

IDC School of Design
अभिकल्प विद्यालय

Spatial Interfaces for Smart Homes

DEP 406: B.Des Design Project 2

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Approval Sheet

The B.Des Project 2, entitled "**Spatial Interfaces for Smart Homes**" by Medhavi Parasar, Roll Number 18U130017, is approved, in fulfilment of the Bachelor's in Design Degree at IDC School of Design, Indian Institute of Technology Bombay.

Project Guide: Prof. Kums P Kumaresan

Internal:

External:

Chairperson:

Declaration

I declare that this written document represents my ideas in my own words, and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated, or falsified any idea/data/fact/ source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been adequately cited or from whom proper permission has not been taken when needed.



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20th June 2022

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I would like to first and foremost thank Prof. Kums P Kumaresan for his ongoing support and help throughout this project. His feedback has been very insightful and motivating. Without his guidance, this project could not have been completed.

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I am also thankful to my panel, Prof. Purba Joshi, Prof. B.K. Chakravarthy, and Prof. R Sandesh for their encouraging feedback throughout the semester.

Lastly, I would like to thank everyone who helped me by participating in the interviews organised for sharing data and allowing me to do user and site studies. I am incredibly grateful for their hospitality and help.

Abstract

In the last few years, home automation products and systems have significantly boosted sales and usage. However, these products are still very rudimentary in application and can be “smarter”. Households have existing infrastructures that are not being utilised to their full potential. This project aims to utilise existing technology to create a system that anticipates the users’ needs and performs tasks to fulfil said needs as intuitively as possible.

Several products exist in the market; however, the types of sensors required are not available in every device, and multiple devices (from different brands) tend to not work together seamlessly or are a part of a system which tends to get expensive because many devices are required.

Furthermore, none of the systems is able to look into their surroundings or anticipate user needs to the full extent.

The aim of this project is to create a more efficient, intuitive, and holistic system. A system that is able to anticipate the user’s needs and recognise and process gestures, motion, positions, and body language as triggers before they have to give commands.

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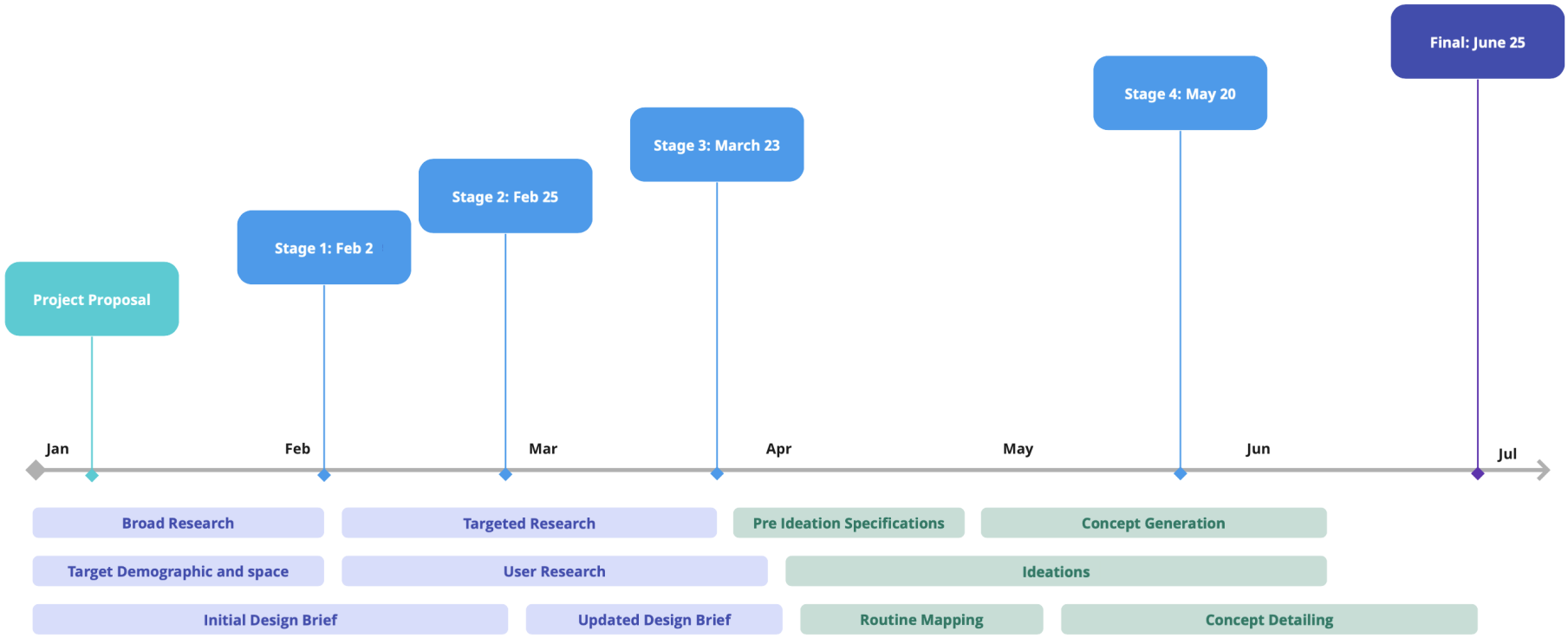
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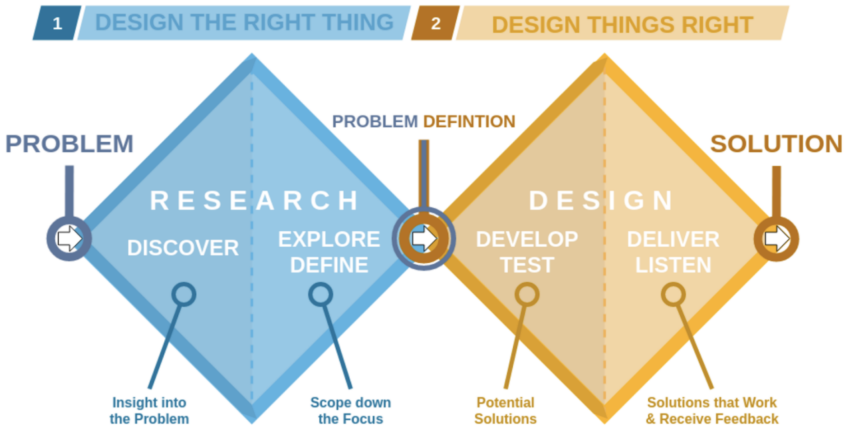
Project Timeline



Project Goals and Methodology

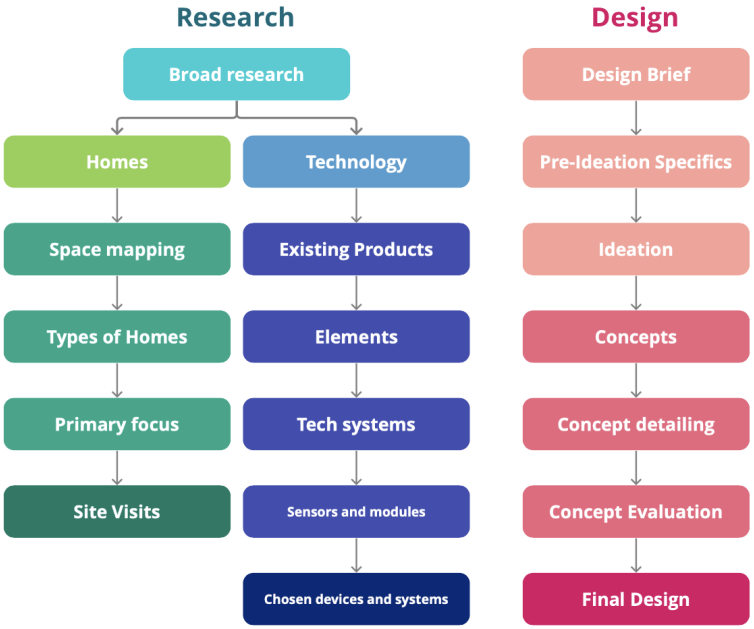
This project aims to create a home automation system that utilises the existing homes' infrastructures and uses soft and hard sensors to create a more automated and intuitive experience.

The methodology followed throughout this project is the double diamond design process, as shown below.



Double Diamond Design Process
https://en.wikipedia.org/wiki/Double_Diamond_(design_process_model)#/media/File:Double_diamond.png

Considering that there are many areas to research and understand, a vague list of research topics was made. Process expected during the design phase was also jotted down.



Steps followed in the design process

Introduction

In the last few years, home automation products and systems have significantly boosted sales and usage. However, these products are still very rudimentary in application and can be “smarter”. Households have existing infrastructures that are not being utilised to their full potential. This project aims to utilise existing technology to create a system that anticipates the users’ needs and performs tasks to fulfil said needs as intuitively as possible.

Target Demographic:

- **Primary Users**: Working professionals in their 20s who have a working knowledge of general technology.

Space Focused on:

- **2BHK Home**: 700-1000 sq. ft in a mid-range society (Mumbai).



Example of a person from the target demographic in space focused on

Literature Study

What are smart homes?

A smart home refers to a convenient home setup where appliances and devices can be automatically controlled from anywhere using another device with an internet connection.

The smart devices in a home can aid in tasks that can be easily automated and scheduled. A well-implemented system can make the users' lives easier and save energy in the long run.

Why use home automations?

1. Convenience: Smart home devices provide users with increased functionality and generally have a low learning curve.

2. Flexibility: Smart home systems provide users with customisability and allow for the integration of new technologies.

3. Energy Efficiency: Sensors can be used for optimal temperature control and lights to minimise electricity waste.

4. Insights: Usage of the system over time can help users understand and organise their daily lives, give the user insights into habits and patterns, and help them make adjustments.

5. Security: The systems provide not only security against home invasions they also alert users about fires, carbon monoxide, etc.

Why do we need new designs?

Despite many products and systems in the market, smart homes can be improved further by mixing the existing home infrastructures, further automating tasks and taking advantage of dependencies better.

Research

Existing Products and Systems

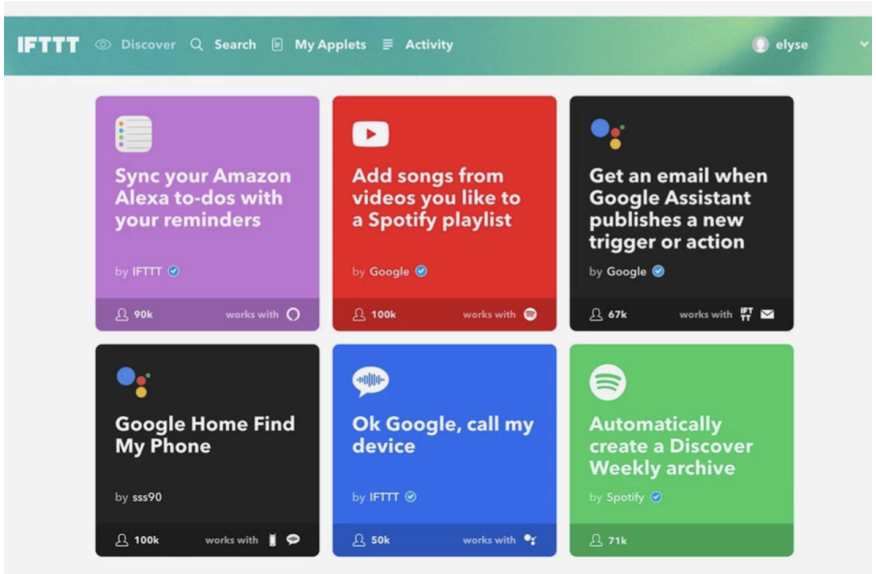
There are many smart home products in the market, like bulbs, fridges, speakers, clocks, TVs, etc. There exist many home automation systems as well, which are usually quite expensive. Many apps can help with more complicated routines and tasks but have issues with cross-platform compatibility.

The issues that arise in these products vary from product to product; however, the common problem is that they are often not compatible with each other, fail to integrate well or take quite a while to set up. These devices store information, but the link between them needs to be stronger so that they can use the shared information to make the system work more efficiently and seamlessly.

Another issue with these devices is that they sometimes have a rigid and glitchy feel; making them easier to interact with and more automatic would make it easier for users. There also needs to be an easy manual override system to counteract issues with automated tasks that are triggered accidentally.



Smart Bulb by Wixann
https://dengarden.com/home-improvement/wixann-9w-smart-led-light-bulb-review-cheap-color-bulb-for-all



IFTTT App: Used for task scheduling, series of actions that need a trigger (if this then that)
https://www.pocket-lint.com/smart-home/news/130082-what-is-ifttt-and-how-does-it-work



Roku Smart TV Interface
https://www.amazon.com/TCL-4K-Smart-LED-43S435/dp/B08DHDS4T3



Philips Hue: Smart Lighting System
https://techcrunch.com/2020/09/03/philips-hues-new-play-gradient-lightstrip-promises-a-big-upgrade-for-home-entertainment-spaces/



Bose speaker with Alexa, Apple Homepod, and a smart bedside clock
https://www.wired.com/story/how-to-set-up-smart-home/

Many companies create multiple smart systems (lighting, window kits, audio control, etc.) that work well with each other. However, these kits and systems are not typically compatible with other smart devices or even kits or systems from other companies.

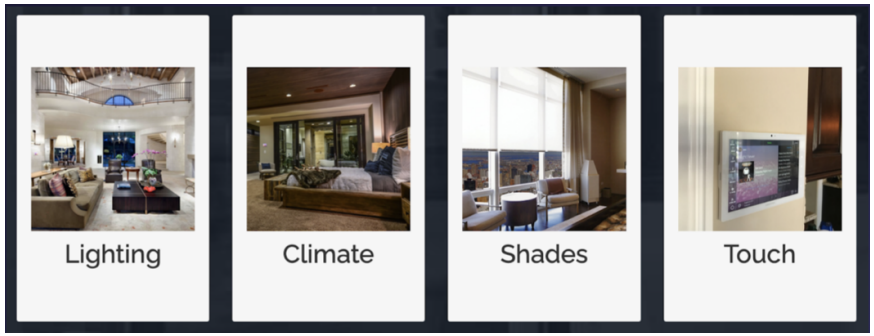
Most of these companies implement their systems and products during the construction process of the house and provide controls as such. Their apps or controls usually provide basic task scheduling but need to be time-based in most cases.

While these companies provide “holistic” solutions, they are costly, hard to retrofit, and not as intuitive as they can be.





Hogar Controls: Company that makes home automation systems
https://hogarcontrols.com



Domotics: Company that makes home automation systems
https://thedomotics.com/luxury-smart-home-automation-company/

Products like wifi modules help control existing appliances through switchboards. IR receiver and emitter devices also help reprogram appliances with “dumb” remotes to respond to smart home commands.



