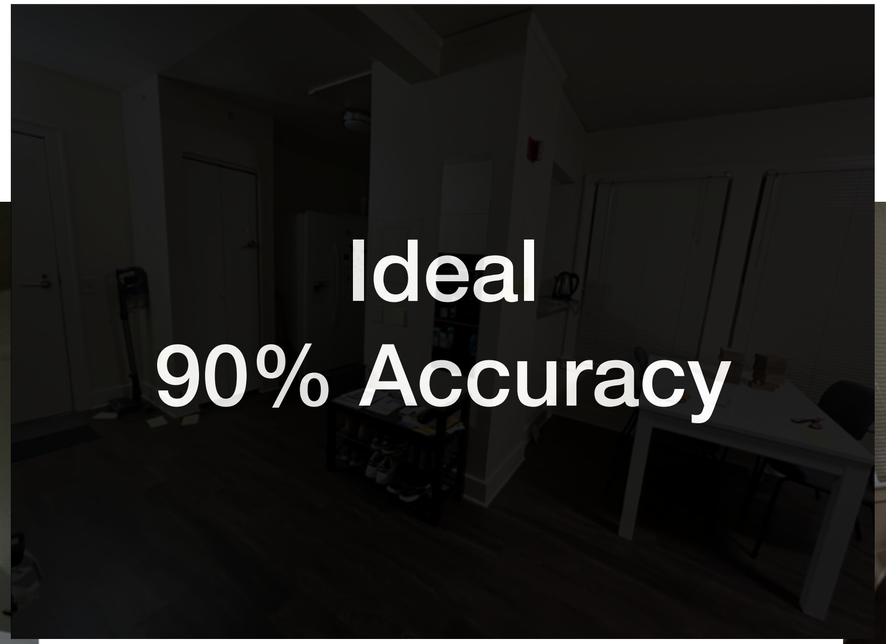
YOLO



Accessibility Literature

Prototype

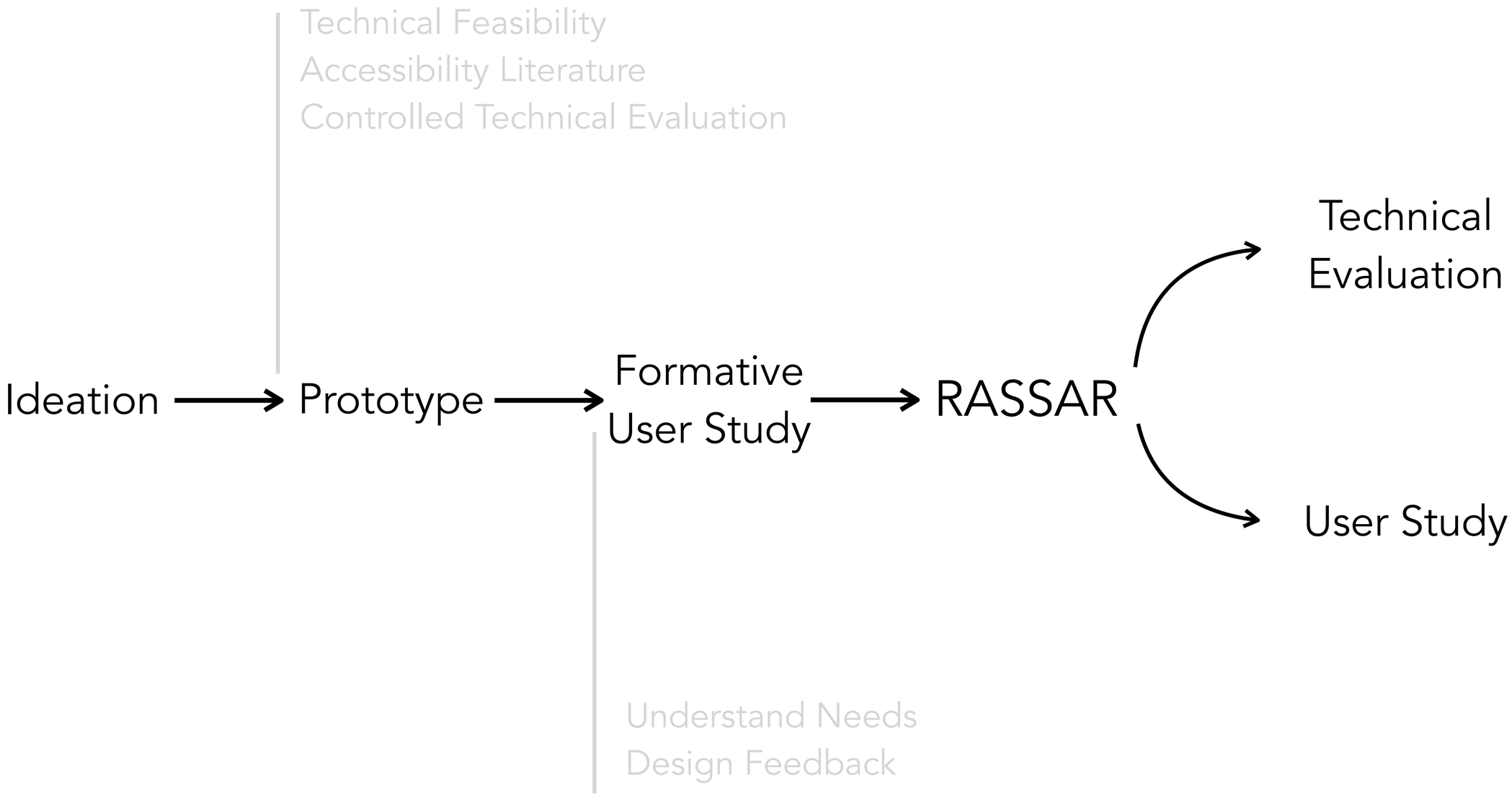




Well-lit

Tidy

Scan with medium speed (1min/room)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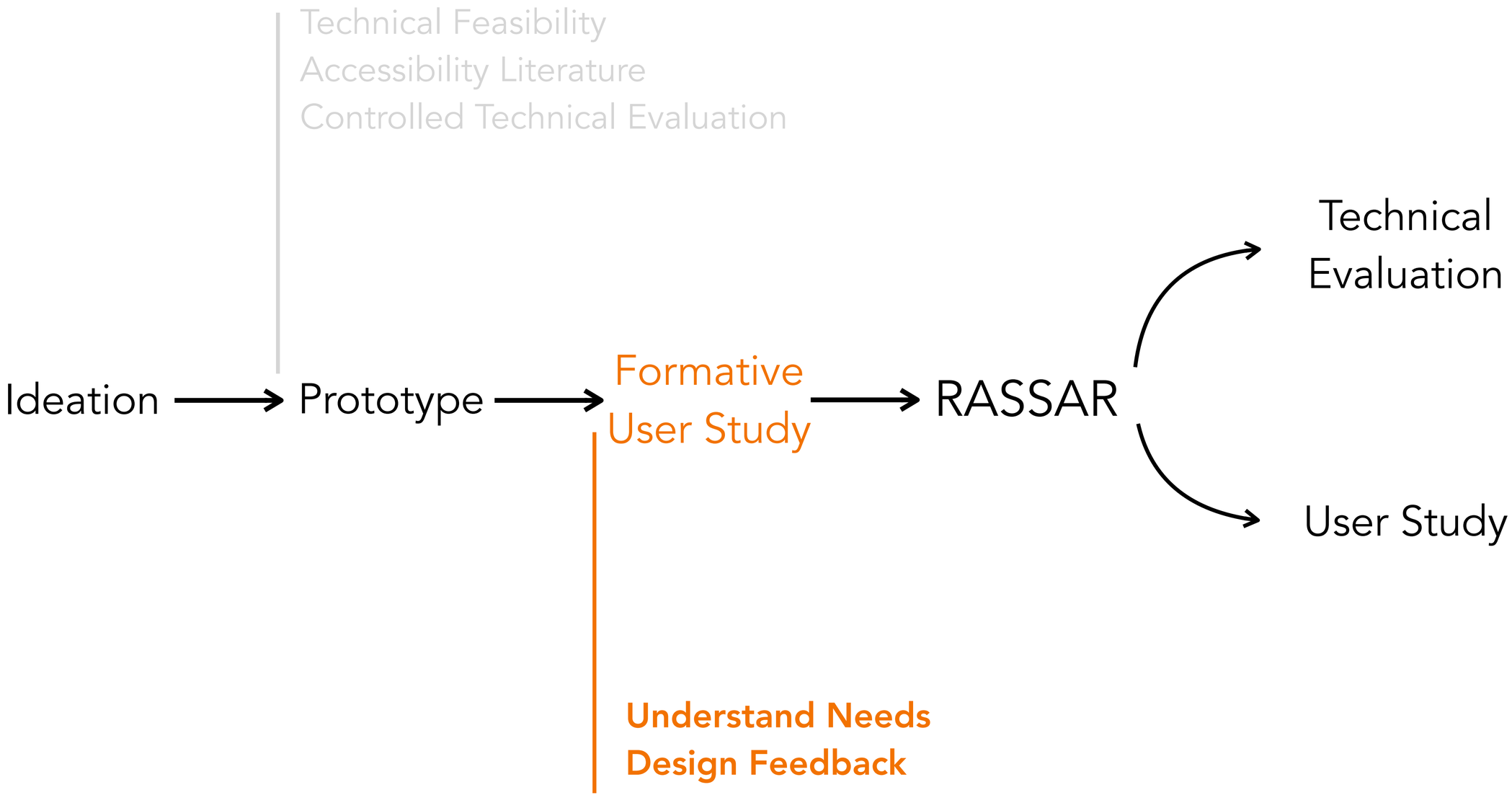
Design Feedback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Formative Study

Total N=18

~1h

Wheelchair Users

N=8

BLV People

N=4

Older Adults

N=6

Families with Young Children

N=3

Occupational Therapists

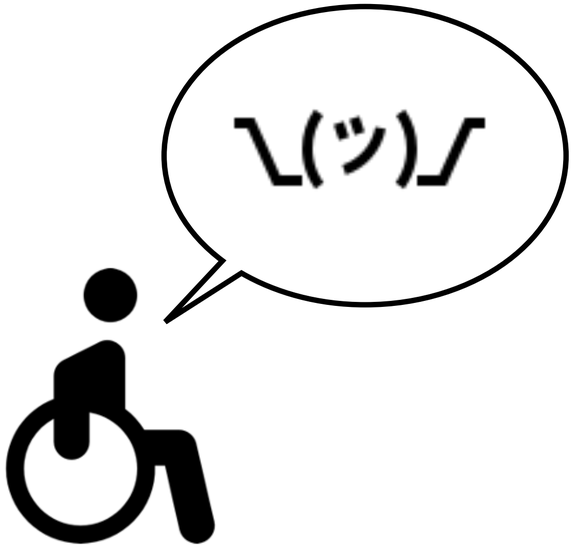
N=3

Formative Study

“I think it could really help people have more confidence when they go to a new space”

-Participant No.18, Blind

Formative Study

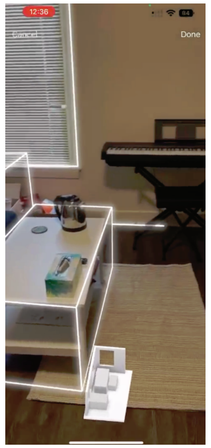


Design Probe

How should RASSAR support scans?

A
Video Guide

B
Text Guide



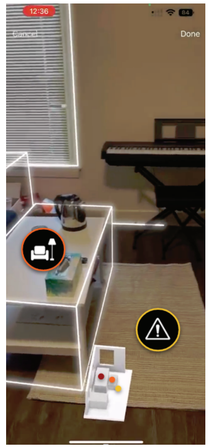
C
Mini-Map

D
Task Based Guide

How Should RASSAR Show the Detected Issues?

A
Minimal Solution

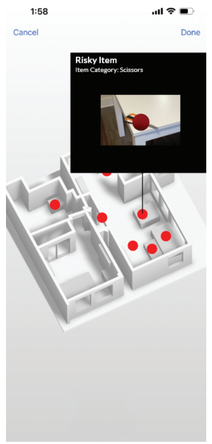
B
Rich Text Pop-Up



C
Model with Dots

D
List in AR

How Should RASSAR Summarize Scan Results?