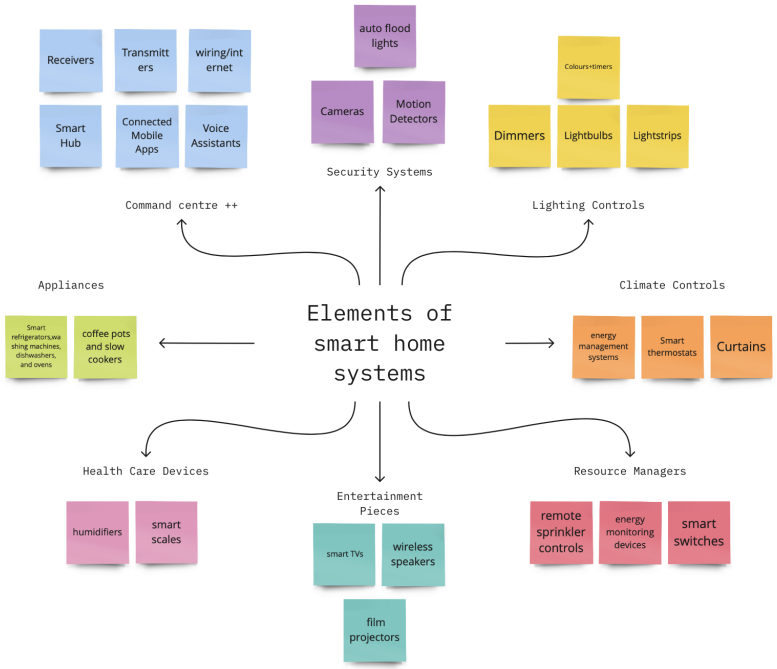
IR emitter and receiver device, and a wifi module for switchboards
https://www.jd.co.th/product/smart-ir-remote-controller-smart-universal-infrared-remote-control-automation-hub-with-all-in-one-wifi-ir-controller_16186102.html
https://www.amazon.in/Phlipton-Automation-Control-Required-Compatible/dp/B08P35F2N2

Technology in home automations

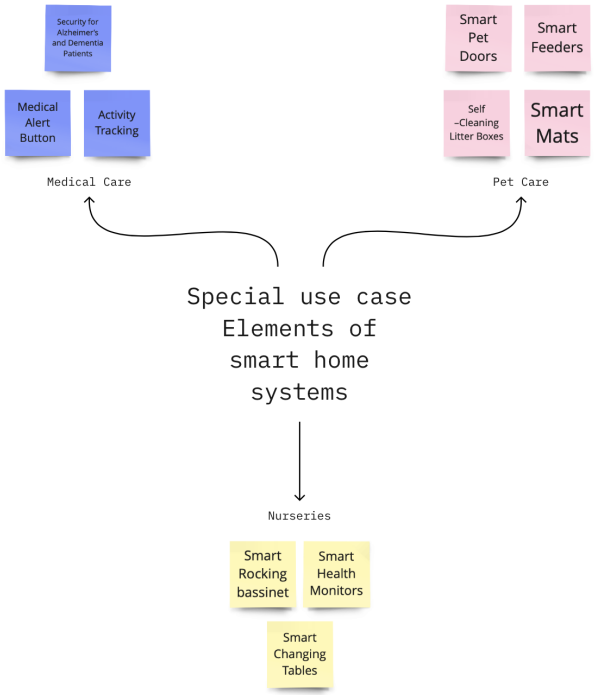
Current systems

There are various elements in a smart home system, each serving a different function, from lighting to climate control to security.

There are also specialised devices and systems in place for certain use-case scenarios (e.g., medical, childcare, etc.)

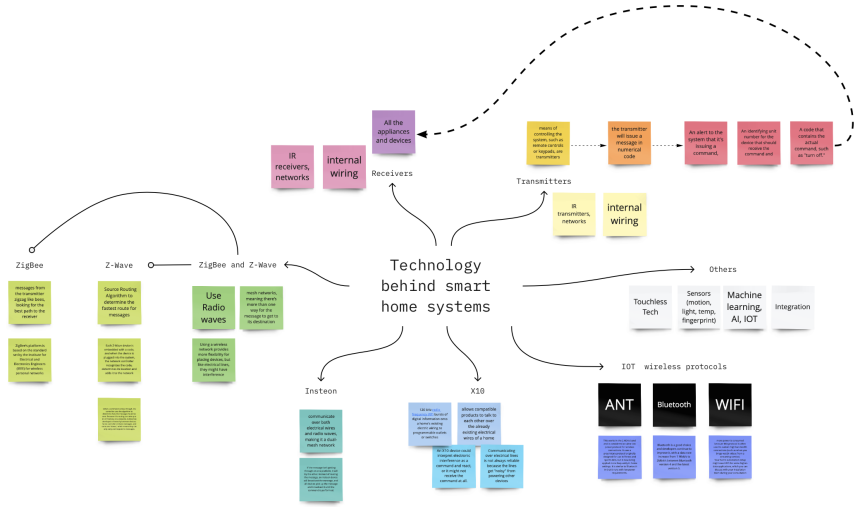


Home Automation systems: Elements Mapping

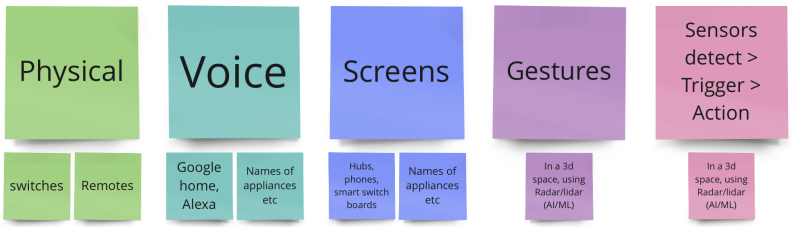


Home Automation systems: Special Use-Case Elements Mapping

Communication between these various elements happens via wireless protocols and utilises a hub, receivers, and transmitters. There are many ways to interact with these devices and systems; voice, screens, switches, remotes, etc.

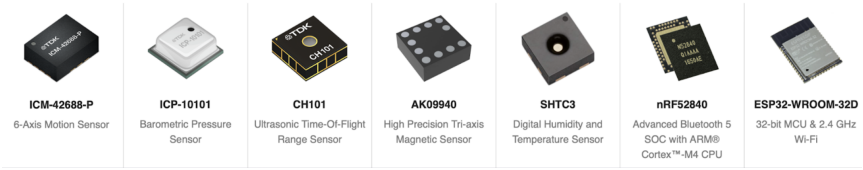


Home Automation Communication systems: Elements Mapping

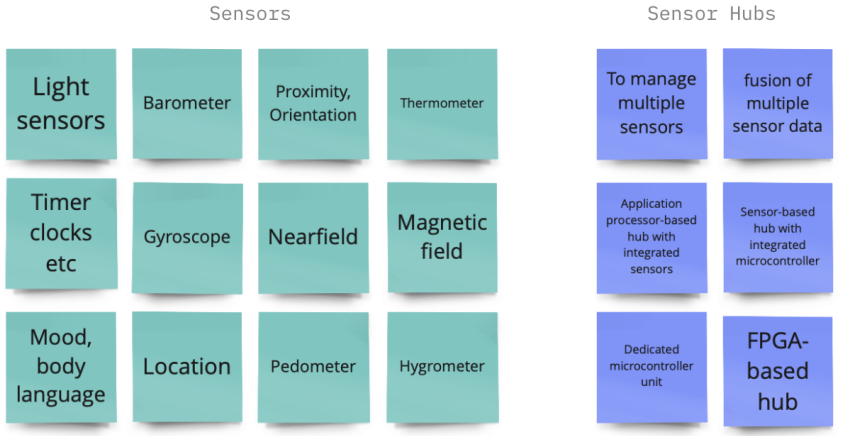


Home Automation systems: Interaction methods mapping

Besides these, the most important elements in smart homes are the sensors being used. Sensors gather data from around them and relay it to the hub or command centre. They also for triggered tasks, and data from each is collated and utilised, they can help create a more seamless and intuitive experience.



Examples of different types of sensors
https://invensense.tdk.com/smartbug

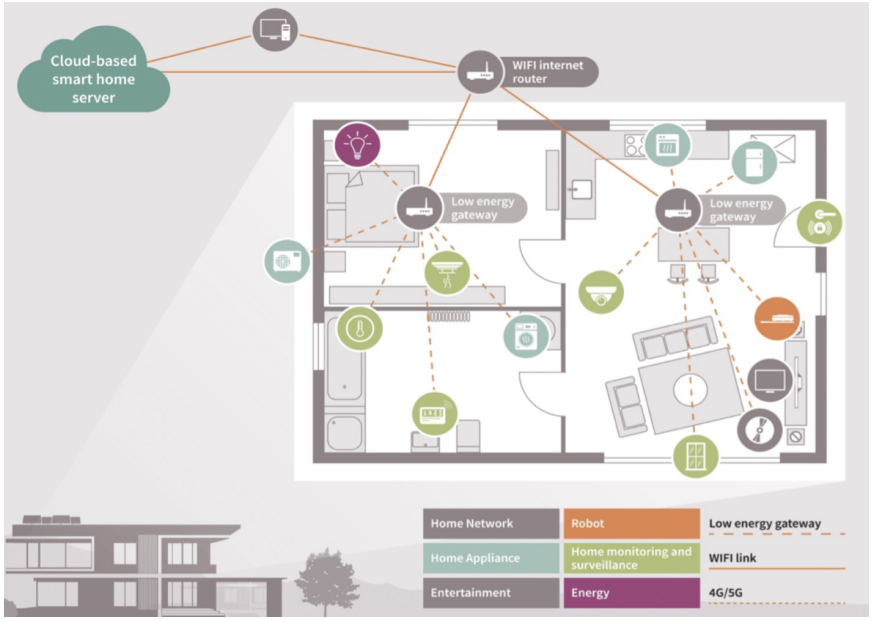


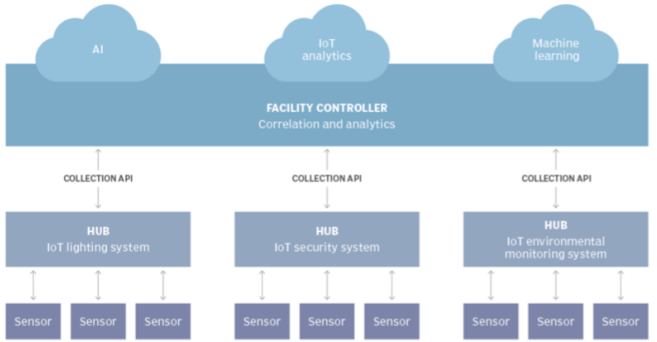
List of sensors and sensor hub types

Wifi					
Bluetooth					
IR	Blaster	Reciever	Emitter		
NFC					
RFID					
GPS					
Temperature	Thermocouples	RTD	Thermistors	IC	IR
Motion	Lidar	Radar	PIR	Ultrasonic	Microwave
Proximity	Lidar/Radar	Capacitive	Photoelectric	Ultrasonic	
Pressure					
Water Qual					
Chemical					
Gas	Air Qual	CO etc			
Smoke					
Level	Point level	Continuous			
Img	CCD	CMOS			
Accelerometer					
Gyroscope					
Humidity					
Optical sensors	Photodetector	Fiber Optics	Pyrometer	Proximity &IR	Camera
Solar Cells					
Biomedical					
Light					
Ultrasonic					
Sound	Omnidirectional	3 mics	Speaker		
Laser					
GMR					
EEG					
Vibration					
Lux					
Air					

List of sensors

All of the elements work and communicate via a system. The system architecture of smart home systems is explained in the images below.

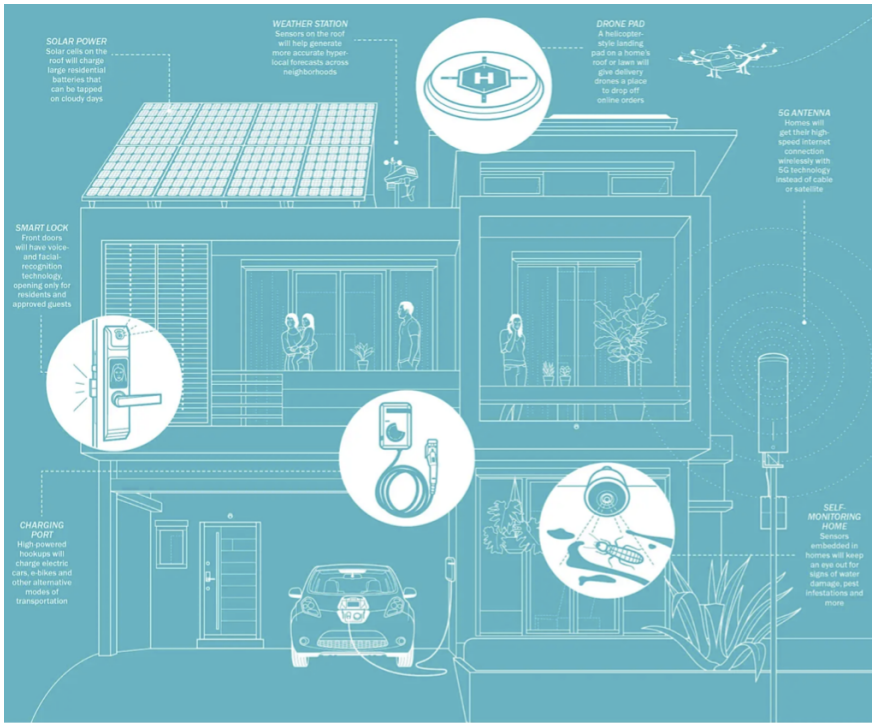




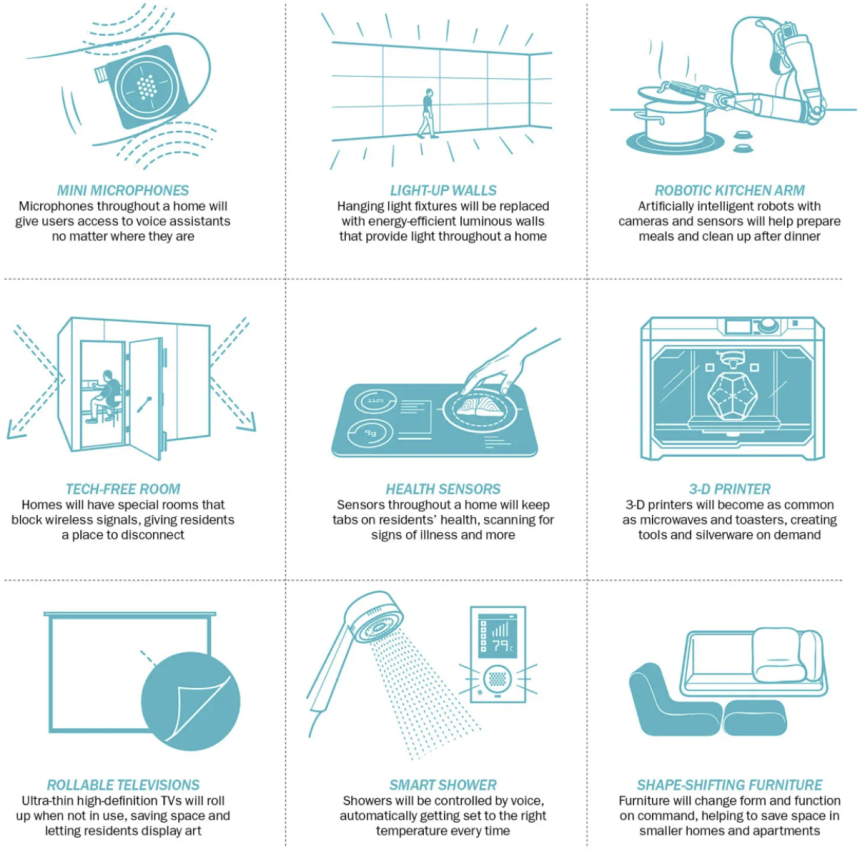
Smart Home Systems: System Architecture
https://www.infineon.com/cms/en/discoveries/smart-home-basics/
https://internetofthingsagenda.techtarget.com/definition/smart-home-or-building

Future Technology Expectations

Future technology expected in this area was also looked at. While not in the scope of the project, it was looked into to get an idea of what is expected in the future and to keep new ideas in mind for further scope while designing the final outcome.



Future technology expected in smart homes
https://time.com/5634791/smart-homes-future/



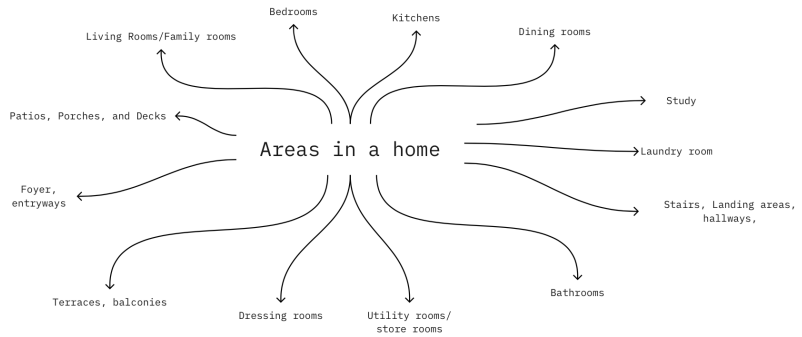
Future technology expected in smart homes
https://time.com/5634791/smart-homes-future/

Most devices and systems expected in the future utilise sensors and wireless protocols. This is kept in mind while designing the final outcome.

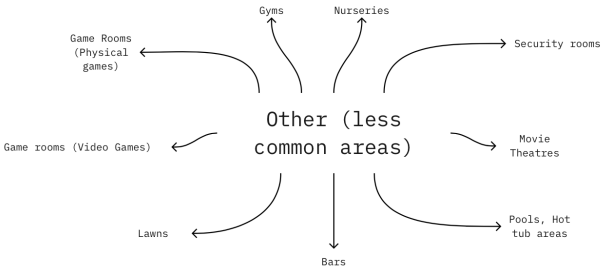
Research on houses

Areas in a home

In a smart home, each area, zone, or space needs to be tailored according to the needs of the space. Maps of areas, zone types, and possible devices in different areas were made to understand the spaces.



Types of areas typically in a home



Types of areas less commonly in a home



Zone-wise classification of areas in a home

Living room / Family room	Kitchen	Dining rooms	Bedroom	Bathroom
Smart Speaker	Smart Refrigerators	Smart Fans	Smart Beds	Smart Toilets
Smart Floors	Smart Ovens	Smart Shades	Smart Floors	Smart Mirrors
Smart Tv	Smart Dishwashers		Smart Tv	Smart Showers
Smart Shades	Smart Dishes		Smart Shades	Smart Privacy Windows
	Smart Slow Cookers			
Universal	Smart Coffee Pot			
Smart AC	Smart Trash Cans			
Smart Lighting	Dash Buttons			

Possible devices area-wise list

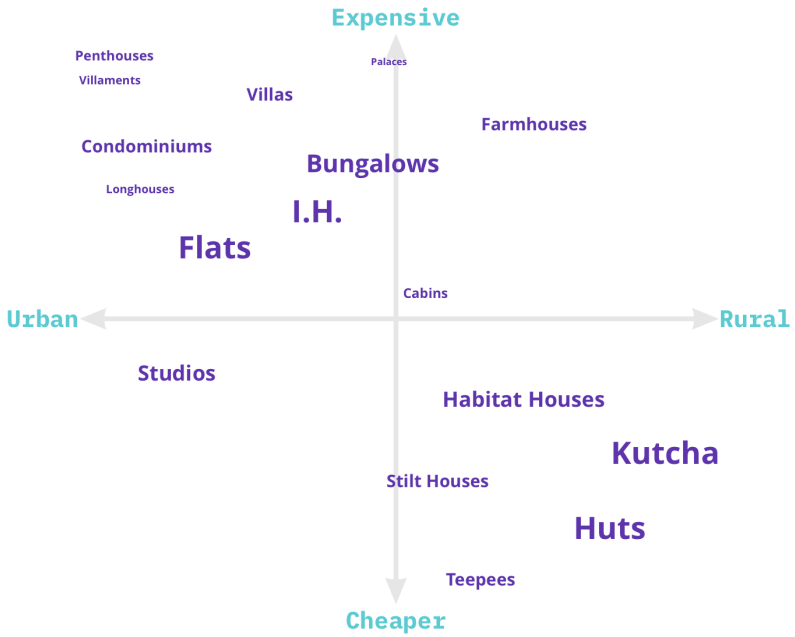
These areas and spaces needed to be set in the context of particular types of houses to better understand the specifications and requirements.

Types of houses in India

There are various types of houses in India, ranging from flats to huts and teepees. A list of the different types of houses was created.

- Huts
- Bungalows
- Apartments/Flats
- Villas
- Farmhouses
- Tepees
- Cabin
- Longhouses
- Palaces
- Independent Houses
- Penthouses
- Studios
- Habitat Houses
- Condominium
- Kutcha Houses
- Row Houses
- Stilt Houses
- Villaments
- Duplexes
- Detached houses

List of types of houses in India



Types of houses in India: distributed and sized on a graph according to 3 variables

For further context, the types of houses were mapped on a graph measuring: if they were in urban or rural areas, their average prices, and how abundant they were throughout the country.

All of these types of houses have many different space types and requirements; it is difficult to define the space if taking all of them into account. A particular problem space was specified to simplify this. Statistics about types of houses were taken into consideration to decide this.

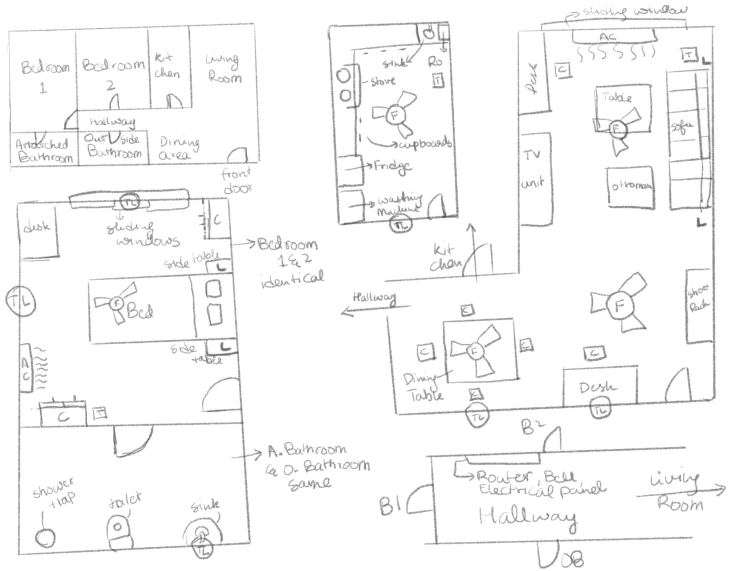
>50%	>40%	Avg
Apartment	2BHK	~1150 sq. ft.
More than 50% of new home buyers prefer flats over other housing options	The most preferred apartment size in urban areas is a 2BHK flat.	Average apartment sizes in metro cities. Mumbai: 932 sq. ft.

Indian houses statistics
Data extrapolated from: https://www.business-standard.com/article/companies/average-apartment-size-in-the-top-7-cities-grows-10-in-2020-report-121012101713_1.html
https://economictimes.indiatimes.com/industry/services/property-/-cstruction/average-apartment-size-increases-for-the-first-time-since-2016-report/articleshow/
https://timesofindia.indiatimes.com/business/indians-still-prefer-a-2-bhk-property/articleshow/73351050.cms
https://www.financialexpress.com › Money

Primary focus

Based on these statistics mentioned above, a **2BHK flat** in a **mid-range society** in a **metropolitan city** was chosen as the primary focus space. Most site visits (done alongside user interviews) took place in Mumbai, and some took place in Bangalore and Delhi.

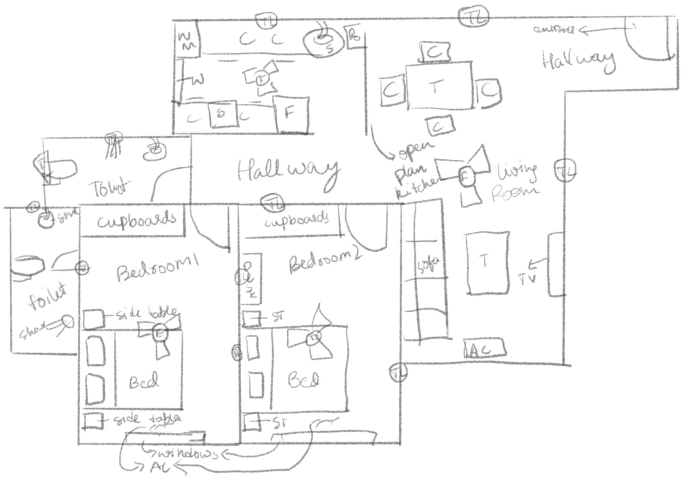
The site visits of the 2BHK have been sketched out with furniture and appliances.



Ashok Towers, Marol, Mumbai



Vasant Oasis, Marol, Mumbai



Vrindavan Apartments, Chakala, Mumbai

Smart home site visit

To better understand the problem, a house under construction implementing home automation systems and a constructed smart house were visited.

The system implemented in the houses was quite expensive, and the house was in a luxury colony, with the age range of residents being about 40-60 years old.

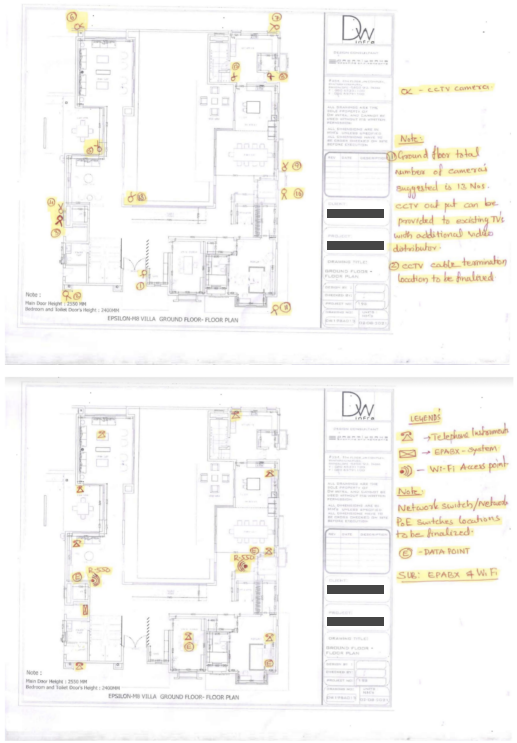
There were some primary insights after discussing the systems and devices with the residents.

Aesthetic Value	Option for customisability	Special Use Case	Programming is a hassle	Privacy Concerns	Sensor Bugs

Insights from preliminary user interviews

The residents liked the aesthetic value and customisability, and some had systems created for particular use cases that aided them in their daily lives.

However, programming new dependencies and tasks were quite a hassle for them. They also had some privacy concerns regarding who the data was being sold to and sometimes had baggy results for commands which they did not know how to navigate and fix.



Smart system being implemented in a home in Bangalore

Analysis

The systems in place currently have many communication gaps and do not fully utilise the already existing infrastructures in place. Many **soft sensors** can be deployed to fill these spaces. Communication between smart devices of different companies can be fixed with software deployment.

Current methods of interaction are not as intuitive and human as they can be. Many tasks that can start with a trigger can be better automated; they can happen automatically. Anticipation systems or systems that can notice things like a person getting out of bed as a trigger to automate the tasks for their morning can be implemented.

Zone-wise or activity-wise needs can be a seamless experience by adjusting the smart home needs to certain contexts and zones of the house. Manual override systems or failsafes need to be better implemented and easy to use in unexpected situations.



Intuitiveness

Creating a more intuitive, human method of interaction



Automations

Better dependencies, communication, flows, and anticipation systems



Infrastructure

Using existing infrastructures and soft sensors



Overrides

Manual Override systems for unexpected situations

Insights gained from research

User Research

Secondary user research

Secondary research was carried out, and the types of users and tiers of products and appliances were mapped out to better understand the types of users.



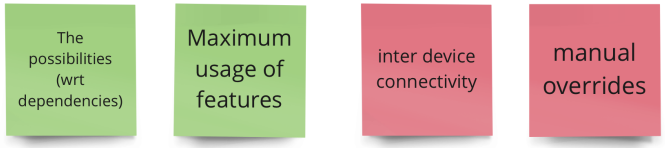
Types of smart home users

Tier 1		Tier 2	Tier 3	Tier 4	Tier 5
Entertainment	**Security**	Voice assistant in multiple rooms	Significant amount of lights/appliances automatic	Motion, temperature, humidity sensors	6 Axis motion sensor
Lights	CCTV	All lights and fans	Motion sensors	window, curtain motors	Barometric sensor
Fans	Motion detector	CCTV	Complex scenes: some manual	All appliances connected to wifi	
Music	Alarm system	Window door closed sensor: alarm		Almost everything is auto	
Speakers				All devices working in tandem	

Tiers of devices used by users: varying based on costs and interests

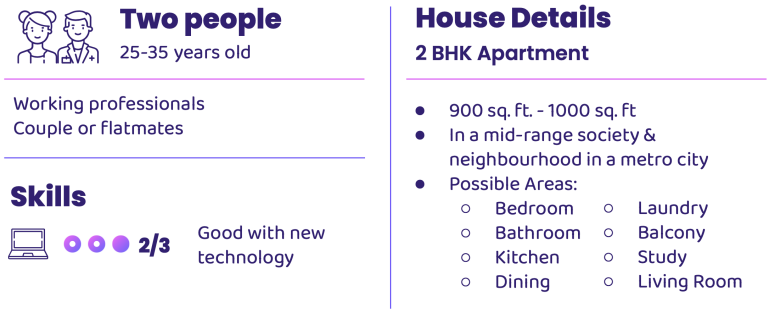
User profile

While meeting people to create a more focused user profile for the interviews, some issues and plus-points about smart devices had been pointed out by the users from the target demographic. These are mentioned below.



Insights gained

Based on the information gathered thus far, a user profile was created.



User Profile

User interviews

Interview Questionnaire

Before the interviews were conducted, a set of questions was created. A set of questions about their lives were asked first to better understand their thoughts in terms of answers to questions regarding the problem space.

Questions regarding the problem space were in 4 different sections; typical day's schedule and tasks performed, proficiency with technology, smart devices they use, their home's layout, etc.

- What does their typical day look like, schedule, etc. What would they like to change about it?
- Do they work from home, what is their set up, where is their desk? What are the pros and cons?
- Details about their house; layout, areas, open concept area, designated spaces, etc. Ideal home layout if any, and why?
- Their experience with smart devices, how much they know about them, general tech learning skills
- What are their menial or repetitive tasks? Can there be a way to offload them?
- Their thoughts on privacy in this tech age, discomforts if any
- Their zones (what are their private, social, and work zones), how do they keep them separate?
- Usage pattern of current spaces (activities), flexibility on usage, how to improve them?
- Appliances they use space-wise, elements required in each zone or area etc.

Interview Questionnaire

Interviews

Sixteen interviewees were chosen from different locations in Mumbai who mostly or somewhat matched the user profile. Site visits happened with four of the interviewees. Some interviewees were also roommates.

The different types of users were further defined during this process.