A
Show 3D Model

B
Show List

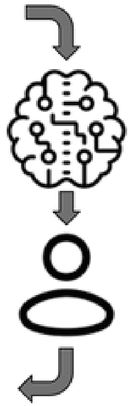
C
Show in AR

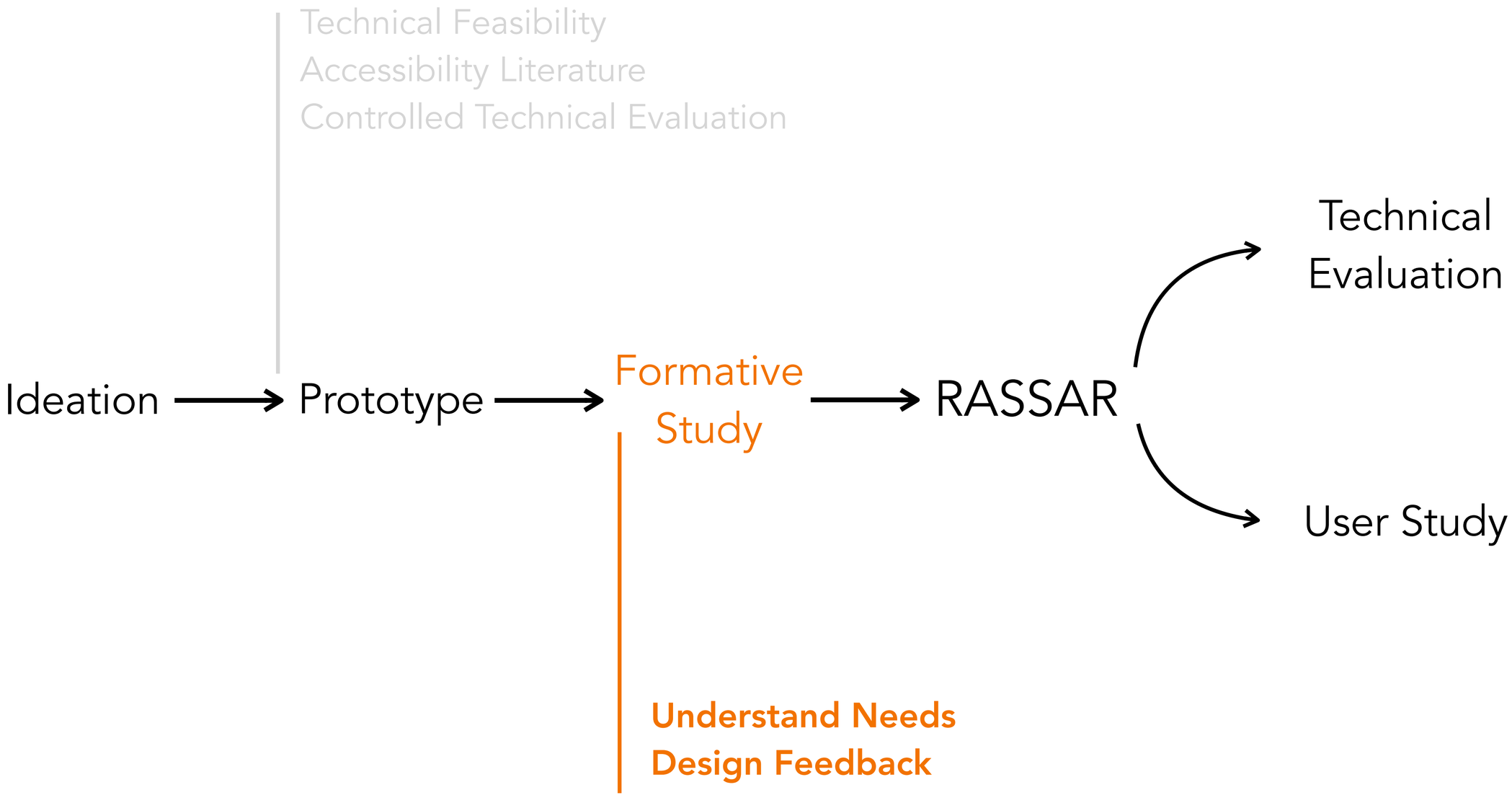
How Should Users Report Errors?

A
Manual Cancelling

B
Manual Adding

C
System Learns

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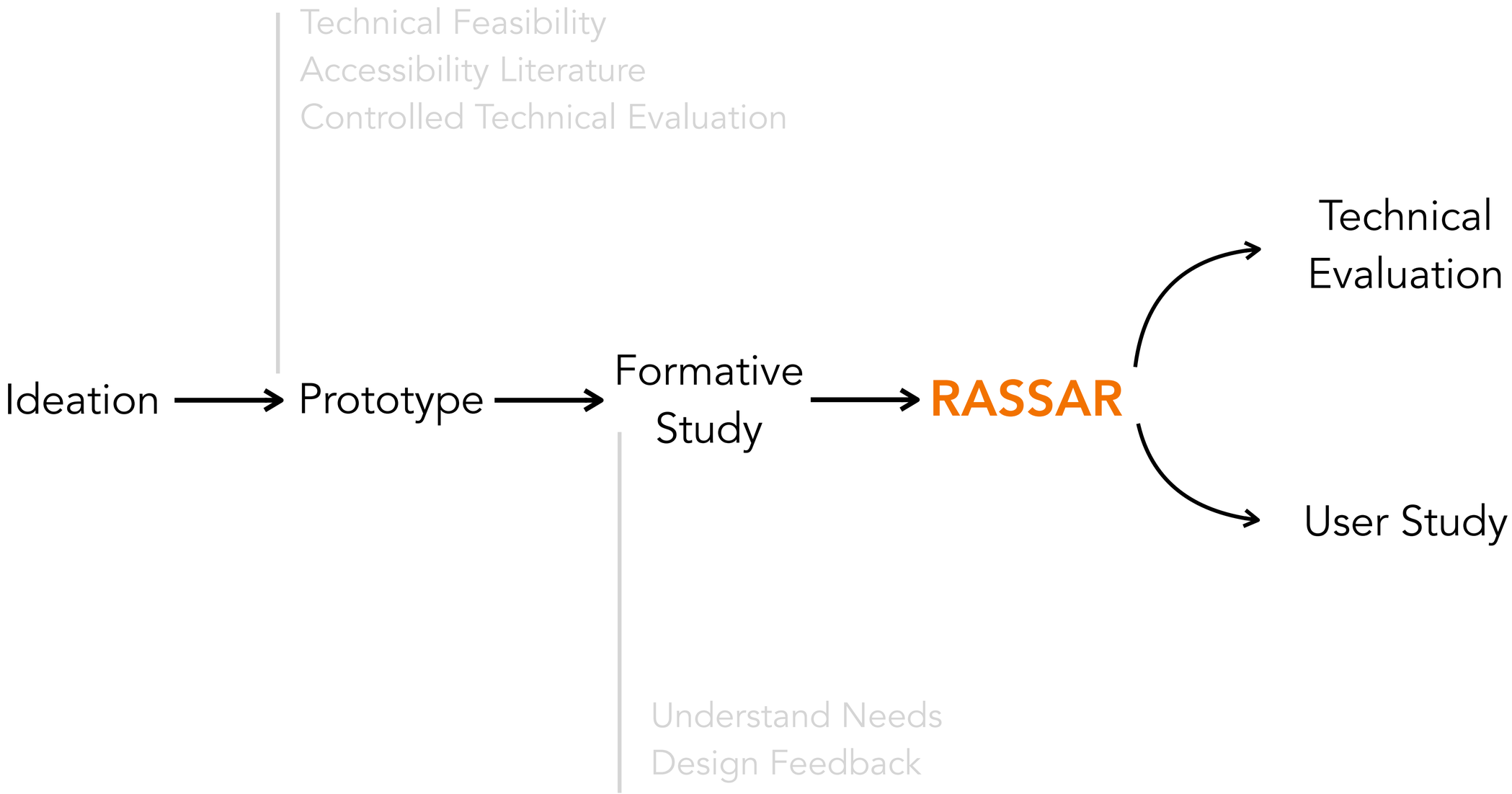
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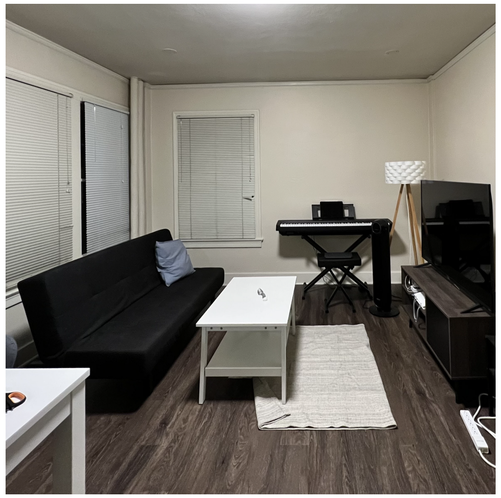
RASSAR

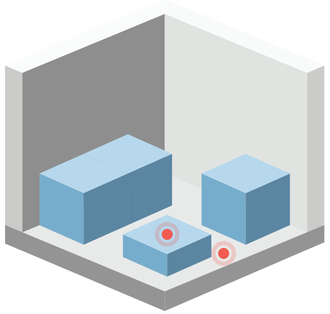
Identify
Localize
Suggest

Pipeline

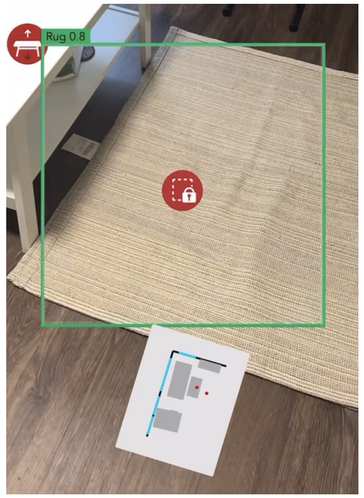


LiDAR &
RGB Camera

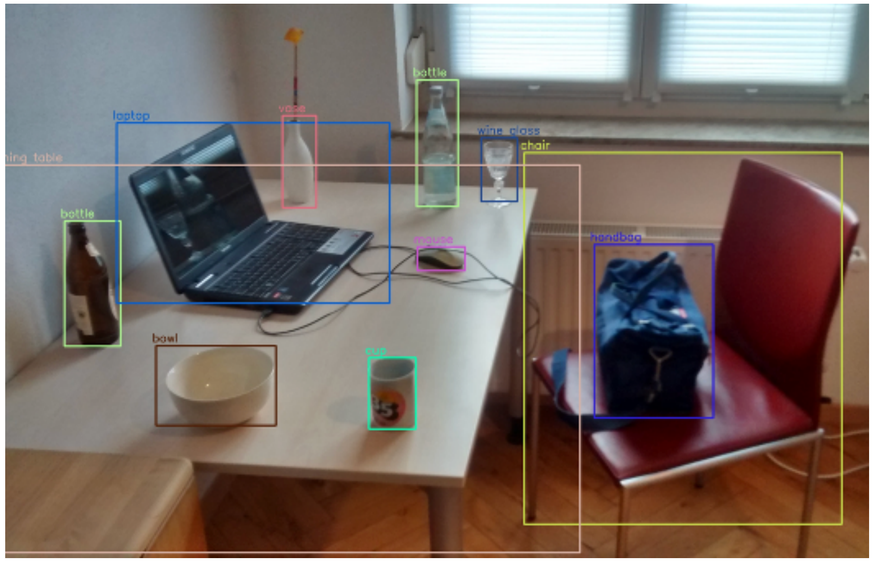
RoomPlan
YoloV5

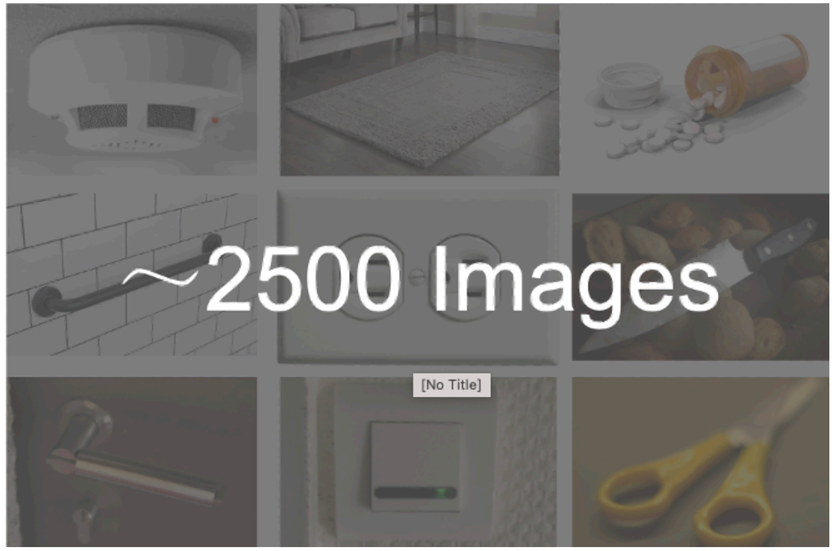


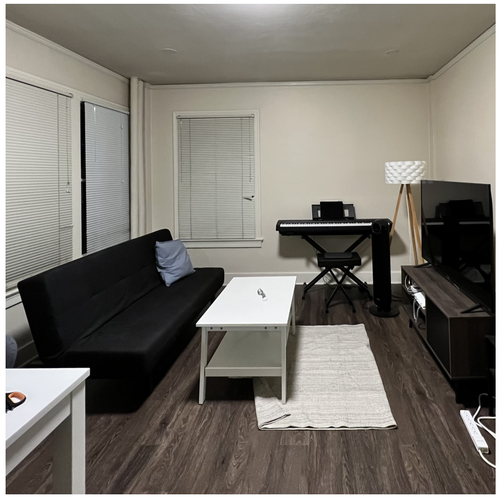
Rubrics in
JSON



Pipeline

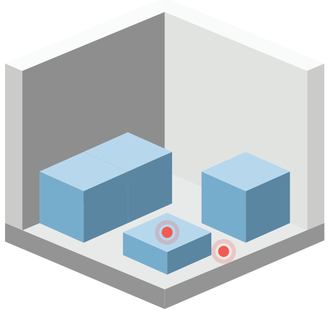




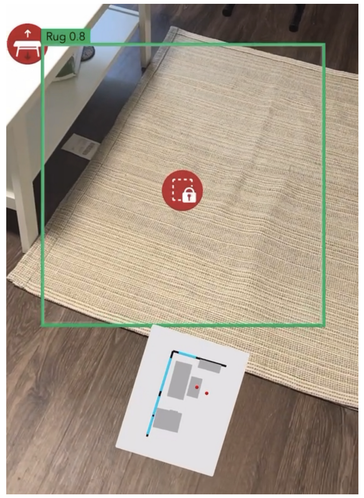


LiDAR &
RGB Camera

RoomPlan
YoloV5



Rubrics in
JSON



Pipeline

Object Dimension

O

B

Ta

C

D

O

Object Position

High or Low

eig

nt

ht

lle Heig

ch Heigh

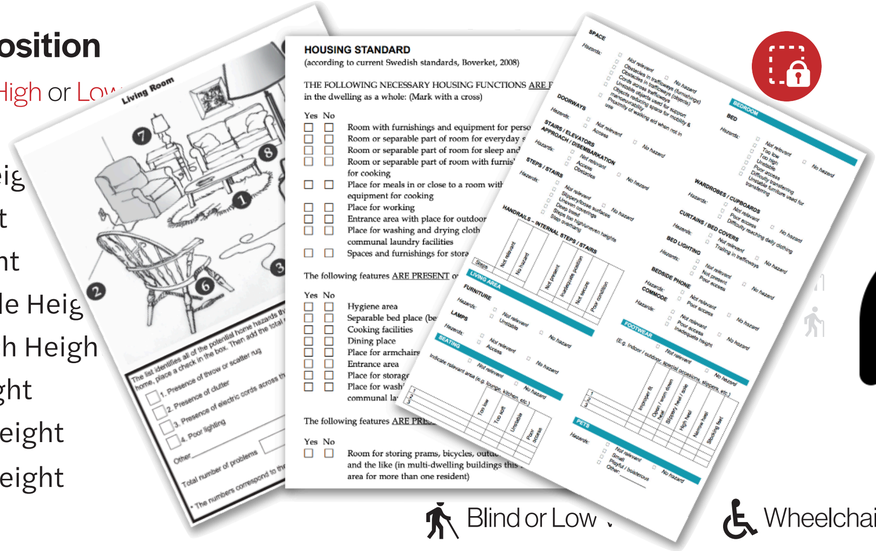
ght

Grab Bar Height

Grab Bar Height

ADA.gov

U.S. Department of Justice
Civil Rights Division



Assistive Item

Non-existent