A	E	G	H	J	K
Codes	**Age+Gender**	**Location**	**Job/Profession**		**Interpretation**
U1	23F	Borivali	Software Engineer		Done
U2	22F	Goregaon	Student / Freelancer		Done
U3	29M	Malad East	Financial Manager		Done
U4	25M	Malad East	Entrepreneur		Done
U5	25M	Powai	Software Engineer		Done
U6	23M	Chembur	Writer		Done
U7	26F	Goregaon	Product Manager		Done
U8	26F	Bhandup	Editor		Done
U9	26M	Bhandup	Director		Done
U10	28F	Mira Road	Content Creator		Done
U11	22F	Vikhroli	UI/UX designer		Done
U12	22M	Marol	Student / Product Designer		Done
U13	22M	Marol	Editor		Done
U14	24F	Vikhroli	Software Engineer		Done
U15	23F	Chandivali	Assistant Stylist		Done
U16	22F	Chandivali	Accessory Designer		Done

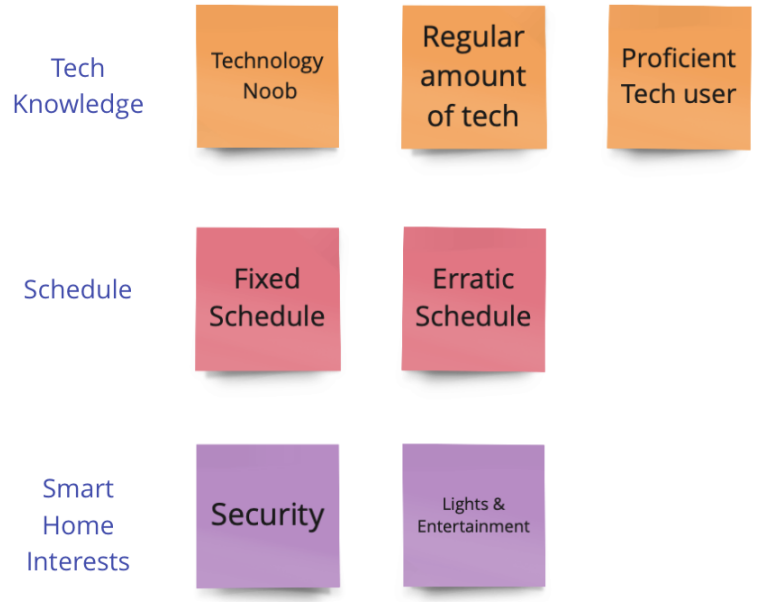
Interviewees list

		B: BREAKDOWN IN:INSIGHT DI: DESIGN IDEA US: USER STATEMENT Q:QUESTION C:CULTURE
User Codes	**Notes**	**Classification**
U-7 001	26F, Goregaon, Product Manager, lives in a fairly expensive society, one room mate (25F, coworker)	Demography
U-7 002	9-5 job (WFH right now), sits on a desk in her room. Goes to friend's house after, then comes home late and sleeps.	US
U-7 003	Travel time is zero, homemade food (pros)	US
U-7 004	No work-life Balance separation, everything feels like its in one space (cons)	IN
U-7 005	Creating a separation between workspace and home space using scenes through automation	DI
U-7 006	House has 2 bedrooms w/bathrooms, kitchen, living room w/dining room	US
U-7 007	She can understand the tech, but debugging is a struggle	IN
U-7 008	Doesn't have a lot of smart devices, also uses apple products mostly	US
U-7 009	Recently bought a google home, incompatibility with iPhone in many situations	US
U-7 010	Homepod is too expensive, appliances through homepod is too expensive	US
U-7 011	iPhone doesn't have compatibility with a lot of smart devices	B
U-7 012	Uses google home for music, lights and fans	US
U-7 013	Bought a 3rd party device (TtinkC: random local product) to turn on and off lights (connected straight to wifi, needs to be installed into switchboard by electrician)	US
U-7 014	Controlled using google home app and nest mini, even when shes out of the house she can control devices for eg. turn them off if she forgot (pros)	US
U-7 015	Turning off should be automatic	IN
U-7 016	Connected to wifi but no internet (cons)	US

Example of interview notes from a moderately proficient tech user

		B: BREAKDOWN IN:INSIGHT DI: DESIGN IDEA US: USER STATEMENT Q:QUESTION C:CULTURE
User Codes	**Notes**	**Classification**
U-13 001	22M, Marol, Editor, Mid-level exp society, one roommate (22M, Student / PD, college friend)	Bio
U-13 002	Works in a small-sized company, random schedule, work happens whenever as per deadlines	US
U-13 003	Due to randomised schedule, exactly timed automations are not ideal	IN
U-13 004	2 bedroom (1 w/bathroom), 1 common bathroom, kitchen, living room w/dining room, washing area	US
U-13 005	Spaces are the socialising (living room), work (desk in the living room), private (bedroom)	US
U-13 006	The workspace and socialising space are somewhat separated due to deak being to the wall, but the monitor is used in the social setting as well	US
U-13 007	The desk also feels separate due to lighting conditions	IN
U-13 008	Very good with tech, knows the tech behind appliances, able to debug and has good control over the network	US
U-13 009	Has a google nest, nest mini, multiple smart bulbs, remote controller with switchboard, Wifi controlled IR emitter, IFTTT app	US
U-13 010	Lights on and off as usual: repetitive	US
U-13 011	Operating the coffee machine, kettle, kitchen appliances, opening curtains & windows	US
U-13 012	Mosquitoes come in after it starts getting dark, you have to remember to close them, then open in morning	US
U-13 013	Light sensor: window	DI
U-13 014	People can see when you're turning on/off stuff: data	US
U-13 015	Opposed to cameras fs, but sensors are okay	US
U-13 016	Commands are executed slowly, not fast enough due to it going to internet server	IN

Example of interview notes from an almost professional-level proficient tech user



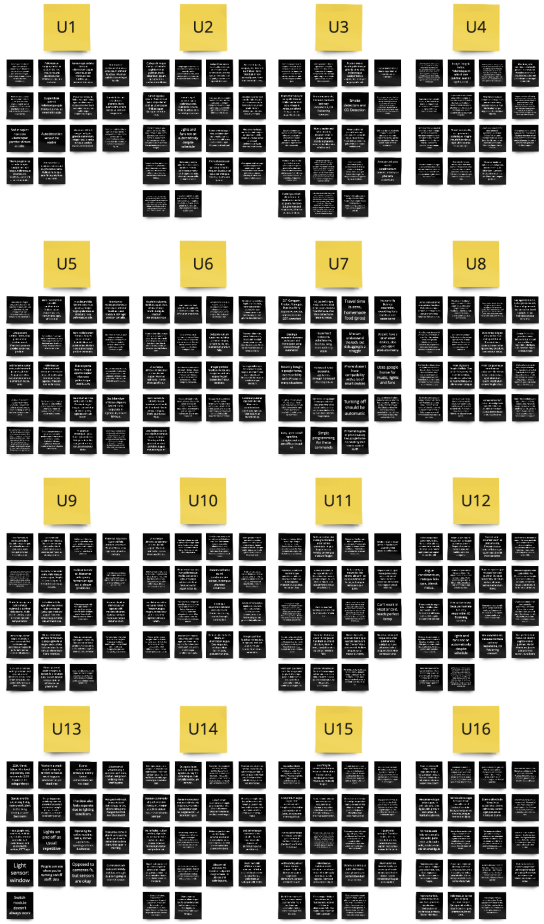
Users divided up based on different metrics



Areas in users' houses

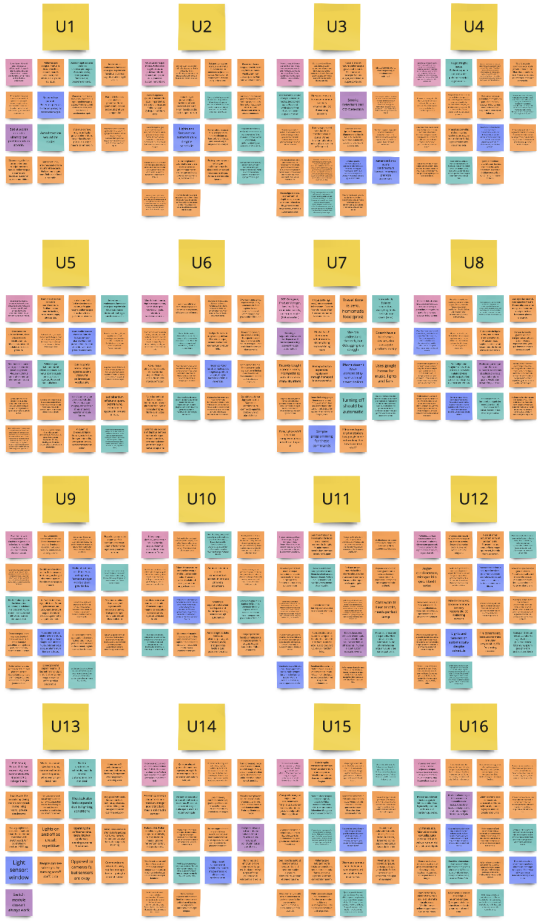
Affinity Mapping and Insights

All notes from the interviews were placed and mapped out on a board.



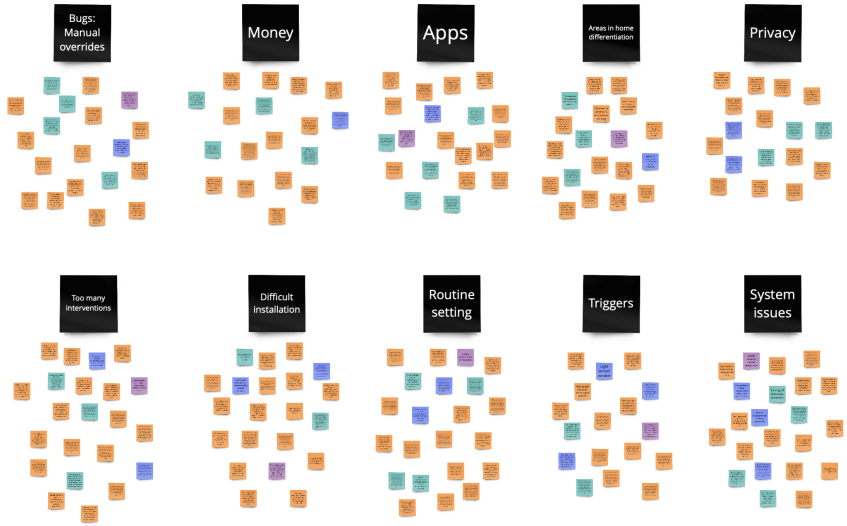
All user notes

The important user statements, bio, breakdowns, insights and design statements were colour-coded.



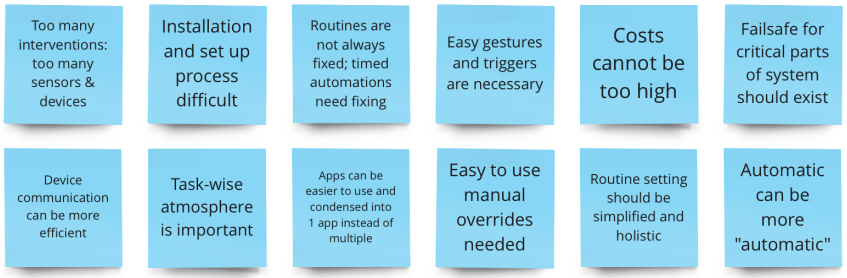
All user notes: colour coded

Next, the notes were placed into clusters and labelled.



Affinity mapping: clusters

Insights gained from this exercise have been noted below.



Insights gained

Problem Identification

System:

- Compatibility issues and communication gaps between devices, servers, and hubs.
- The installation and set-up process is difficult.
- Costs are high to get all the necessary devices.
- Failsafes and manual overrides should be in place and should be easy to use.

Sensors:

- Placement of so many different sensors and devices become difficult in terms of cost and set-up time.
- However, without sensor data, automated tasks are difficult.

Software:

- Too many apps are needed for certain functionalities and setting routines.
- Data on what apps or website types are being run needed for mood setting.
- Device compatibility can be fixed with simple commands

Design

Initial design brief

Creating a spatial interface for smart homes using:

- Intuitive gestures for a better user experience.
- Automating tasks and environments by anticipating or detecting the needs of the user.
- Creating a seamless experience by adjusting the smart home needs to certain contexts and zones of the house, utilisation of smart sensors.

Need for Project:

Many smart home devices are there in the market, but they are not as intuitive as they can be and do not provide a holistic solution.

Motivation:

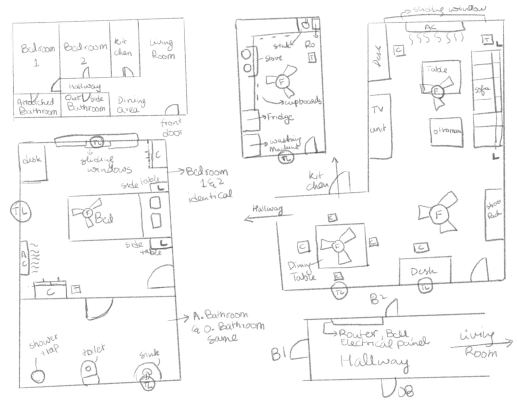
I have bought many smart devices for my flat to try to offload menial tasks and utilise voice assistants, but I have faced many issues. So I delved into the specifics and saw an opportunity to create something new.

Target Demographic:

- **Primary Users**: Working professionals in their 20s who have a working knowledge of general technology.
- **Secondary Users**: People who want smart home systems

Space Focused on:

- **2BHK Home**: 700-1000 sq. ft in a mid-range society (Mumbai).

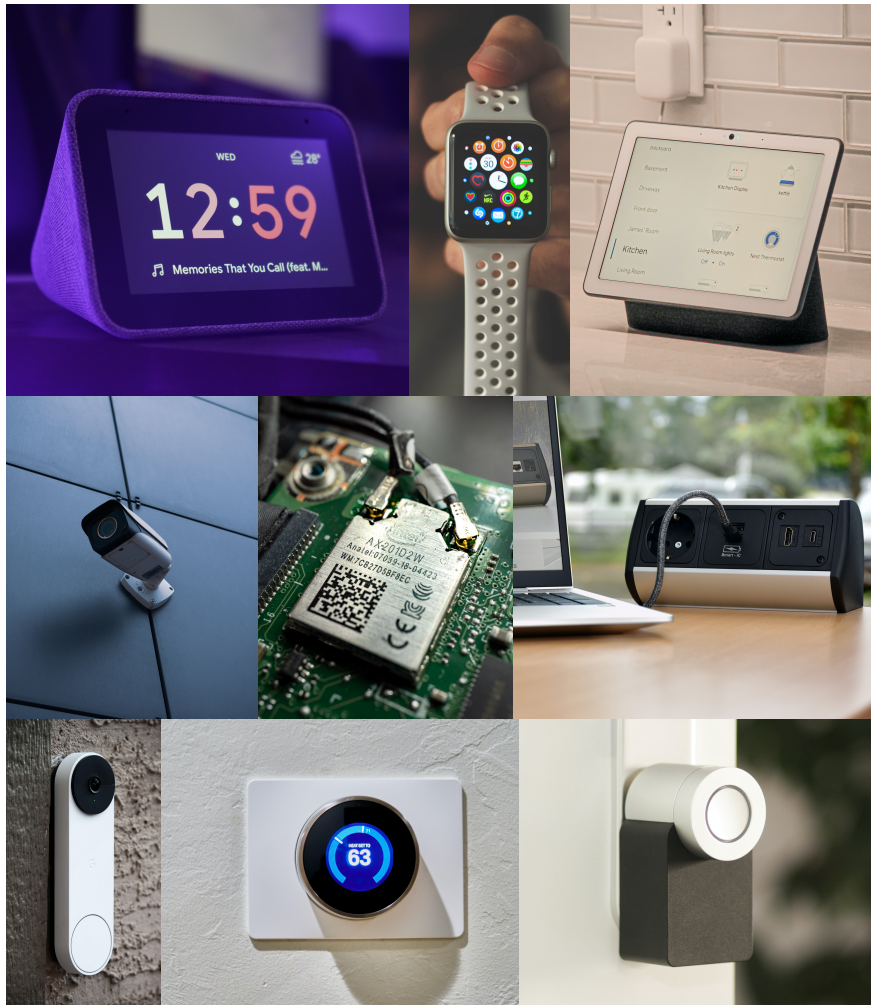


Space focused on



Target demographic

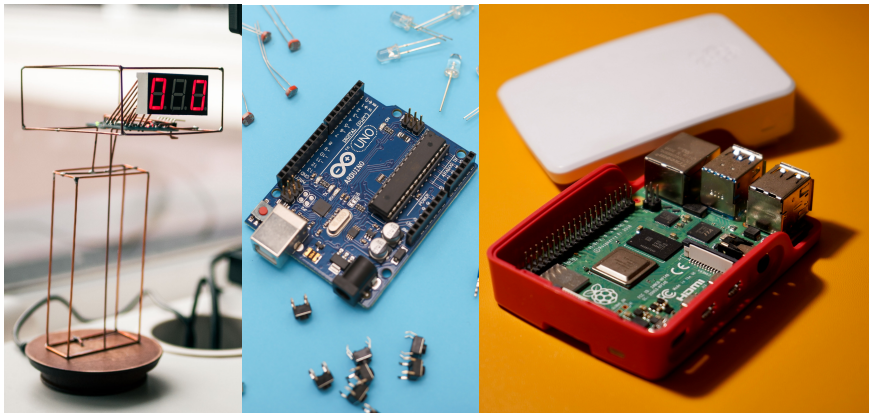
Scope of project



Various different smart devices



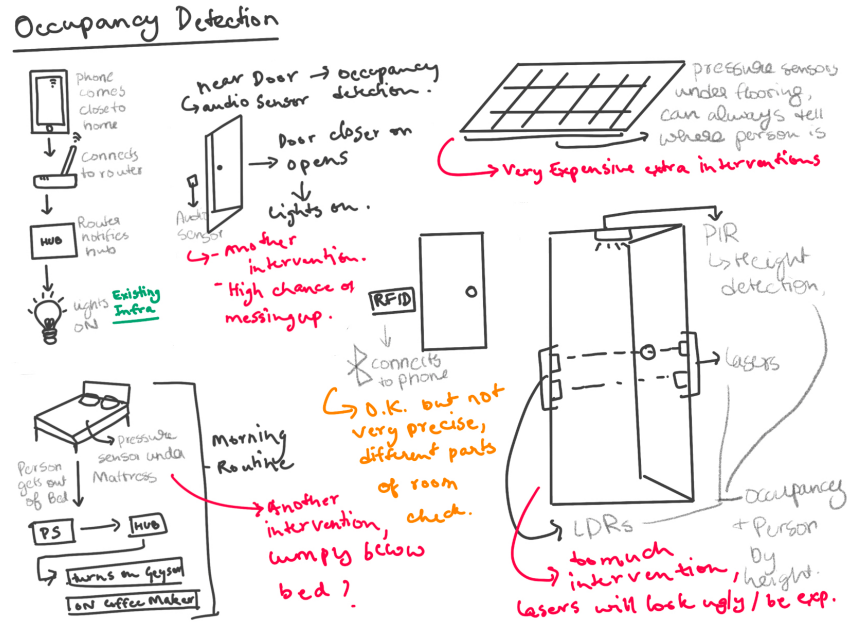
Apps controlling smart home devices



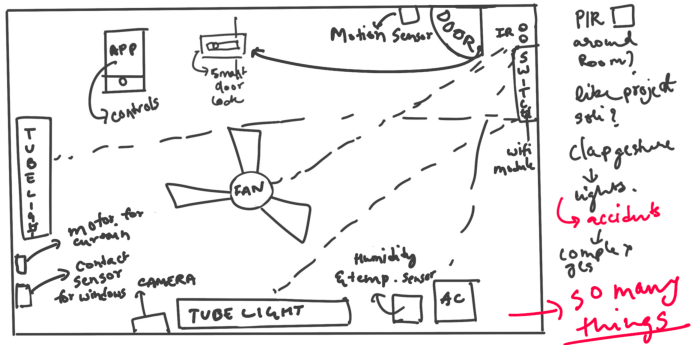
Different Arduino projects

Initial Ideation

In the initial ideation phase, multiple sensors and devices were thought of, placing each sensor in optimal locations; e.g. placing pressure sensors under beds' mattresses to start the morning or night routines, Bluetooth sensors for location tracking, audio sensors for doors opening or closing to track occupancy detection, etc.