Grab Bar Near Toilet

Grab Bar Near Tub

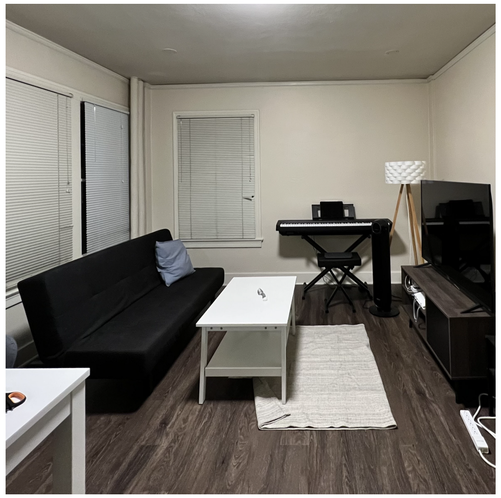
Fire Alarm

Blind or Low

Wheelchair User

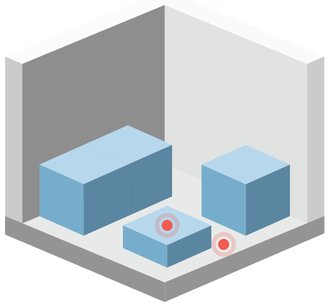
Children

Older Adults

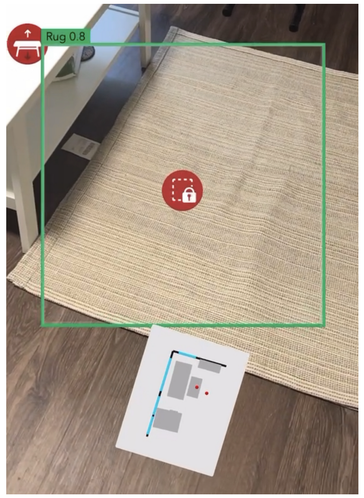


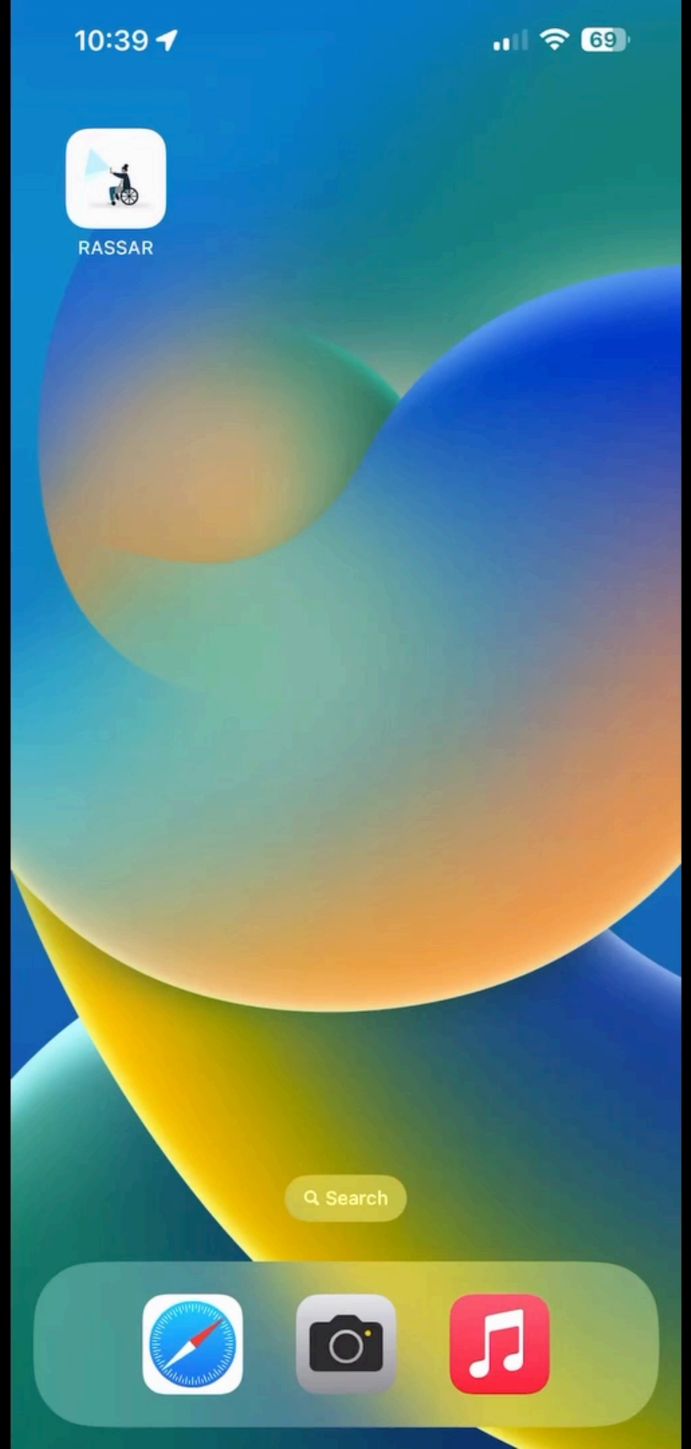
LiDAR &
RGB Camera

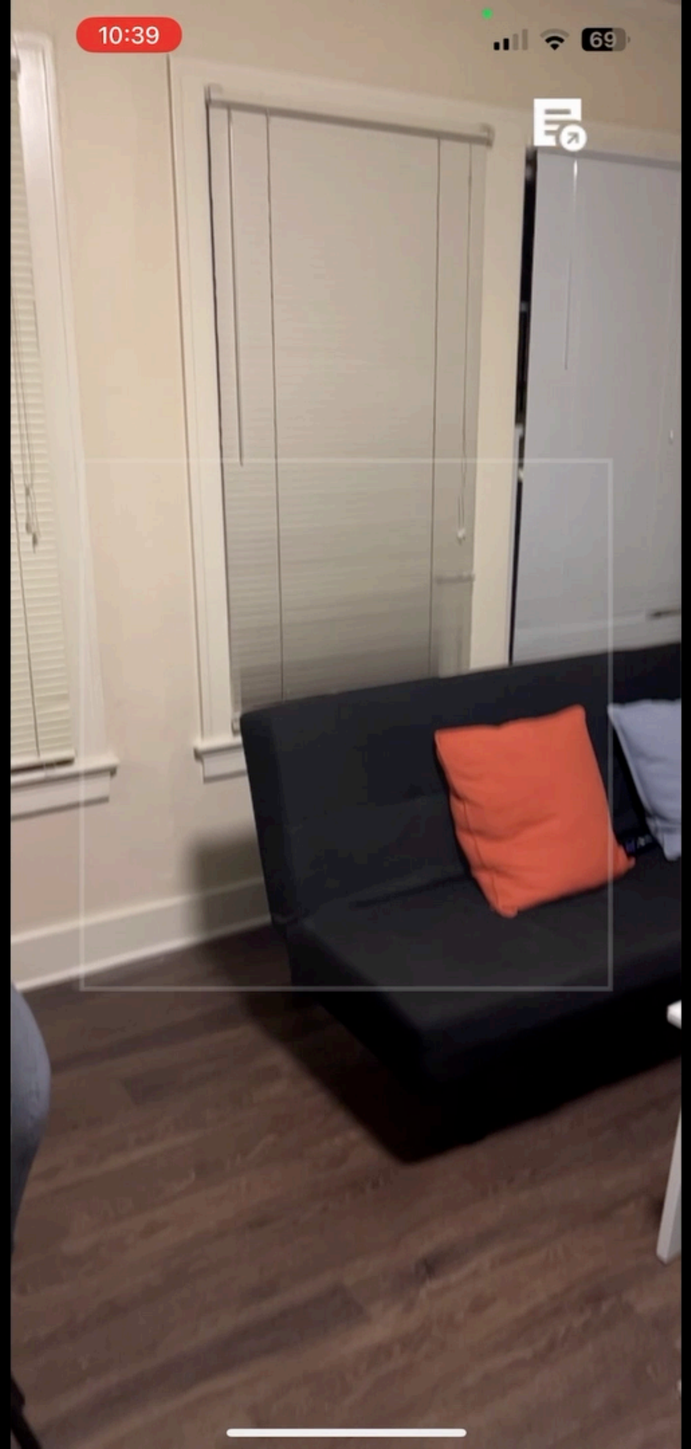
RoomPlan
YoloV5

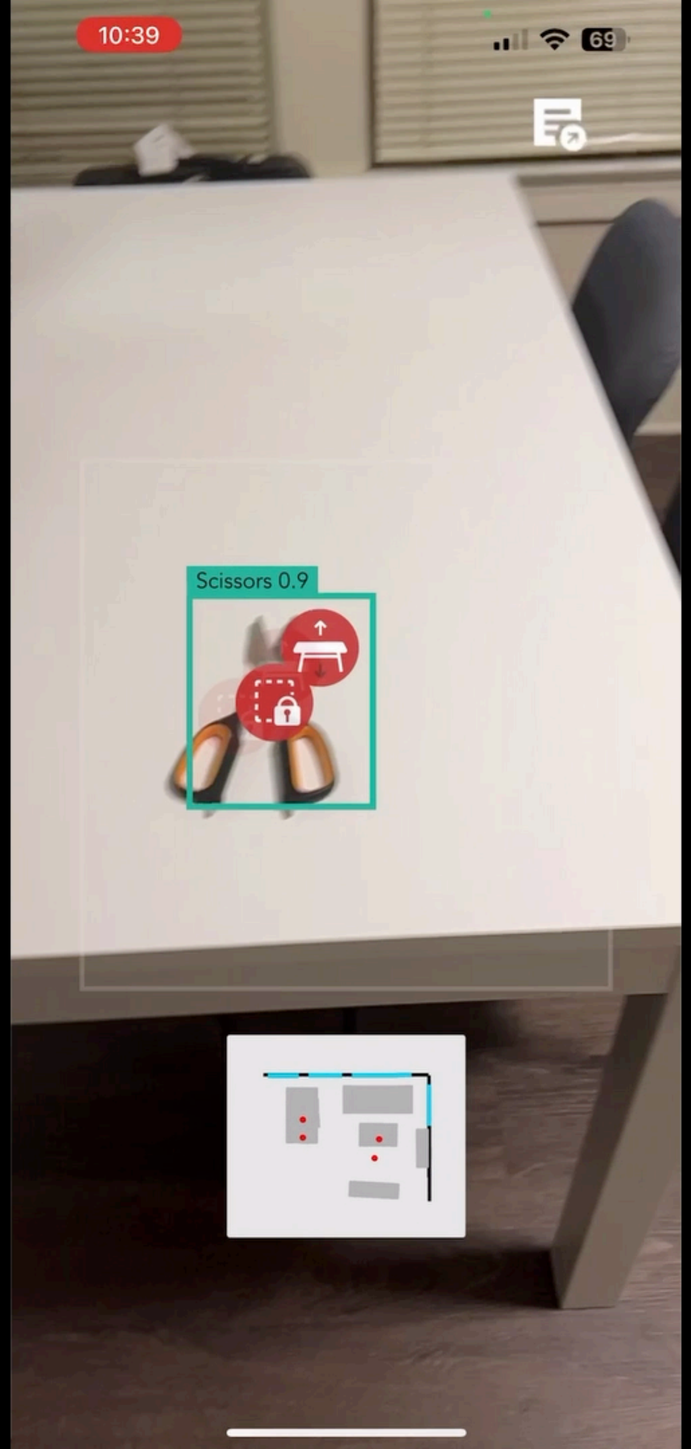


Rubrics in
JSON

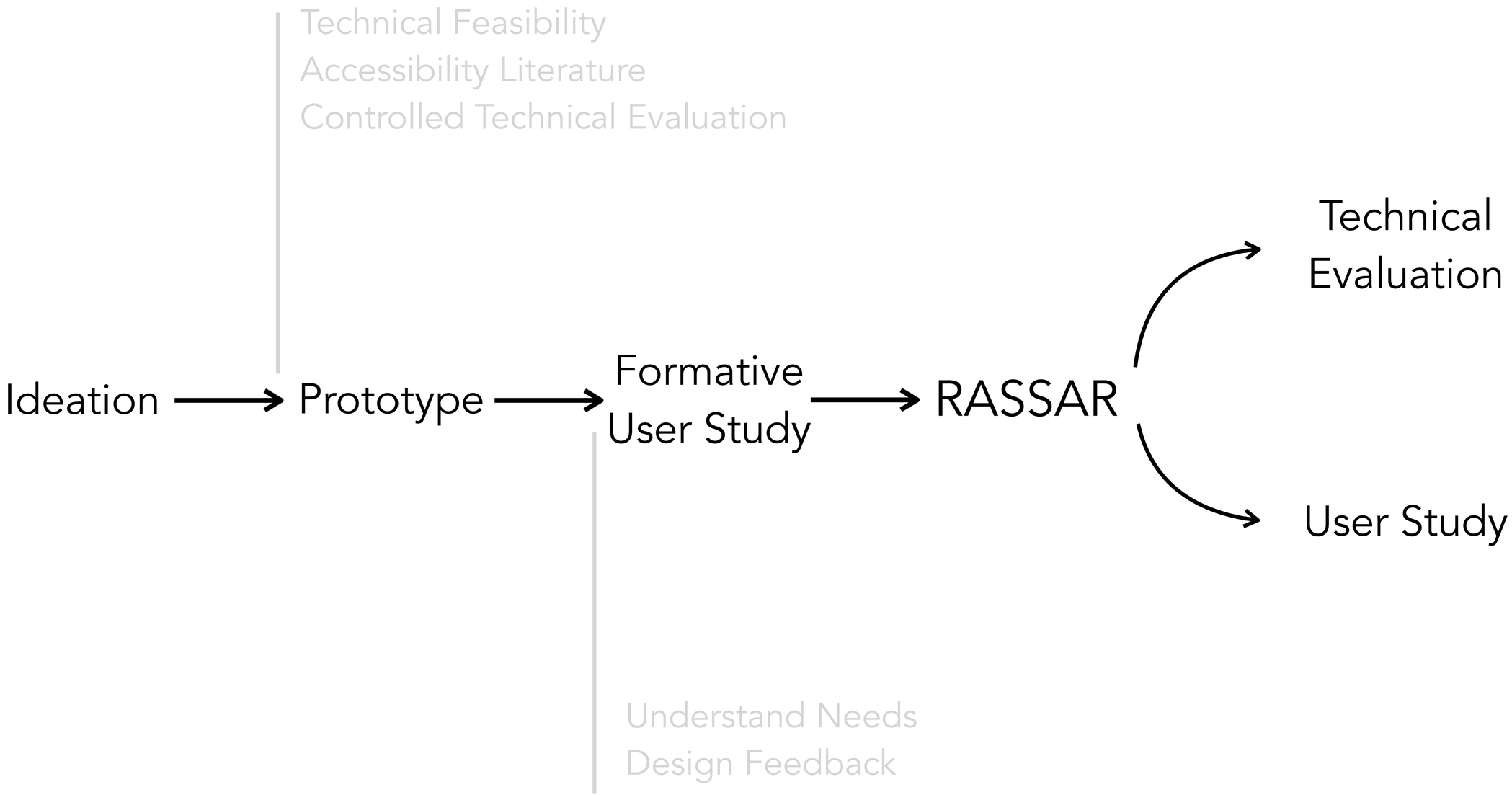



10:39
69
RASSAR
Search


10:39
69


10:39
69
Scissors 0.9

10:41
67
Door Handle 0.7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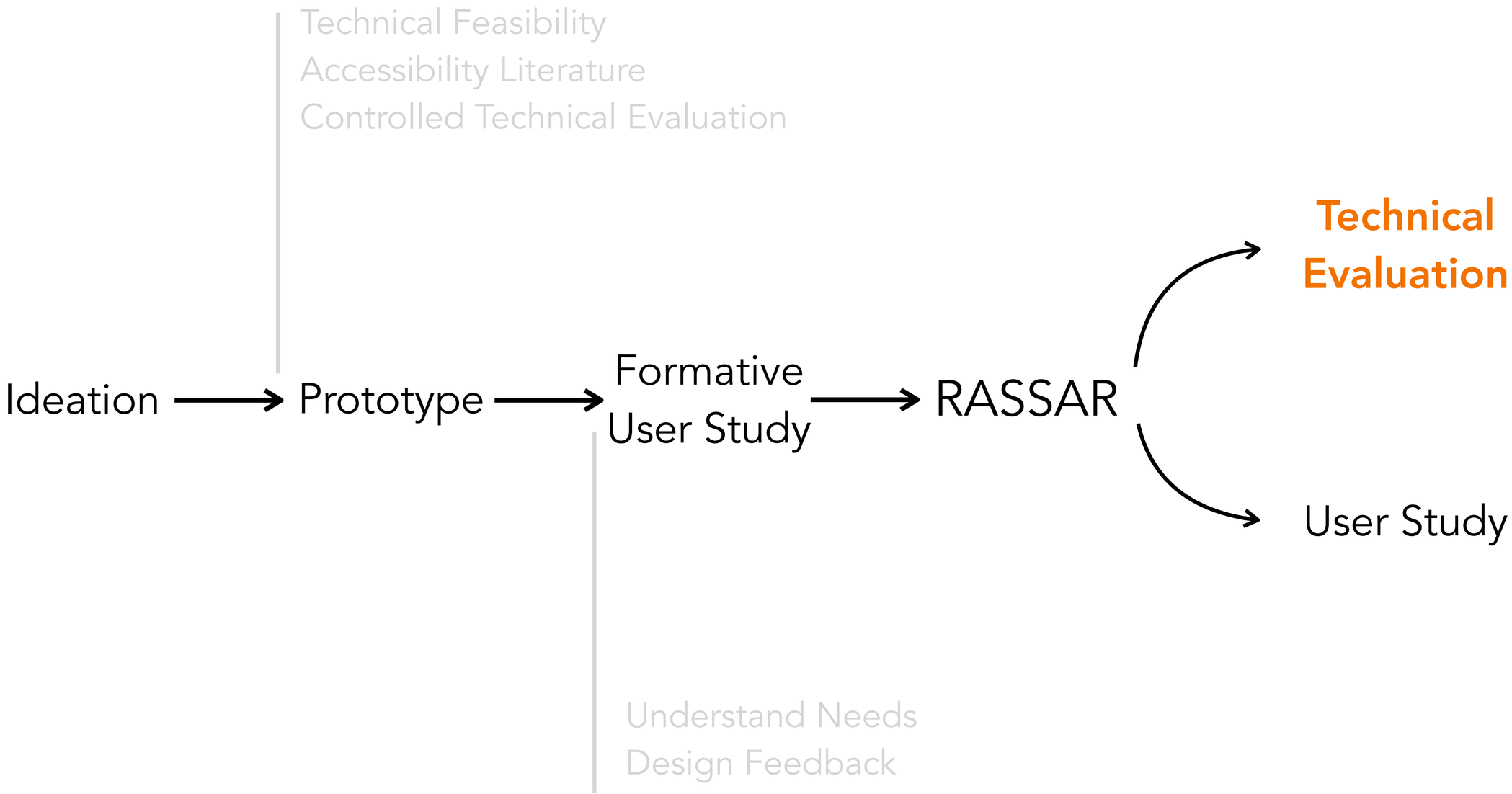
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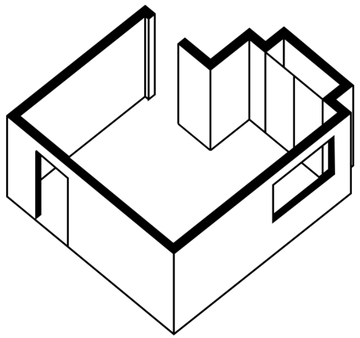
Technical Eval

7 Apartments

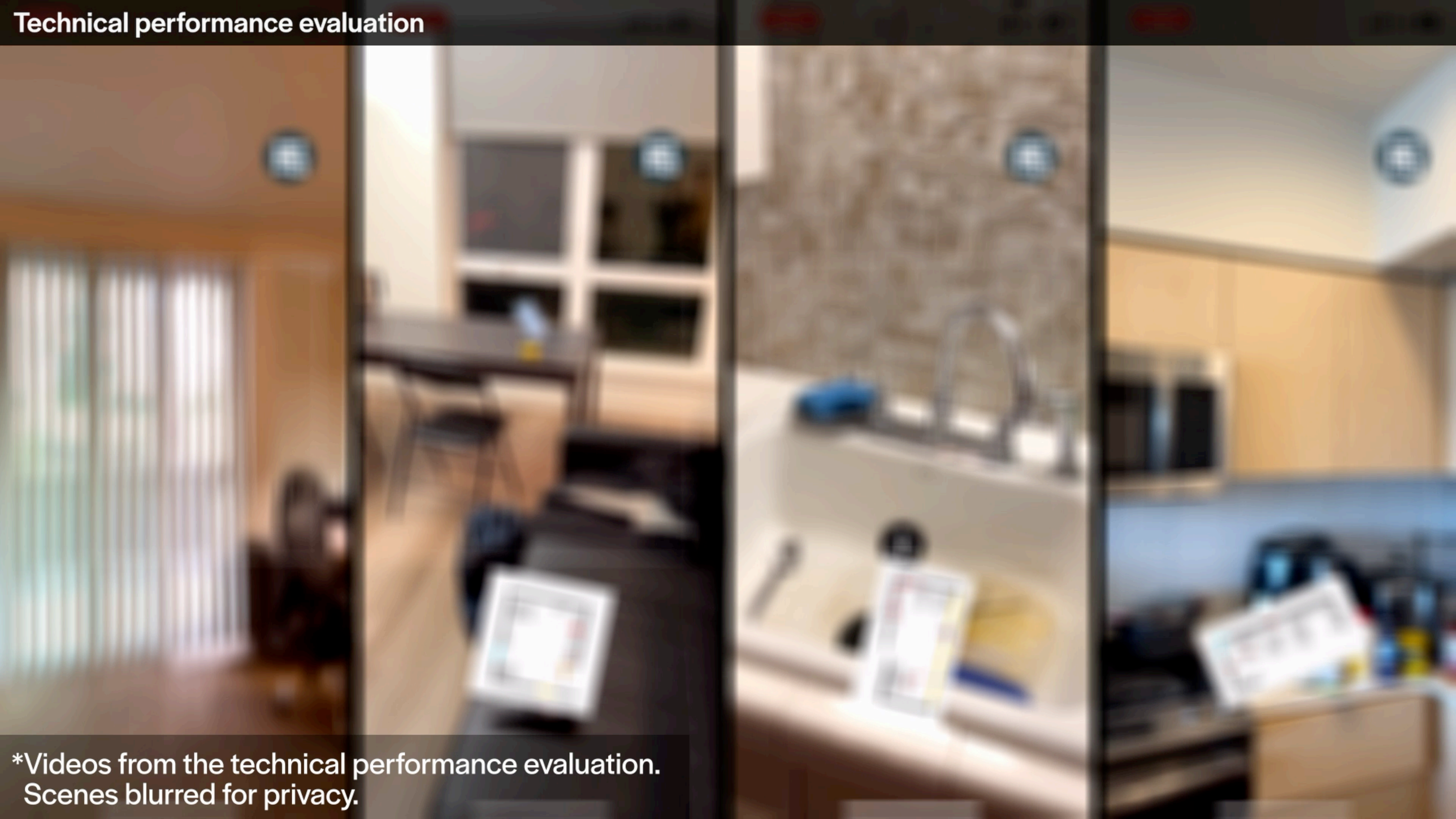
3 Houses



Manual Inspection
Scan 3 times
Compare Results

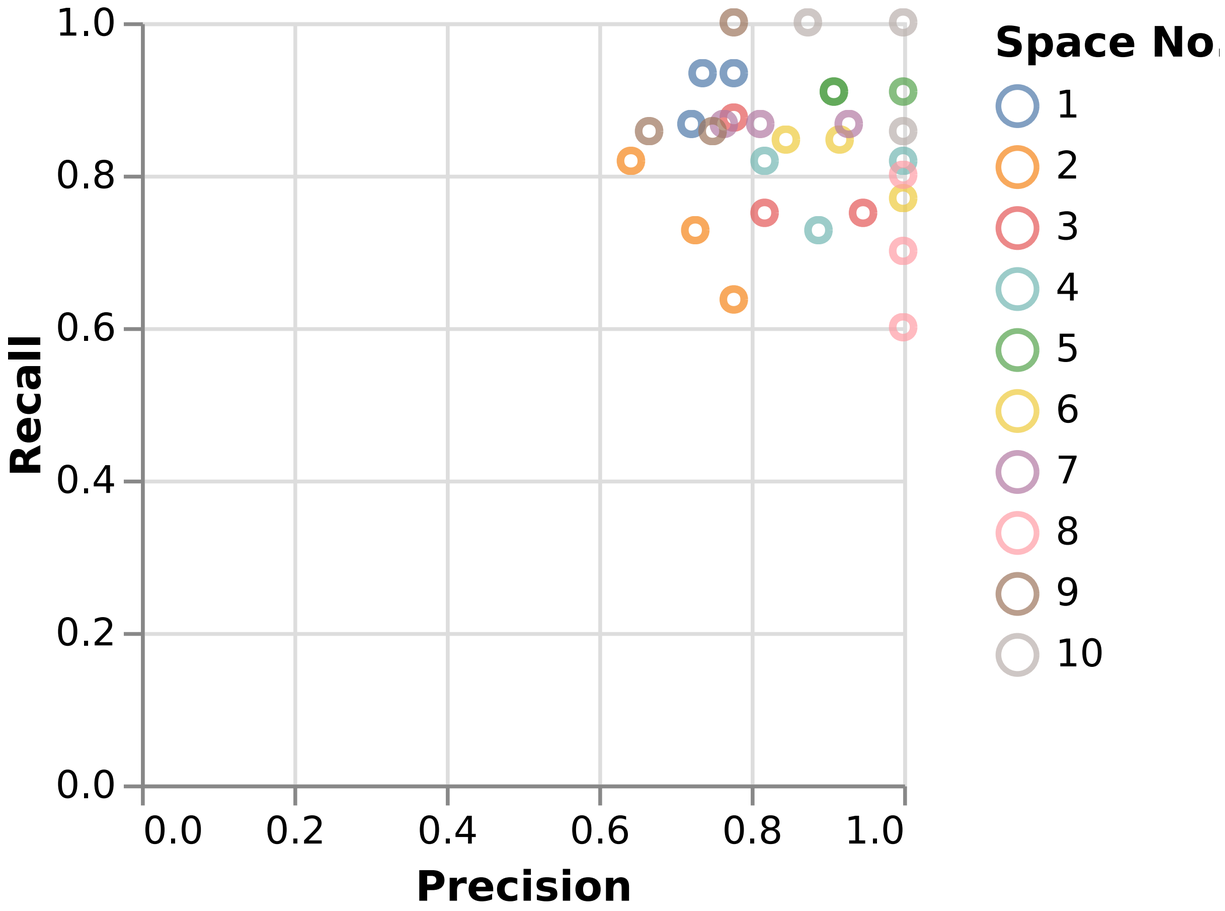
Accuracy
Consistency
Time

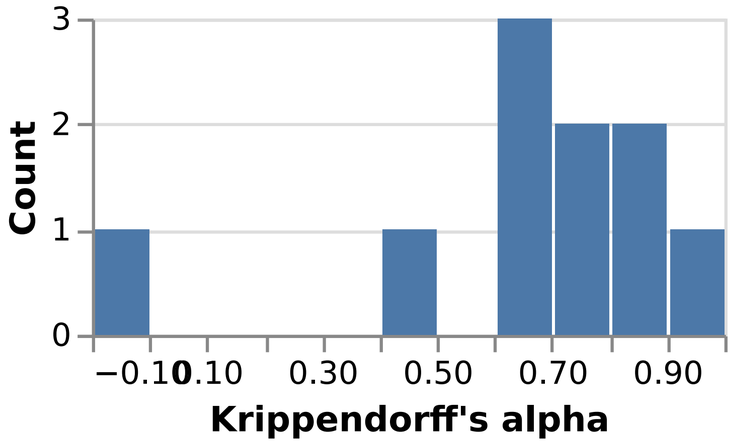
Technical performance evaluation

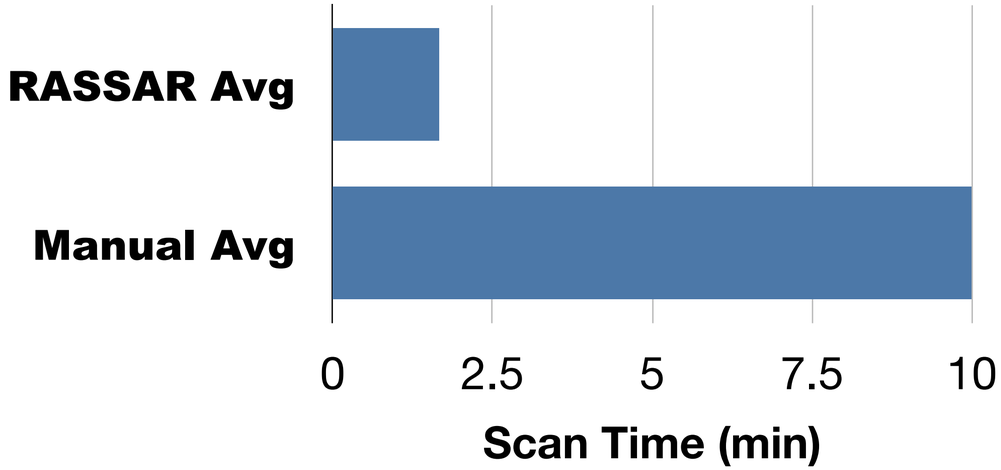


*Videos from the technical performance evaluation.
Scenes blurred for privacy.