Sensors and devices initial ideation



Sensors and devices initial ideation: placement

However, upon trying to map the sensors and devices in the spaces they were required, problems were immediately apparent; there were too many interventions which meant that costs would be high, multiple failsafes might be needed, and set-up times would be high.

The creation of a **unified sensor box** was necessary to resolve these issues. This box would contain all the necessary sensors in the room. The next steps were to figure out the system via which these boxes would work, the sensors and design of the box, and an app to set routines and use the controls.

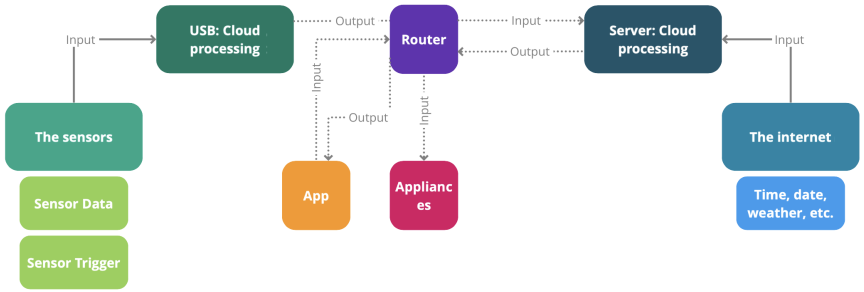
System Design

Concepts

The different processing methods and information flows have been mapped out below.

1. Cloud Processing

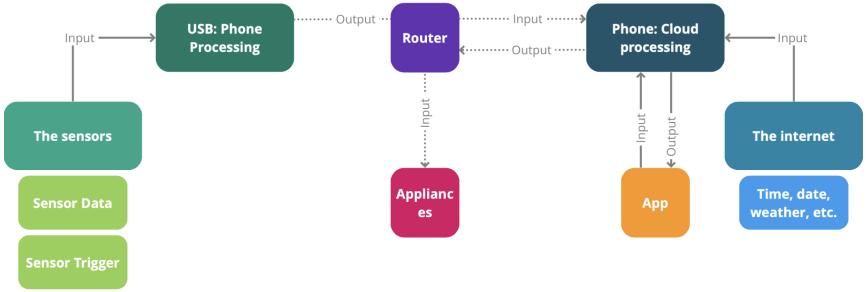
In this model, the processing happens in a server on the cloud. This is the lengthiest process, taking the longest route from the sensor box or app to the appliances.



Cloud Processing Information Flow

2. Phone Processing

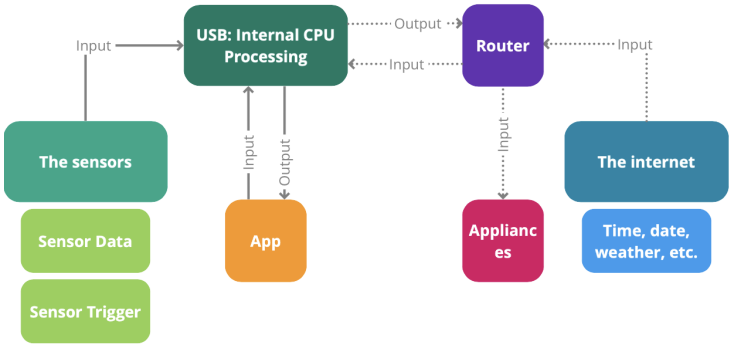
The processing happens on the phone's processor. The length of the process route from sensor box to appliances remains the same but, the route from the app to appliances is shortened. However, there is an issue: when the phone is away from home, there is no CPU inside the home.



Phone Processing Information Flow

3. Internal CPU Processing

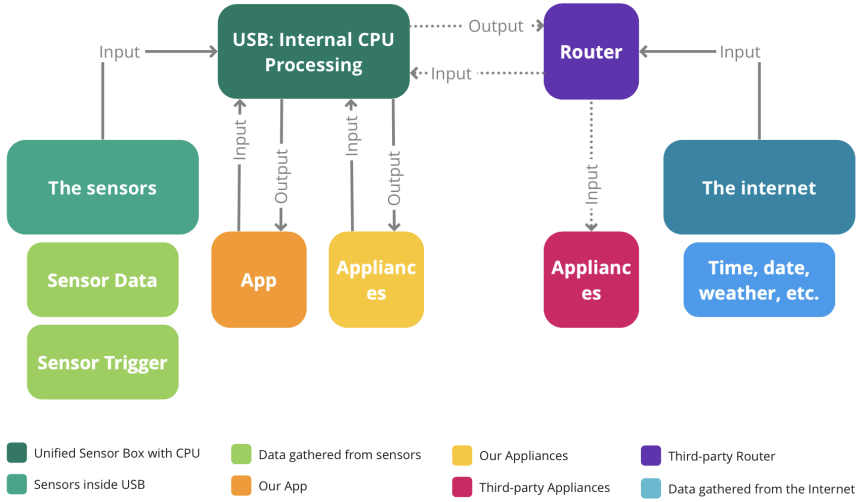
The processing happens inside the sensor box in an internal CPU. It is the most efficient model.



Intervnal CPU Processing Information Flow

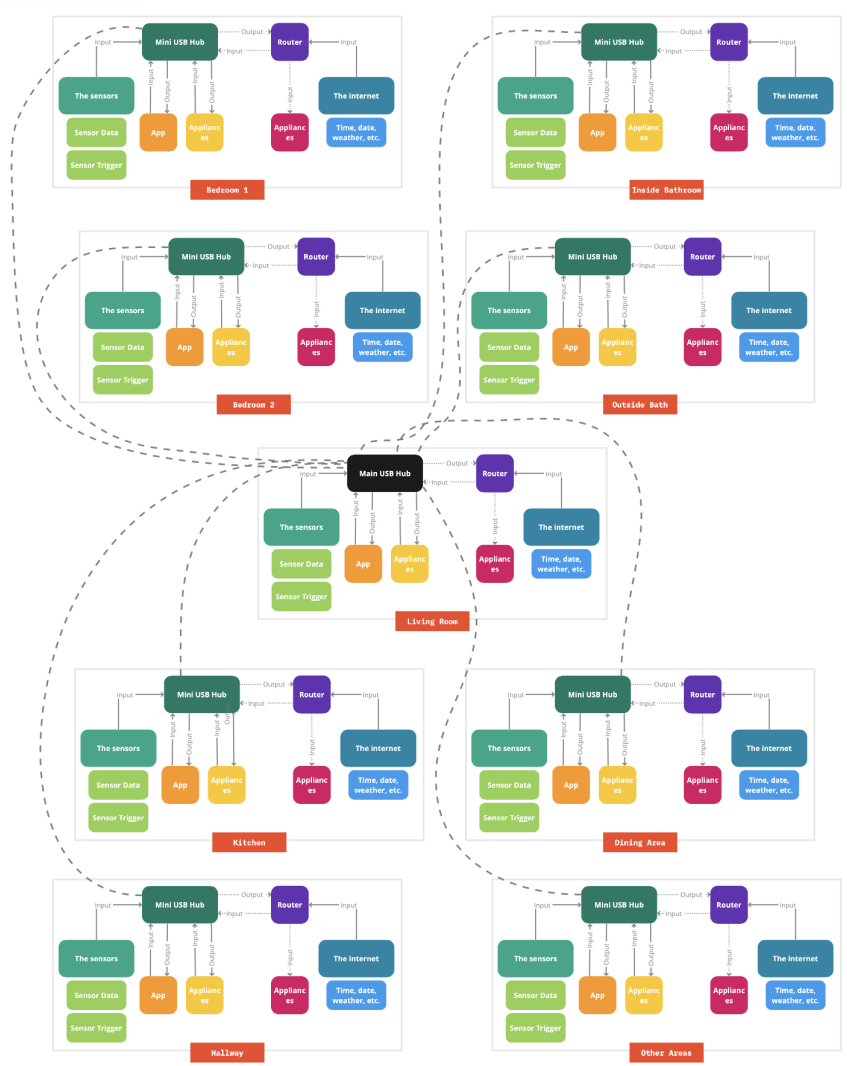
Final Concept

The sensor boxes will have an internal CPU which will communicate with the app and appliances directly. Third-party appliances will be communicated with through the router. The box will gather information through its sensors and from the internet via the router.



Information flow through the system

Since there will be many sensor boxes in a home, one of the sensor boxes will act as the main hub, and the rest of them will be turned into mini-hubs. It will work the way that a mesh network works in routers.



Mini-hub and main hub mapping

Unified Sensor Box

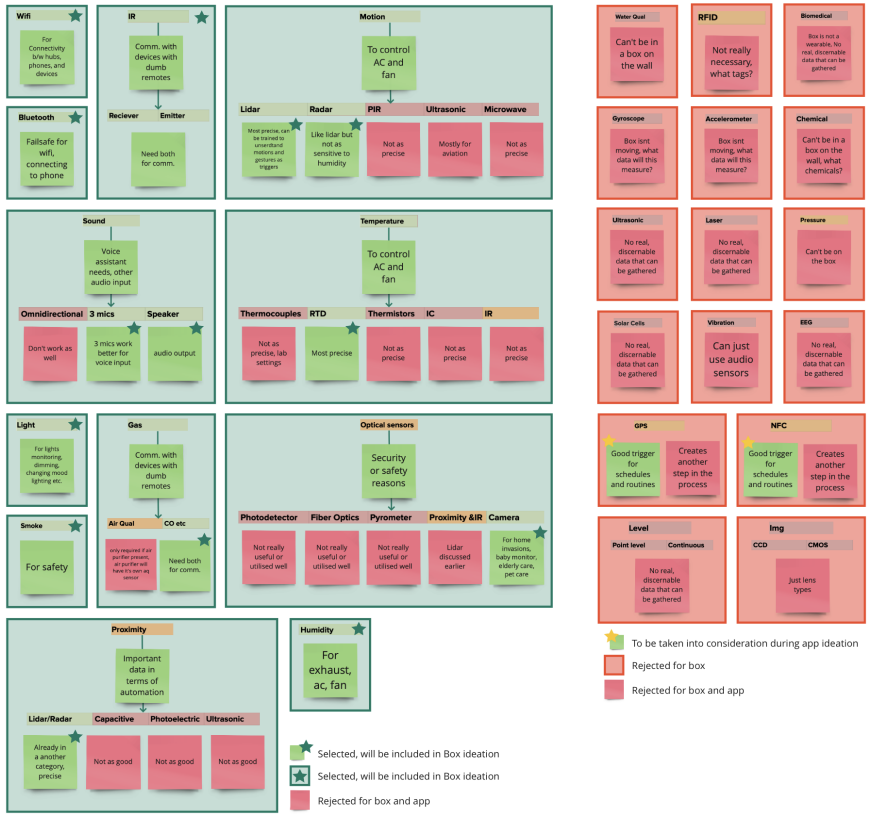
Pre-ideation specifications

Before ideation, the sensors required had to be decided. A list of sensors was made, to begin with.

Wifi					
Bluetooth					
IR	**Blaster**	**Reciever**	**Emitter**		
NFC					
RFID					
GPS					
Temperature	**Thermocouples**	**RTD**	**Thermistors**	**IC**	**IR**
Motion	**Lidar**	**Radar**	**PIR**	**Ultrasonic**	**Microwave**
Proximity	**Lidar/Radar**	**Capacitive**	**Photoelectric**	**Ultrasonic**	
Pressure					
Water Qual					
Chemical					
Gas	**Air Qual**	**CO etc**			
Smoke					
Level	**Point level**	**Continuous**			
Img	**CCD**	**CMOS**			
Accelerometer					
Gyroscope					
Humidity					
Optical sensors	**Photodetector**	**Fiber Optics**	**Pyrometer**	**Proximity &IR**	**Camera**
Solar Cells					
Biomedical					
Light					
Ultrasonic					
Sound	**Omnidirectional**	**3 mics**	**Speaker**		
Laser					
GMR					
EEG					
Vibration					

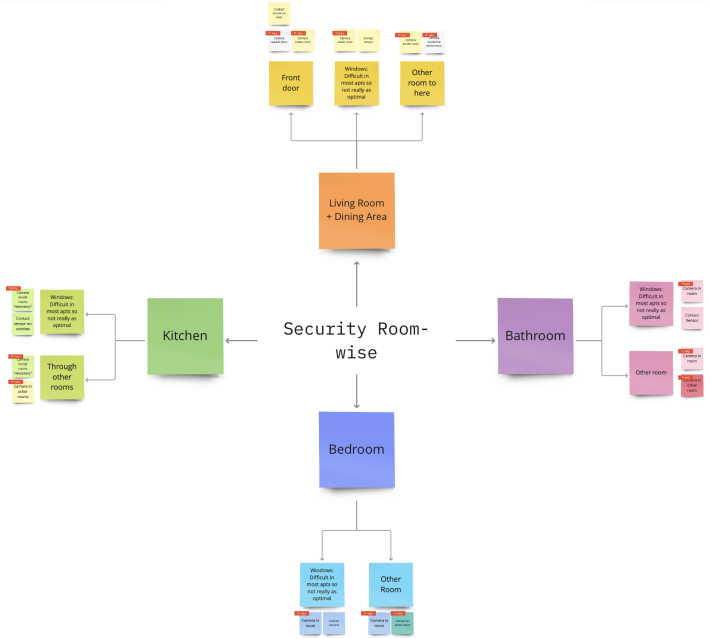
List of sensors

The sensors were mapped out to determine potential use and necessity. Based on use and data gathered, sensors were either rejected, further mapped out for the design of the unified sensor box, or kept in mind for consideration for the app.

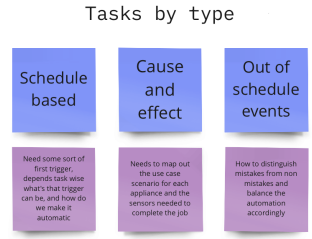


Rejected sensors and sensors being utilised in box or app mapped out

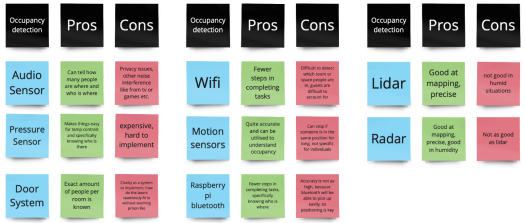
After that, types of tasks and room-wise tasks were mapped for certain selected sensors.