Technical Eval

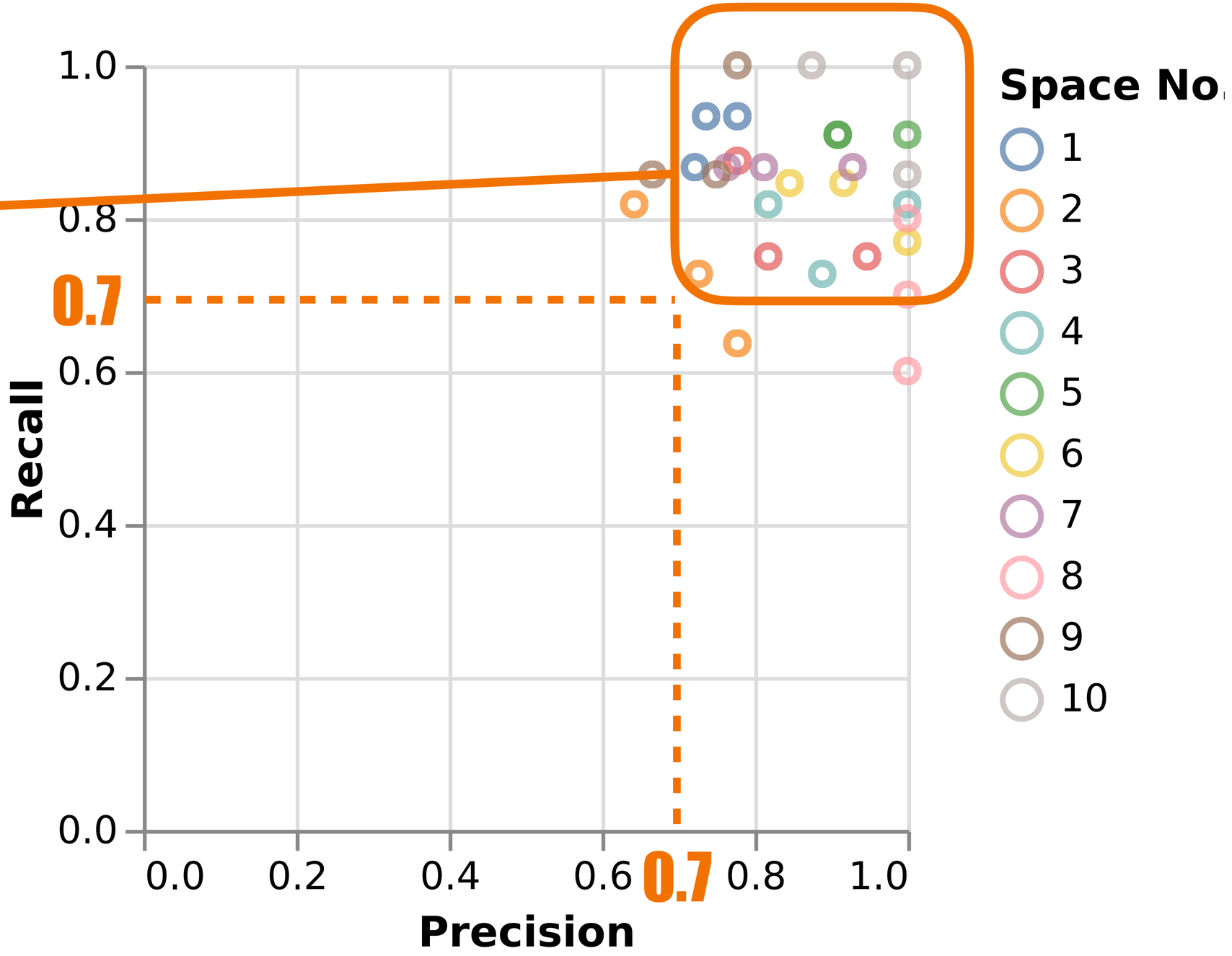






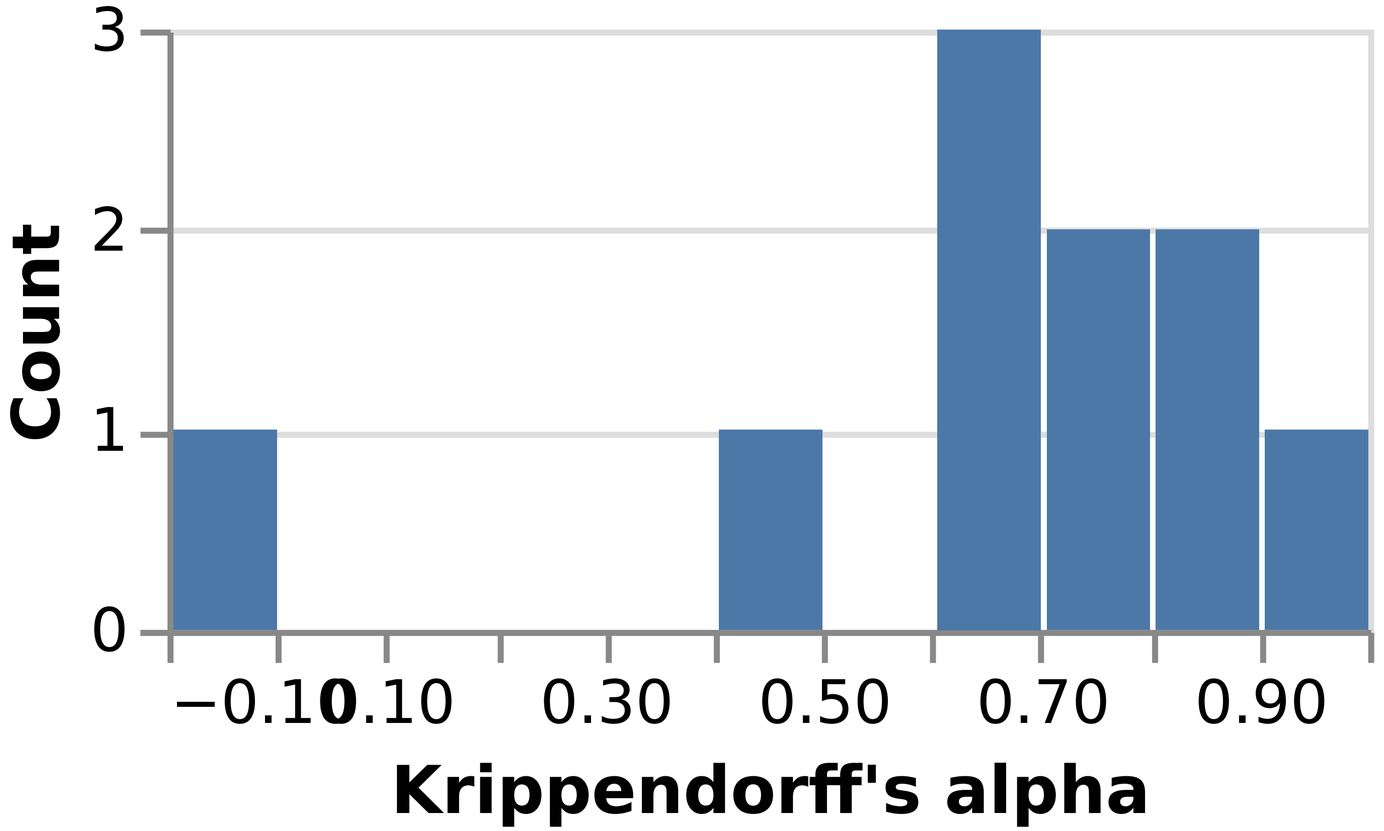
Technical Eval

Scans show high precision/recall



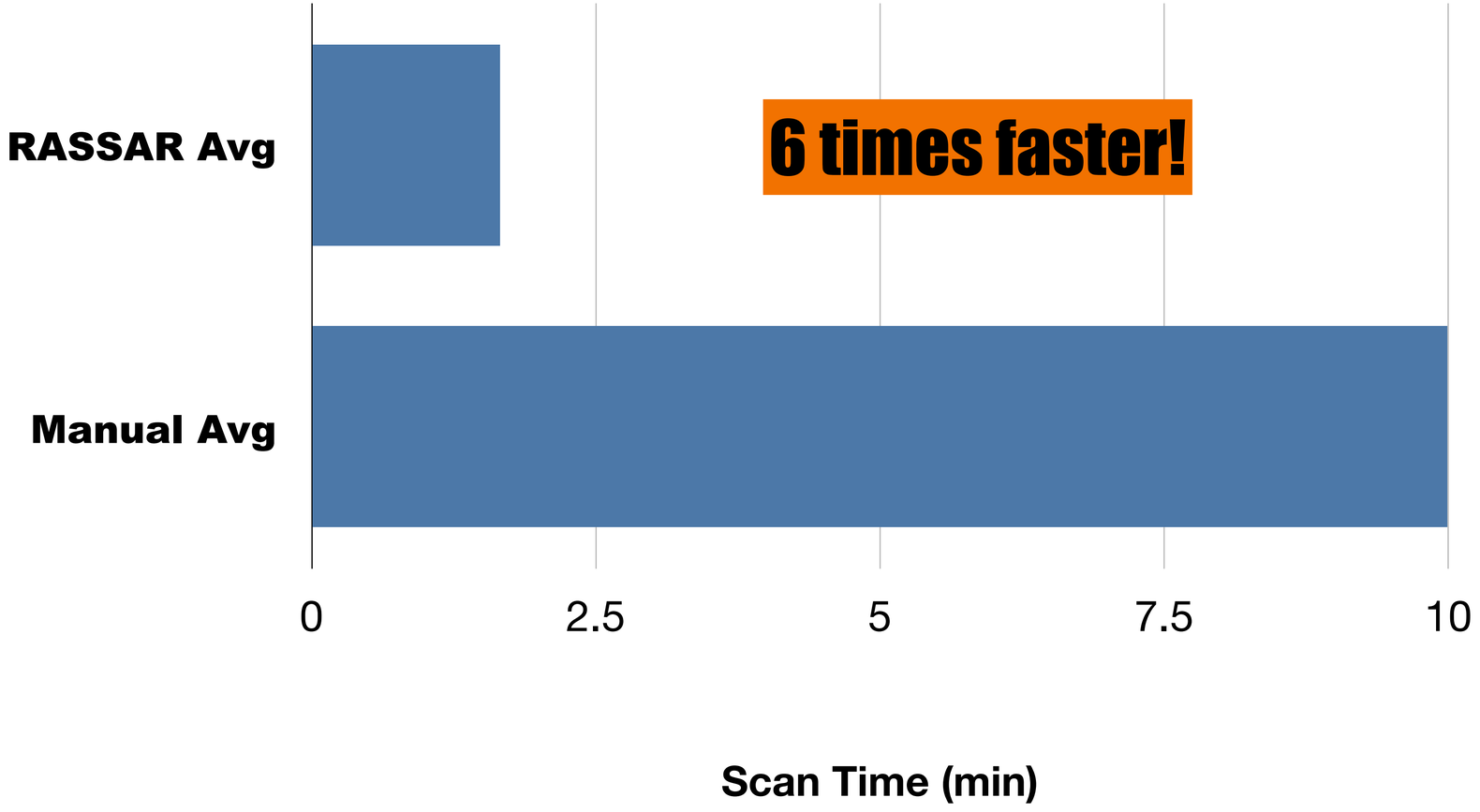
Technical Eval

High agreement over repeated scans



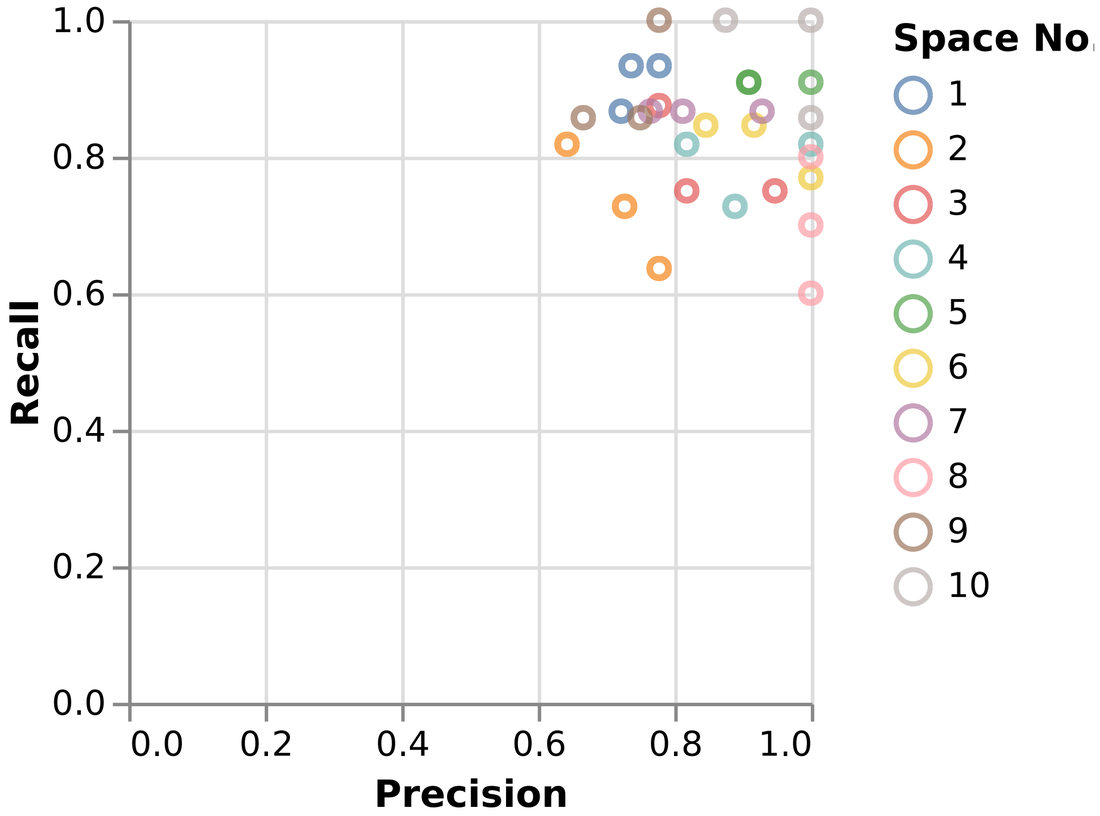
Technical Eval

Krippendorff's alpha

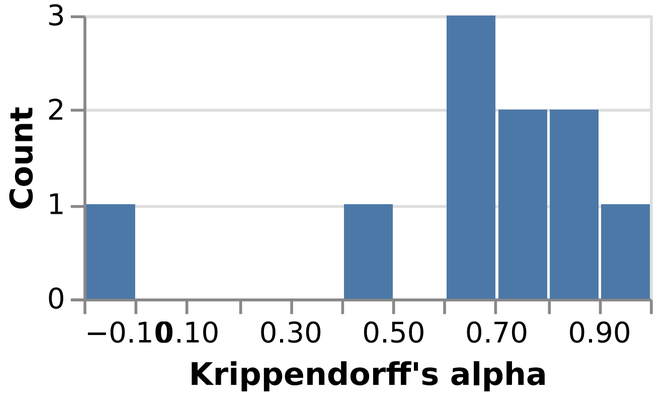


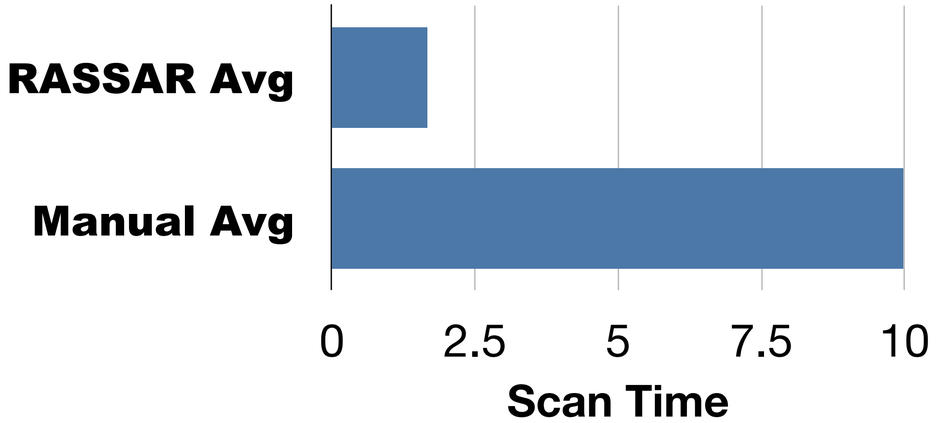
Technical Eval

Accurate

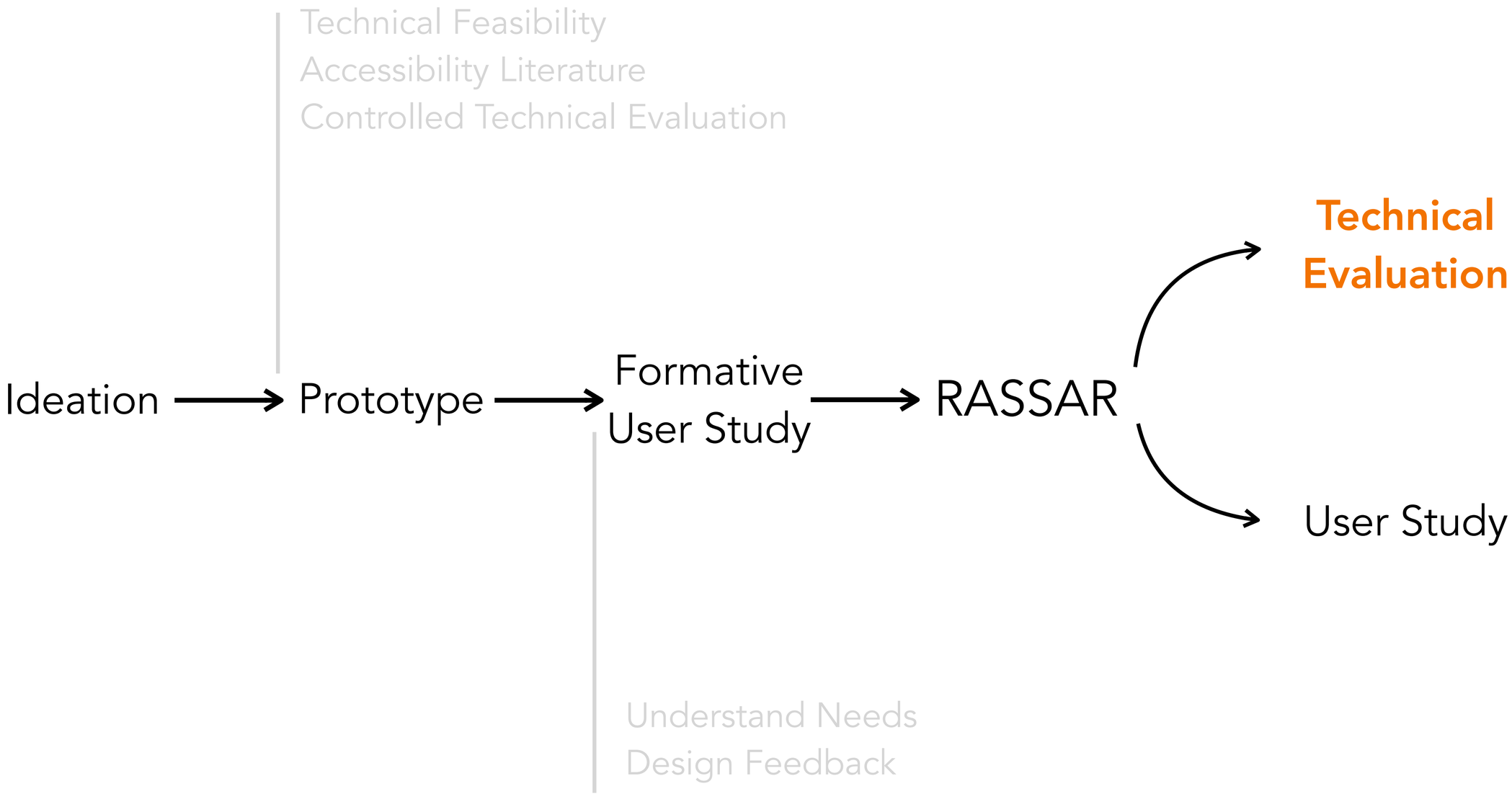


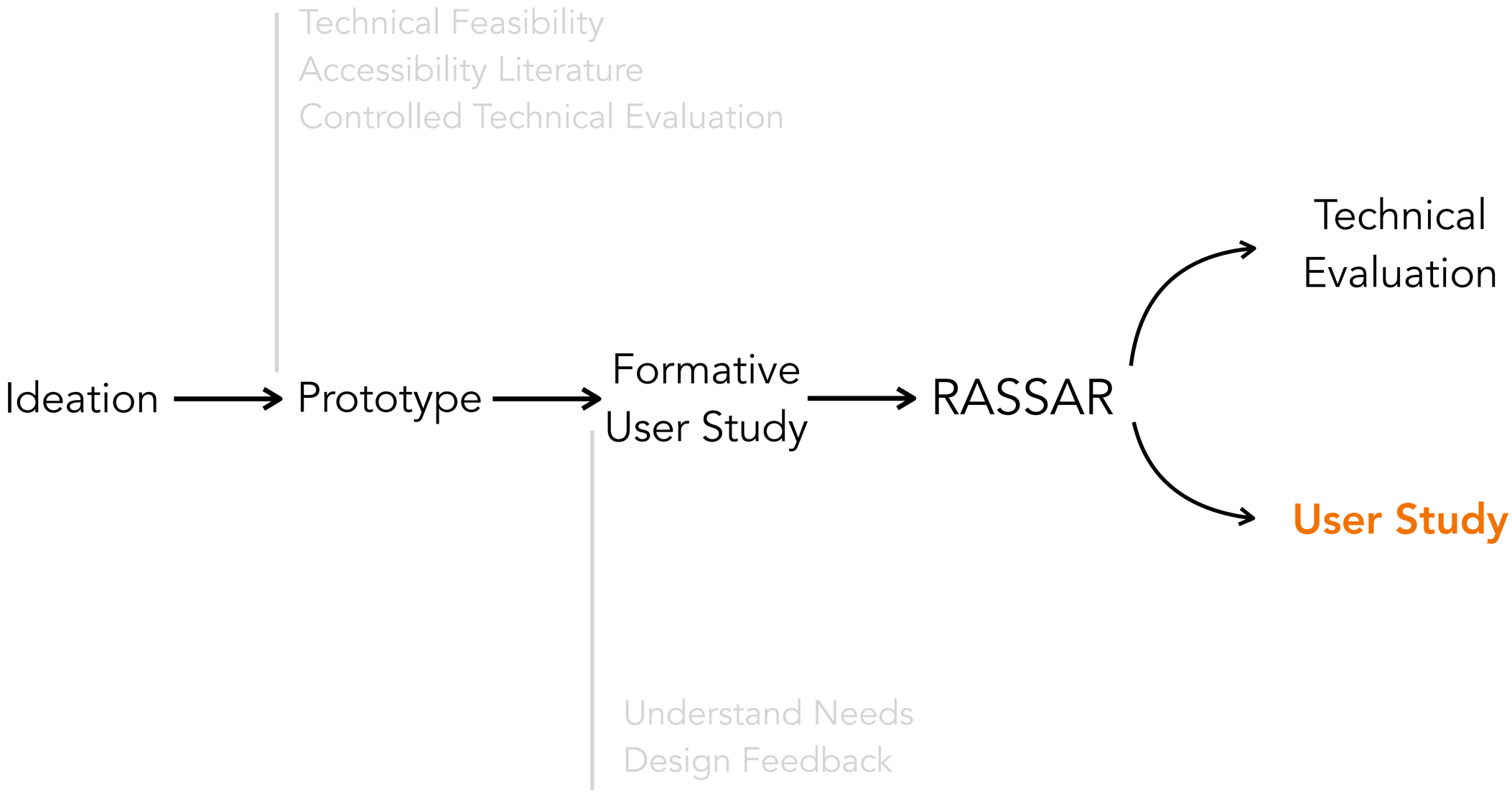
Consistent





Fast


Technical Feasibility
Accessibility Literature
Controlled Technical Evaluation
Ideation
Prototype
Formative
User Study
RASSAR
Technical
Evaluation
User Study
Understand Needs
Design Feedback


Technical Feasibility
Accessibility Literature
Controlled Technical Evaluation
Ideation
Prototype
Formative
User Study
RASSAR
Technical
Evaluation
User Study
Understand Needs
Design Feedback