Security tasks room-wise

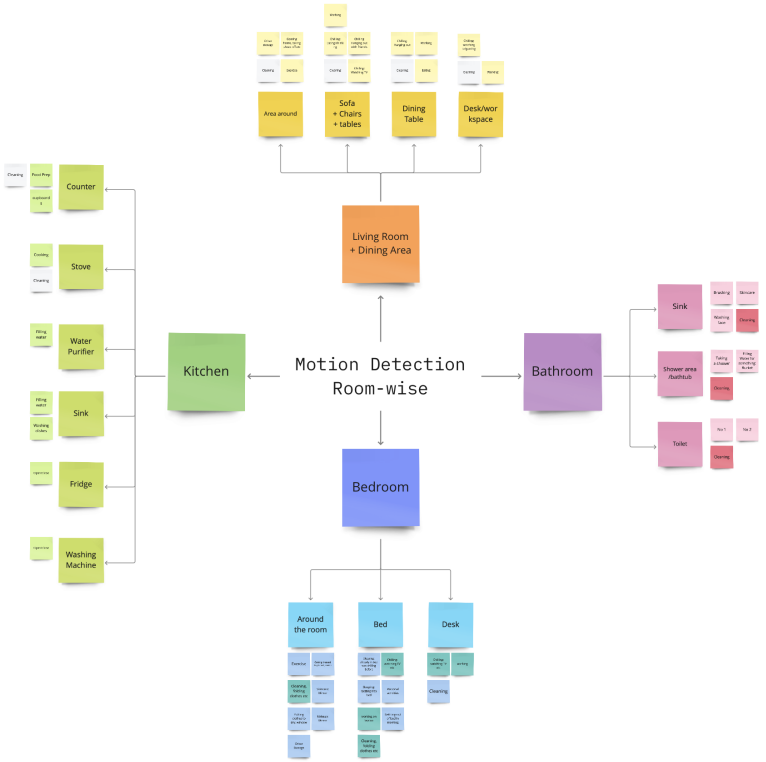


Types of tasks



Occupancy detection methods

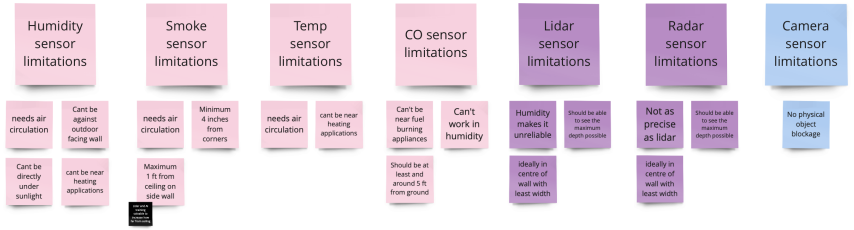
Then, for motion-detection tasks, gestures, body position, and actions were kept in mind.



Motion detection tasks room-wise

Lidar and radar were determined to be the best on this basis because of their accuracy and because they could be trained using AI to understand gestures and motions as triggers, etc.

Then, each of the selected sensors were mapped against areas of the house to see whether they were necessary for the space or had some limitations.

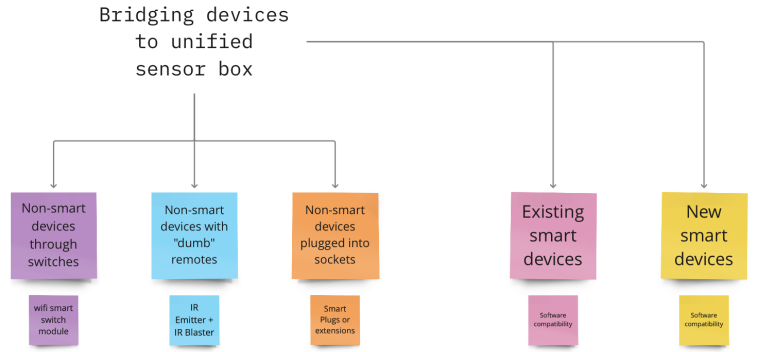


Sensors limitations

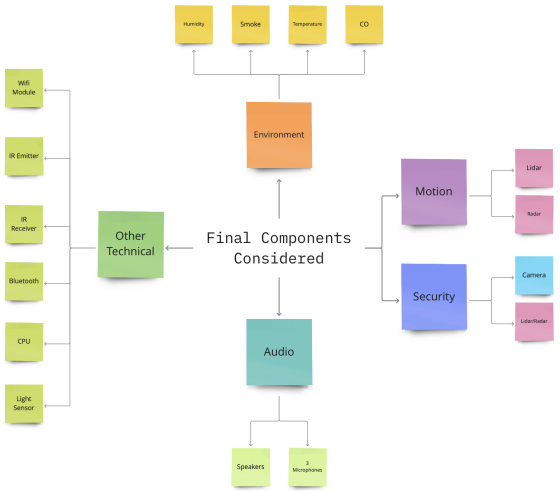


Sensors required for each space

Modules and sensors required to bridge the box with other existing appliances were mapped out. After this, final components were listed.

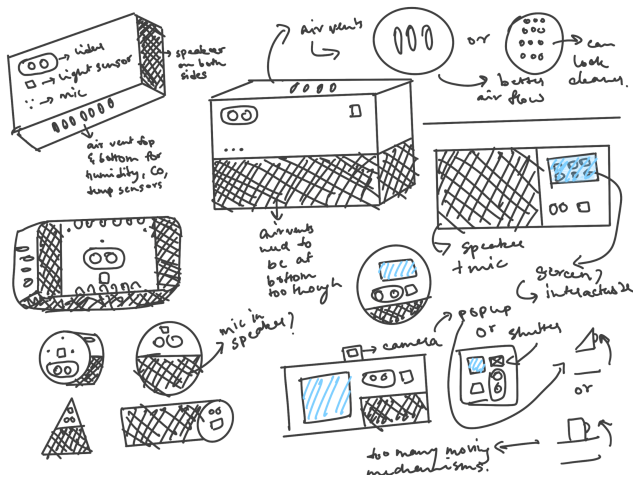


How other devices will be connected to the box

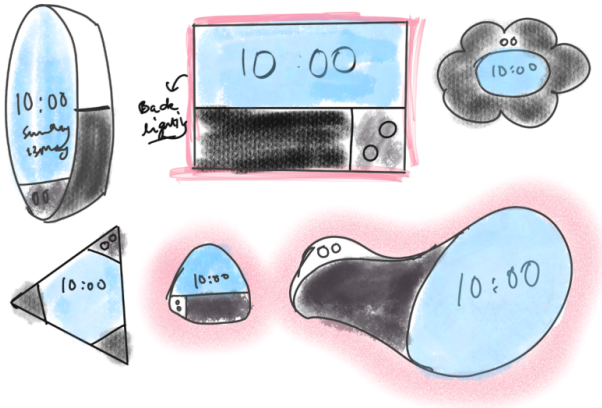


Final Components list

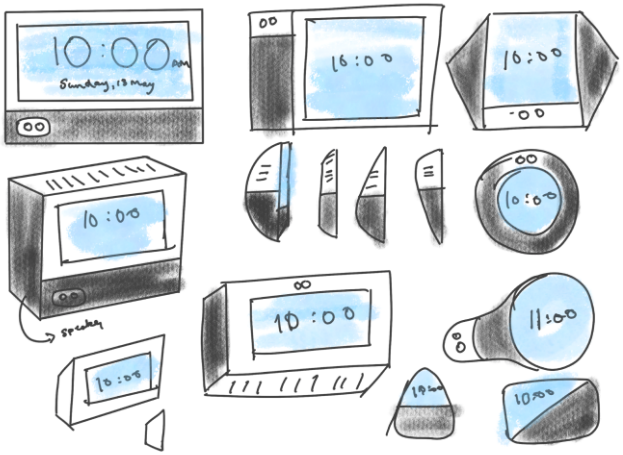
Ideation



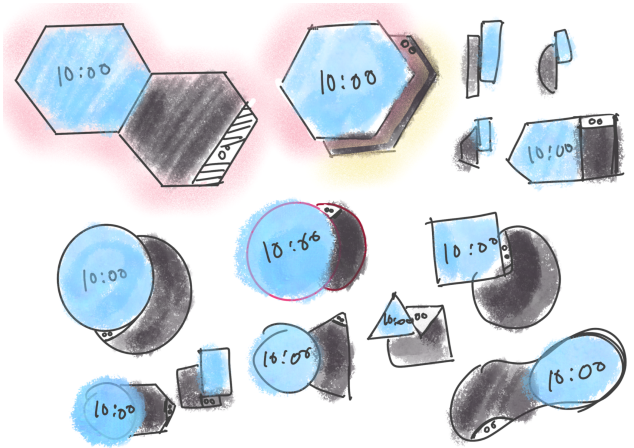
Starting out with the box design, camera unit



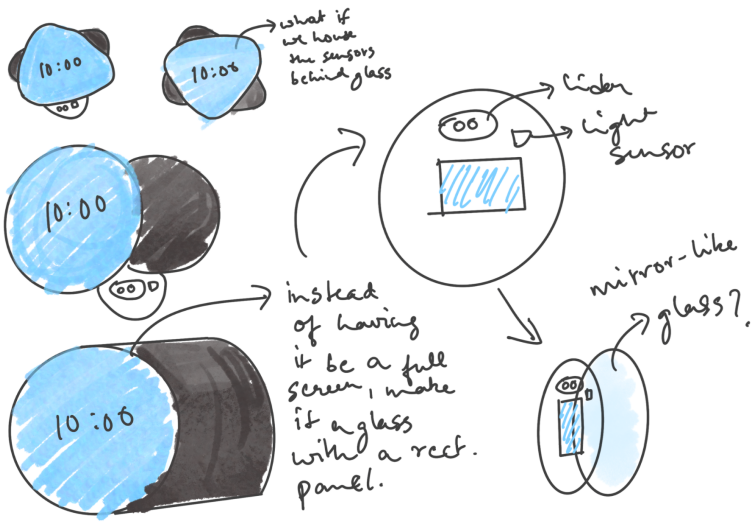
Backlighting



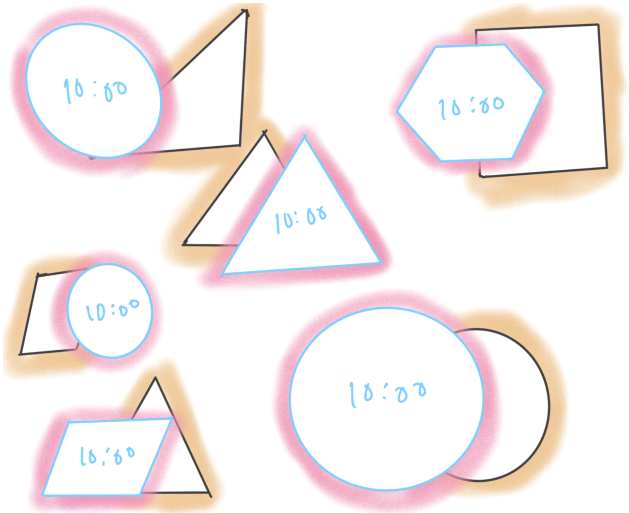
Adding a screen to the box



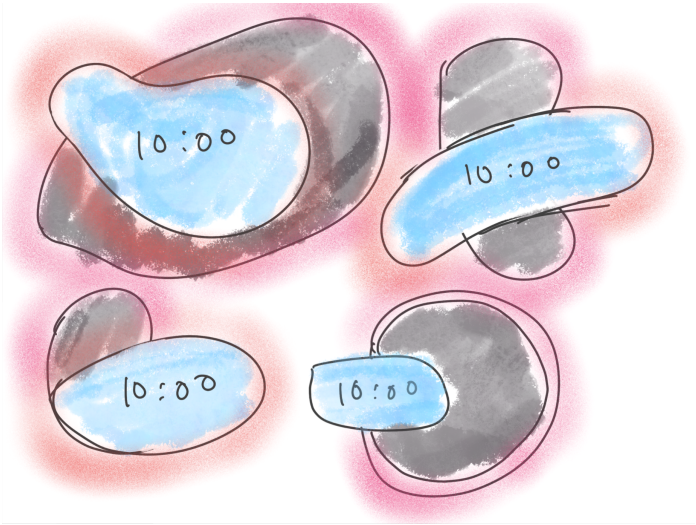
Three different sectios: screen, sensors, and speakers



Placing screen, lidar, and light dectector behind the glass



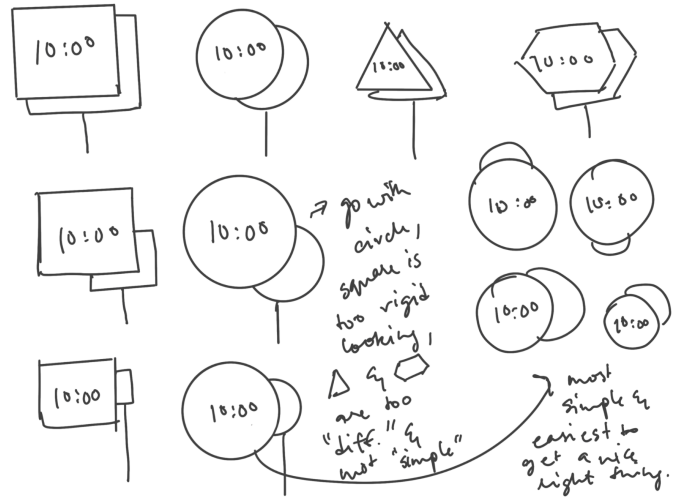
Form exploration: simple shapes



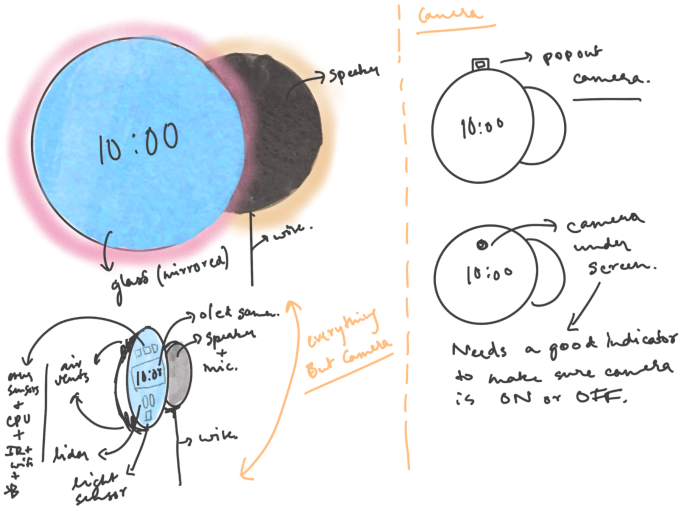
Form exploration, 2 backlights



Form exploration: Abstract shapes



Using simple shapes to see best shapes to use



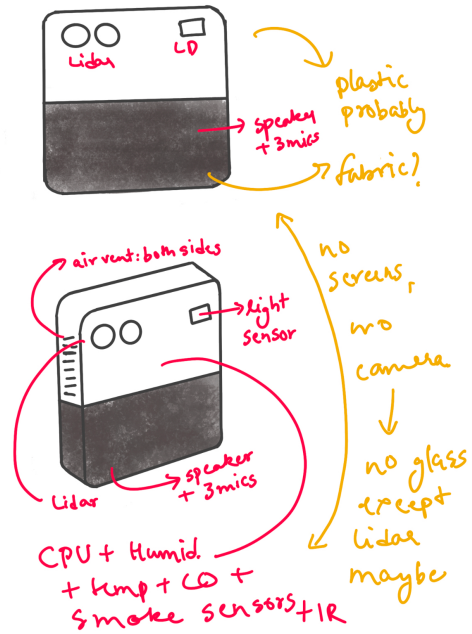
Fleshing out the circles idea

Concepts

1. Simple Box

This concept has a box with just the sensors in it. It has no lights, screens, or cameras. Its key features:

- Simple and Minimal
- Square shape; looks like a technical device
- Cheaper than other concepts
- All required sensors present

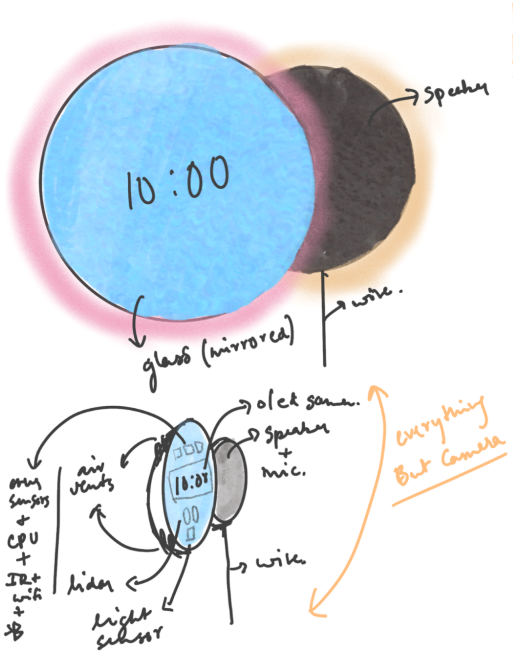


Simple Box

2. Box with Screen

This concept has a box with sensors and a screen behind a glass. No camera. Its key features:

- Displays information
- Round shape; looks like wall clock and speakers
- Slightly more costly than the simple box
- All required sensors present



Box with Screen

Concept Evaluation

Comparison Metrics	Concept 1	Concept 2
Reliability	8	8
Durability	9	8
Features	7	9
Conformance	7	8
Serviceability	8	7
Aesthetics	6	8
Perceived Quality	6	8
Performance	8	8

8 Product Quality Dimensions

Based on these metrics, concept 2 was further detailed.