User Study
JAY J3

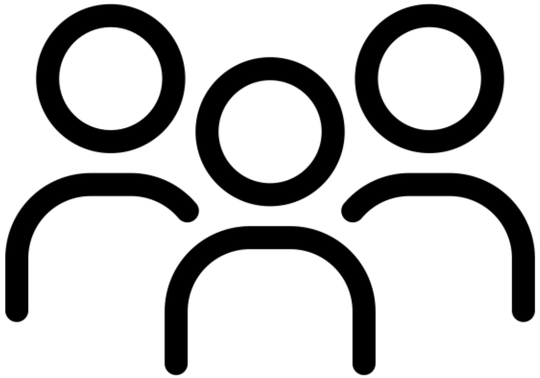
User Study

Manual Inspection

Independent scan

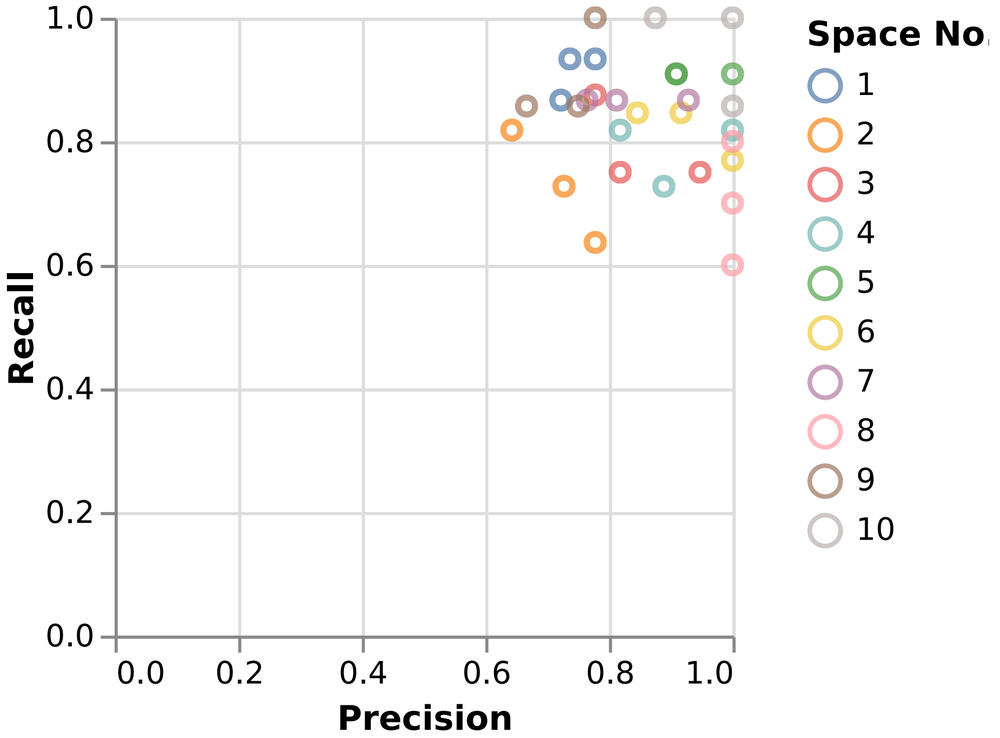
Calculate accuracy

User Study



Precision: **0.79**

Recall: **0.73**

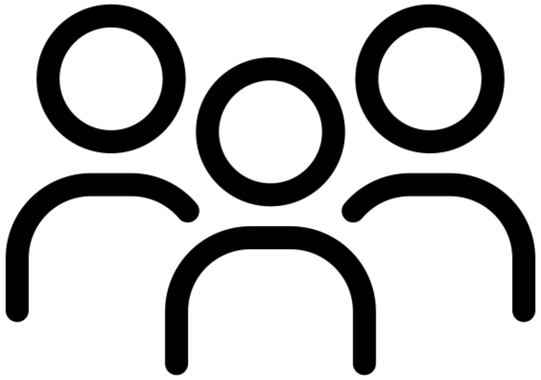


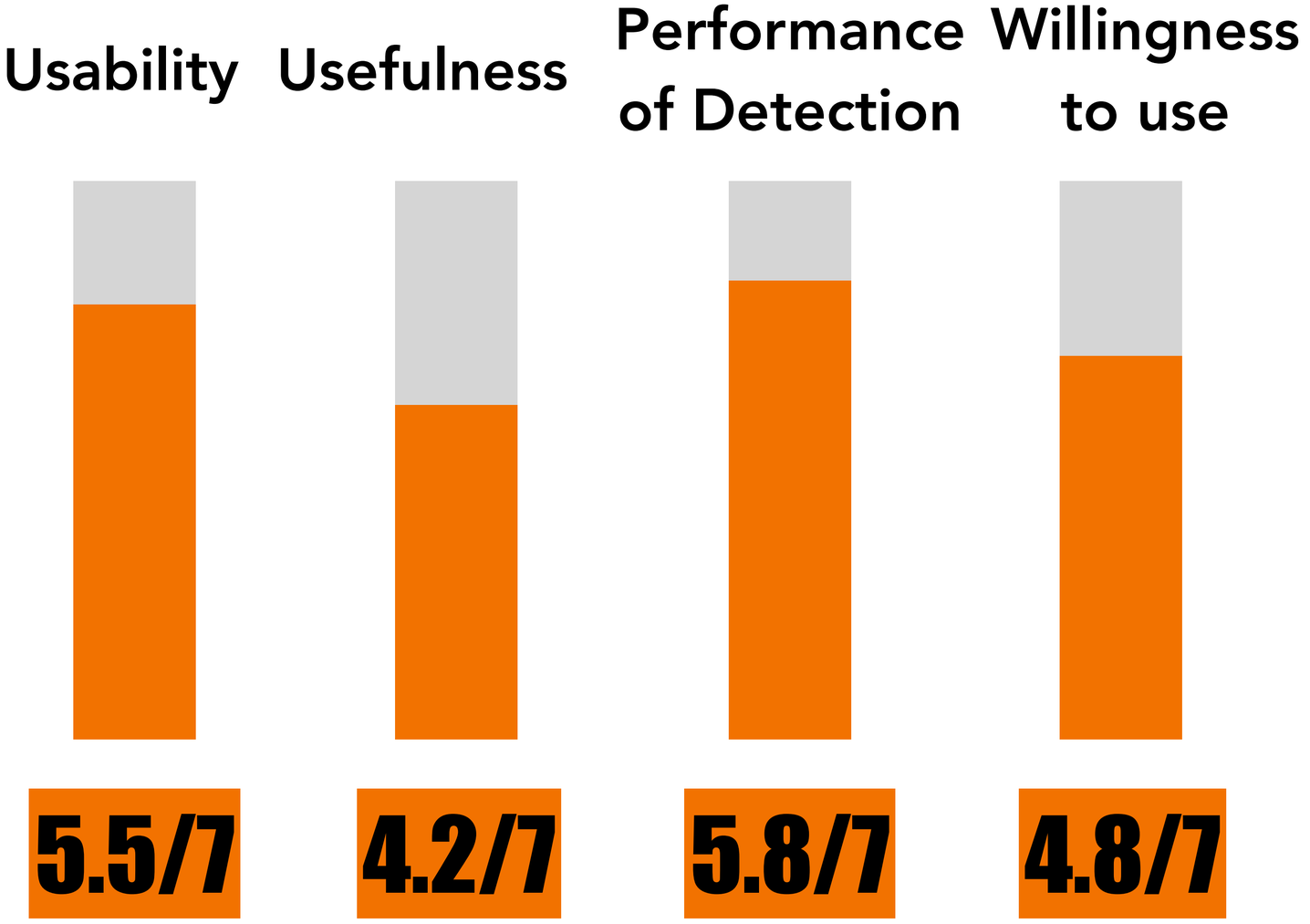
Precision: **0.86**

Recall: **0.83**

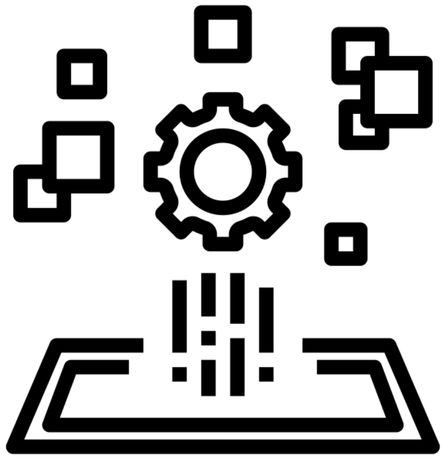
Similar Performance!

User Study




Usability
Usefulness
Performance of Detection
Willingness to use
5.5/7
4.2/7
5.8/7
4.8/7

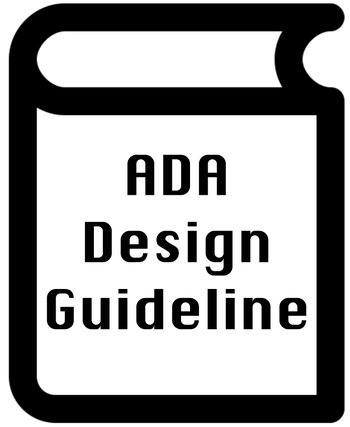
Discussion



Application Scenario

Detection Performance

Accessibility Scope



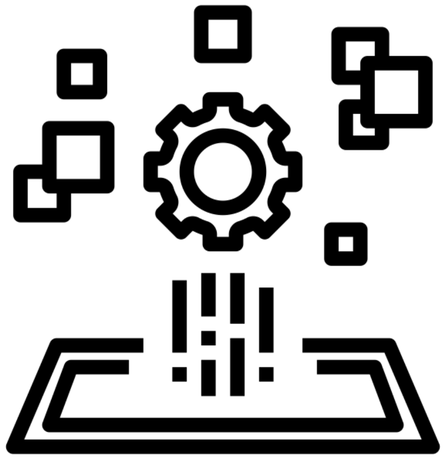
Beyond ADA

Prior-visit
Auditing

Accomodate
Life Change

Complement
OT Visit

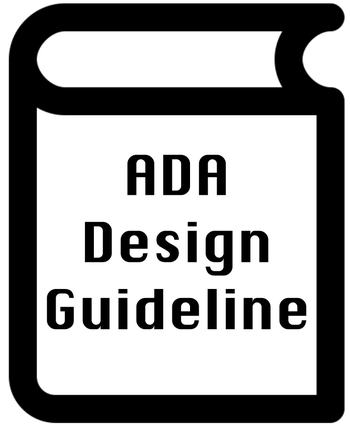
Discussion



Application Scenario

Detection Performance

Accessibility Scope



Beyond ADA

Object Dimension

Object Too Tall or Short

Bed Height
Table Height
Counter Height
Door Width
Opening Width


```
"Counter":{
    "Dim_Height":{
        "Community":["Wheelchair"],
        "Dependency":null,
        "Dimension":{
            "Comparison":"Between",
            "Value":[28,34]
        },
        "RelativePosition":{
            "Comparison":null,
            "Value":null
        },
    "Existence":null,
    "Note":"replace PLACEHOLDER to either 'short' or
↪ 'tall' depends on the actual height of the
↪ counter.",
    "Message":"Warning: Counter is too PLACEHOLDER.",
    "Description":"According to ADA compliance,
↪ counters must be at the proper height (this often
↪ is 28-34 inches from the floor).",
    "Suggestions":["Replace to an adjustable height
↪ counter"],
    "Sources":[
    {"name":"2010 ADA Standards for Accessible
↪ Design", "url":"https://www.ada.gov/regs2010/201
↪ 0ADAStandards/2010ADAstandards.htm"},
    {"name":"Aging in place: Designing, adapting, and
↪ enhancing the home environment","url":"https://s
↪ cholar.google.com/scholar?hl=en&as_sdt=0%2C48&q=
↪ Aging+in+Place+Designing%2C+Adapting%2C+and+Enha
↪ ncing+the+Home+Environment&btnG="}]
    }
},
```

Risky Ite

If Existent


```
"Knives": {
"ExistenceOrNot": {
  "Community": ["Children"],
  "Dependency": null,
  "Dimension": {
    "Comparison": null,
    "Value": null
  },
  "RelativePosition":{
            "Comparison":null,
            "Value":null
        },
  "Existence": false,
  "Note": null,
  "Message": "Warning: Knives have been detected in a
↪  dangerous place!",
  "Description": "For safety, no knives should be
↪  present on reachable surface.",
  "Suggestions": ["Move out of reach of children"],
  "Sources": []
}
```



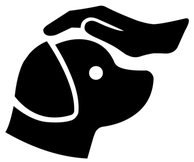
```
"GrabBar_Existence_Tub": {
"ExistenceOrNot": {
  "Community": ["Wheelchair", "Elder"],
  "Dependency": ["Tub"],
  "Dimension": {
    "Comparison": null,
    "Value": null
  },
  "RelativePosition":{
            "Comparison":"LessThan",
            "Value":[27]
        },
  "Existence": true,
  "Note": null,
  "Message": "Warning: No grab bar detected near
↪  tub!",
  "Description": "For safety, there should be grab
↪  bars near tub.",
  "Suggestions": ["Add a bath grab bar on the wall or
↪  a clamp-on grab bar to the tub."],
  "Sources": [
    {"name":"HSSAT","url":"https://www.tompkinscount
↪  yny.gov/files2/cofa/documents/hssat_v3.pdf"}]
}
},
```


ive Item

istent

ar Near Toilet
ar Near Tub
rm

Children
Older Adults



MAKEABILITY LAB

PAUL G. ALLEN SCHOOL
OF COMPUTER SCIENCE & ENGINEERING

Thank you!

Questions?

RASSAR

Room Accessibility & Safety Scan in Augmented Reality

Our Source Code

Xia Su, PhD Student, UW CSE

Han Zhang, Kaiming Cheng, Jaewook Lee, Qiaochu Liu, Wyatt Olson, Jon Forehlich