Final Concept

Concept Explanation

The Unified Sensor box works on the principle outlined in the final concept of the system design. There are two forms of sensor boxes, a bigger unit with a screen and a smaller unit without one.

Each room has different sensor needs:
Living Room Model Sensors: Humidity, Temperature, Smoke, CO, Lidar, IR, Light.
Bedroom Model Sensors: Humidity, Temperature, Smoke, CO, Lidar, IR, Light.
Kitchen Model Sensors: Temperature, Smoke, Lidar, IR, Light.
Bathroom Model Sensors: Humidity, Lidar, IR, Light.
Hallways Model Sensors: Humidity, Temperature, Smoke, CO, Lidar, IR, Light.

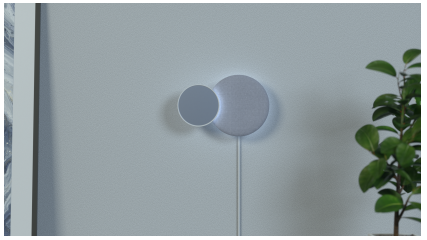
Lidar is the most important sensor; it will be the one detecting motions as triggers in the room (e.g. lidar will detect the user getting out of bed and inform the CPU, which will then start the morning routine.

The lidar sensor will be trained using artificial intelligence and machine learning (by first creating various room models and human behaviour on a computer to train it and then a beta test by placing it in real rooms with real people) to recognise certain motions and body language as triggers for routines or adjusting appliances. Similarly, each sensor has its process (e.g. humidity sensor detects too much humidity in the bathroom and turns on the exhaust, high temperature detected turns on the AC, etc.)

The box is placed in the room on the non-outside-facing wall with the least width to let the lidar sensors gather maximum data. It is placed five-seven feet from the floor to allow all sensors to work well.

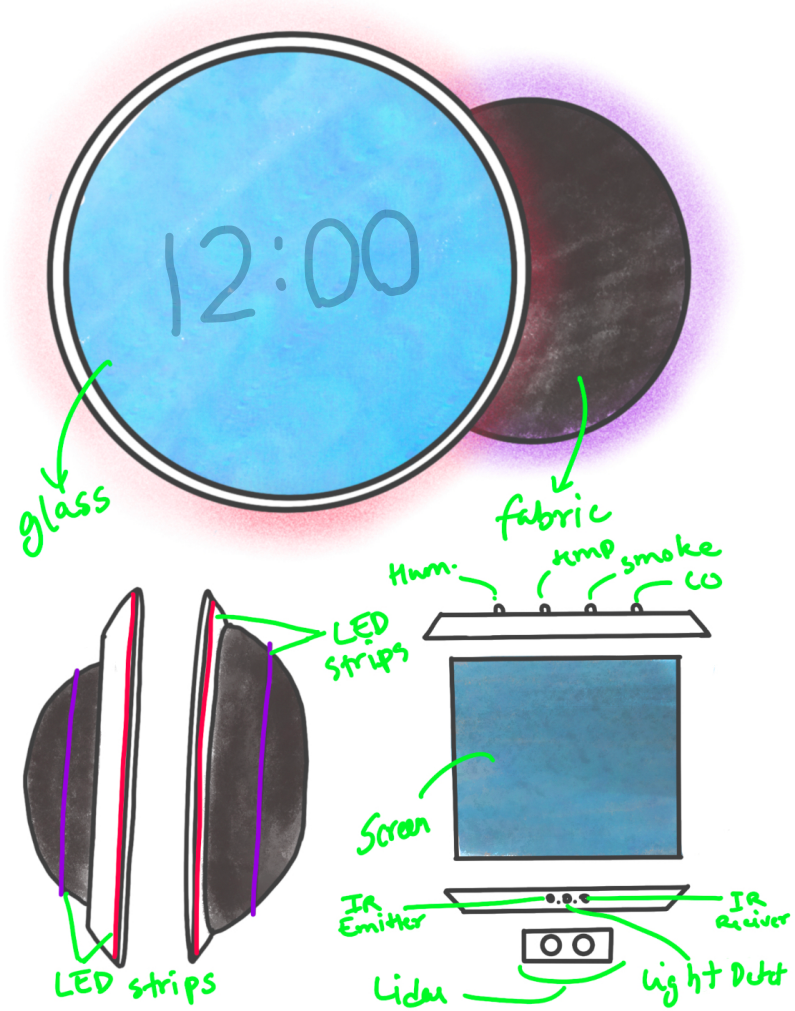


Bigger Unified Sensor Box

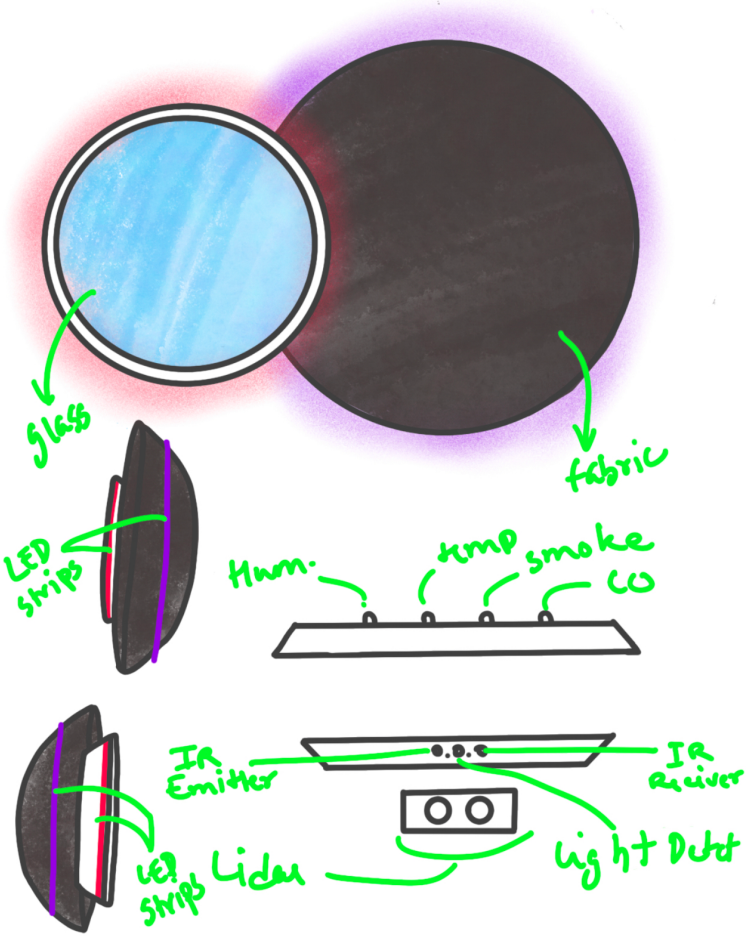


Smaller Unified Sensor Box

Design Sketches



Bigger Unified Sensor Box: Sketches



Smaller Unified Sensor Box: Sketches

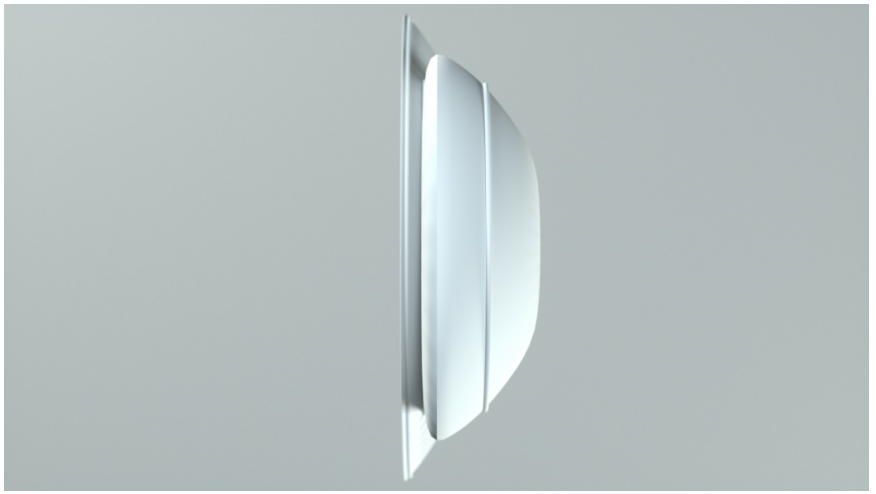
Block Models: Bigger Unit



Bigger Unified Sensor Box: Clay Model Front



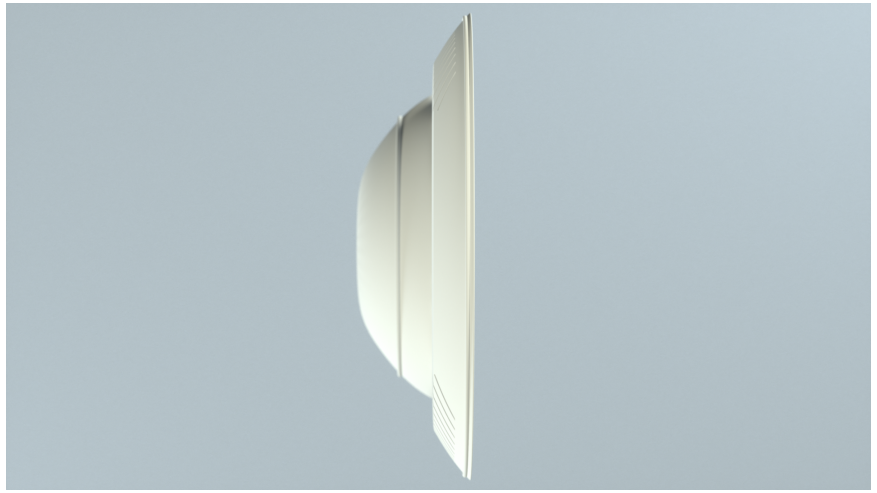
Bigger Unified Sensor Box: Clay Model Front Right



Bigger Unified Sensor Box: Clay Model Right Side

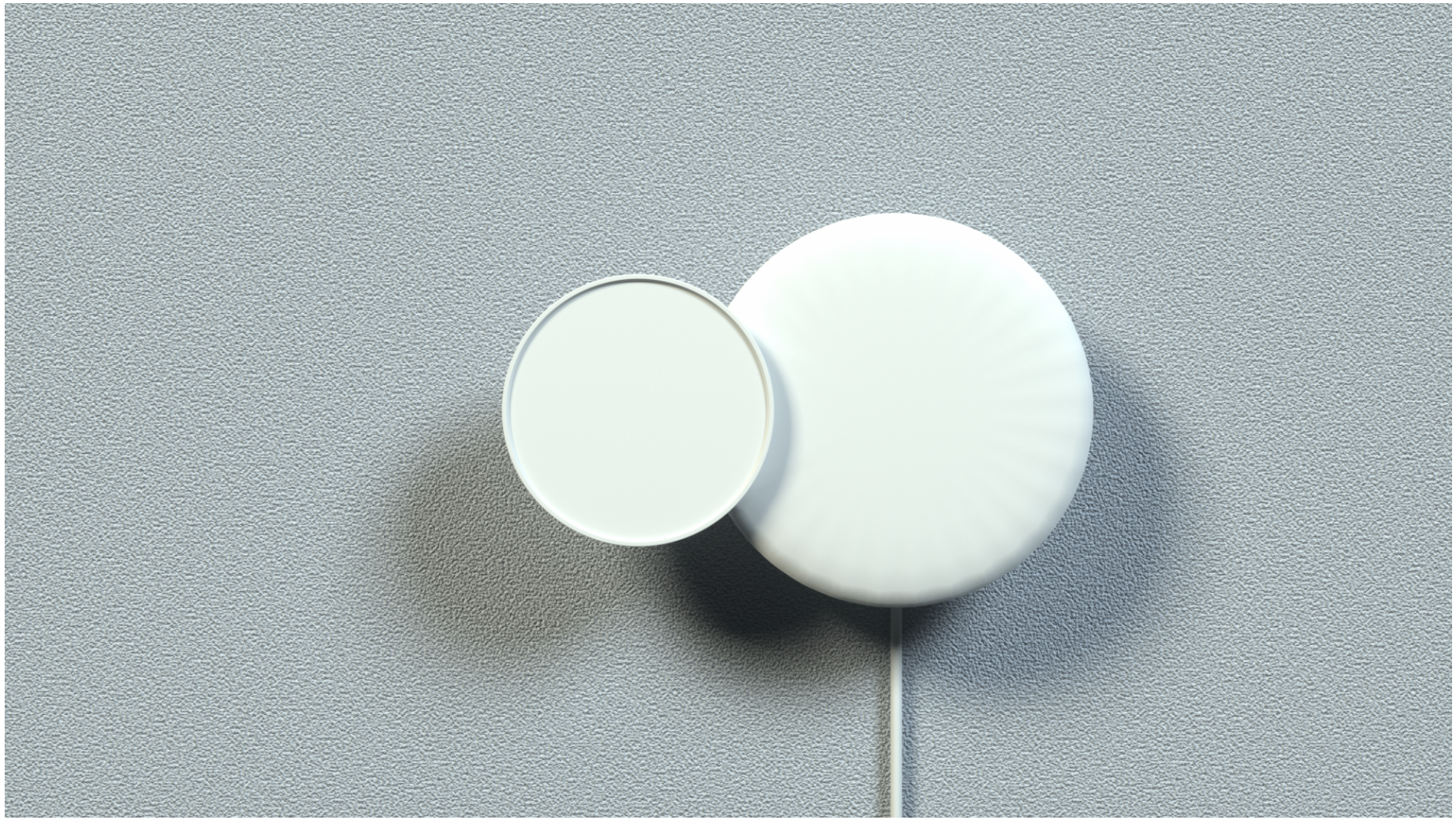


Bigger Unified Sensor Box: Clay Model Front Left

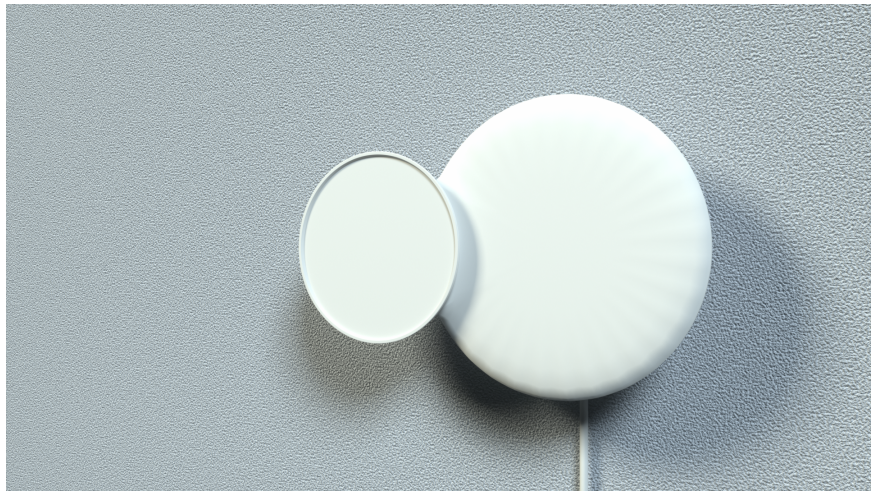


Bigger Unified Sensor Box: Clay Model Left Side

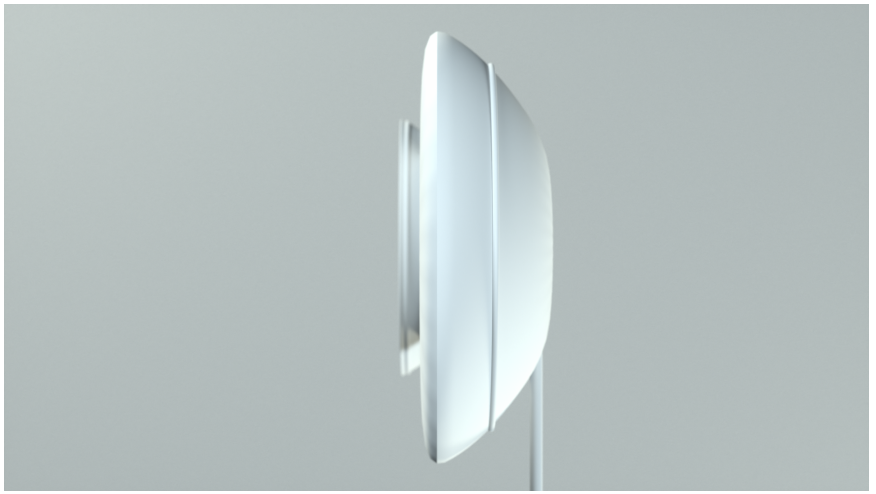
Block Models: Smaller Unit



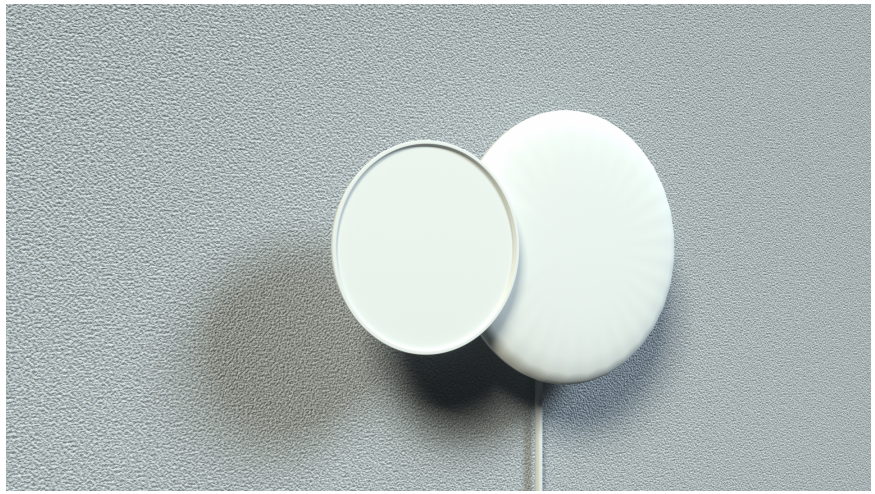
Smaller Unified Sensor Box: Clay Model Front



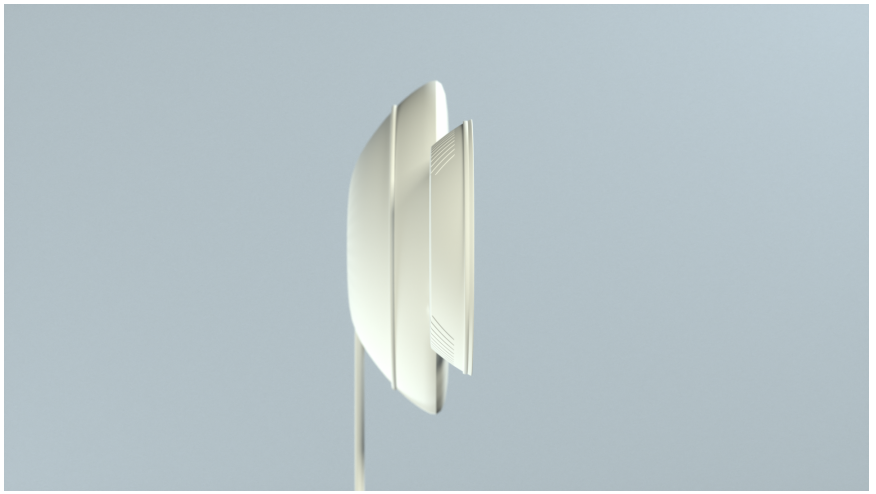
Smaller Unified Sensor Box: Clay Model Front Right



Smaller Unified Sensor Box: Clay Model Right Side

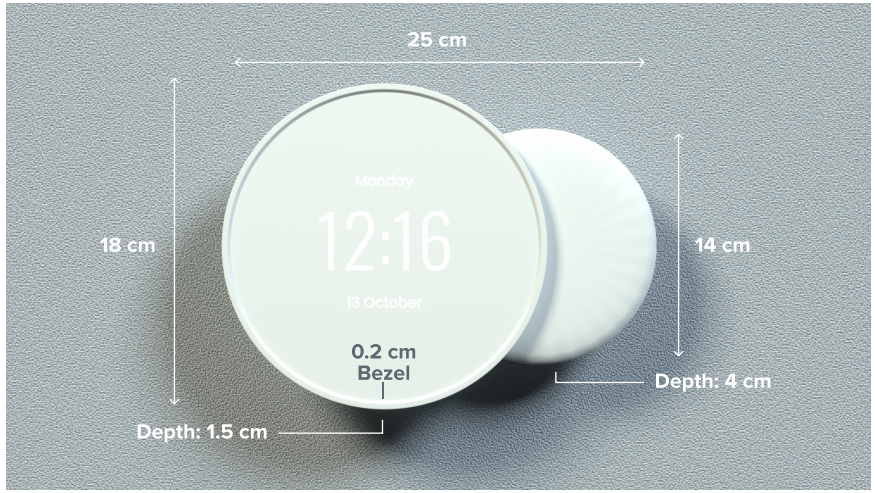


Smaller Unified Sensor Box: Clay Model Front Left



Smaller Unified Sensor Box: Clay Model Left Side

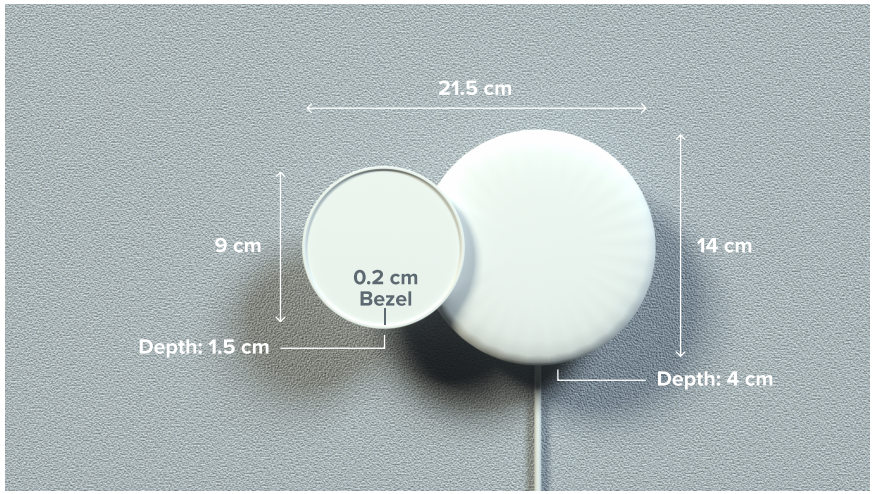
Specifications



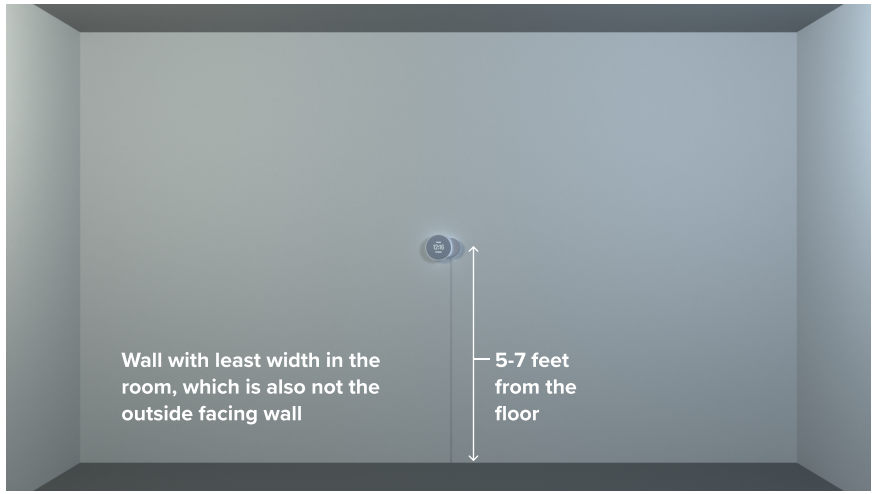
Bigger Unified Sensor Box: Dimensions



Components inside Unified Sensor Box



Smaller Unified Sensor Box: Dimensions



Placement of Unified Sensor Box

Renders



Pink Bigger Unified Sensor Box: Front



Pink Bigger Unified Sensor Box: Front Wide



Pink Bigger Unified Sensor Box: Front Left



Pink Bigger Unified Sensor Box: Front Right



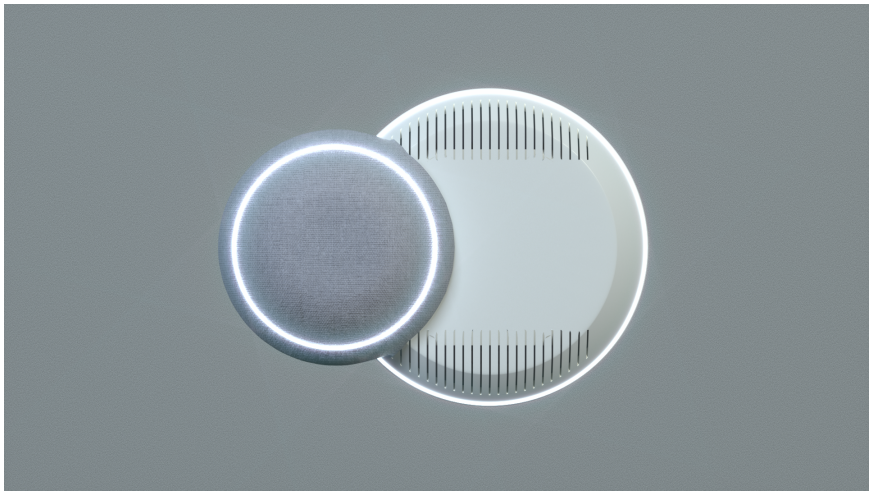
Pink Bigger Unified Sensor Box: Front Right



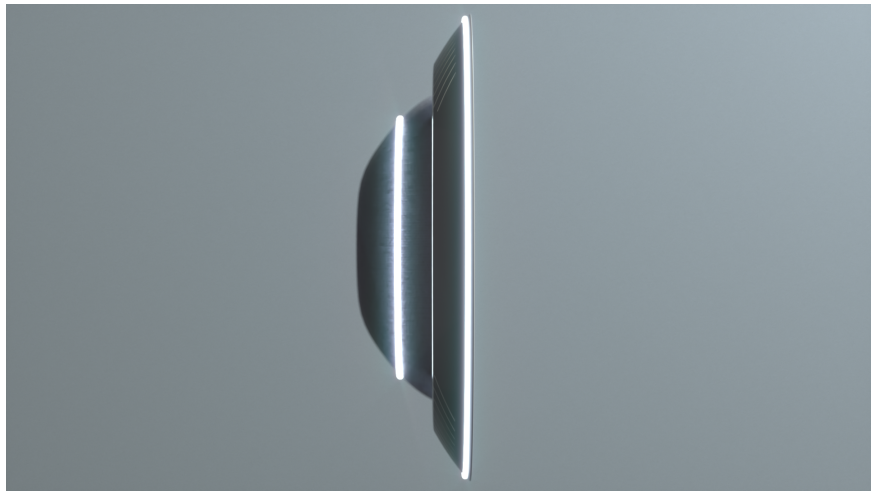
Grey Bigger Unified Sensor Box: Front Wide



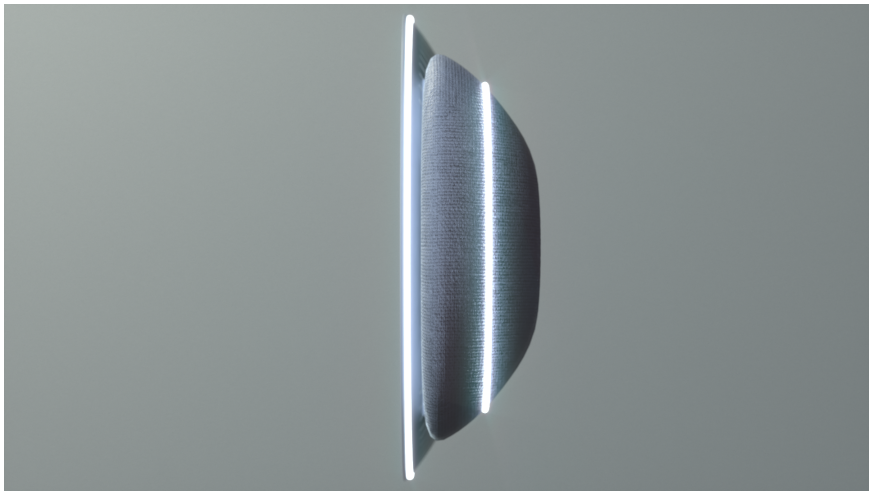
Grey Bigger Unified Sensor Box: Front



Grey Bigger Unified Sensor Box: Back



Grey Bigger Unified Sensor Box: Left Side



Grey Bigger Unified Sensor Box: Right Side



Grey Bigger Unified Sensor Box: Front Left



Grey Bigger Unified Sensor Box: Front Right



Grey Bigger Unified Sensor Box: In room



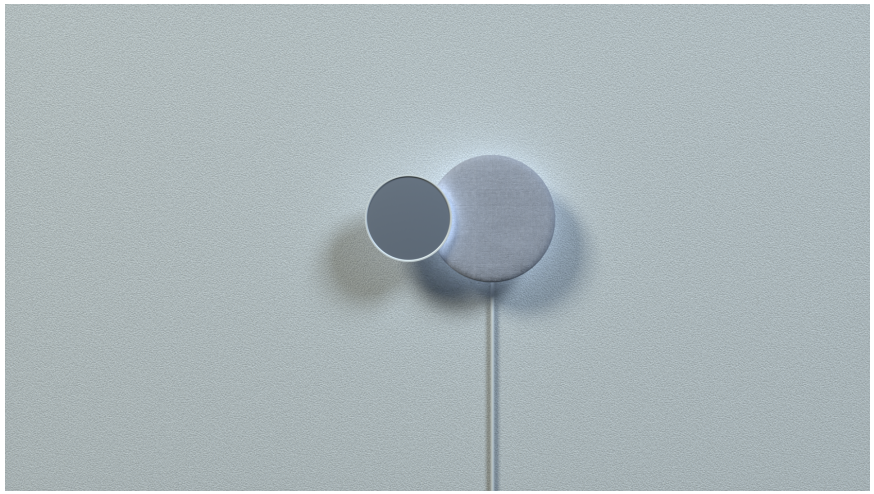
Grey Bigger Unified Sensor Box: In room



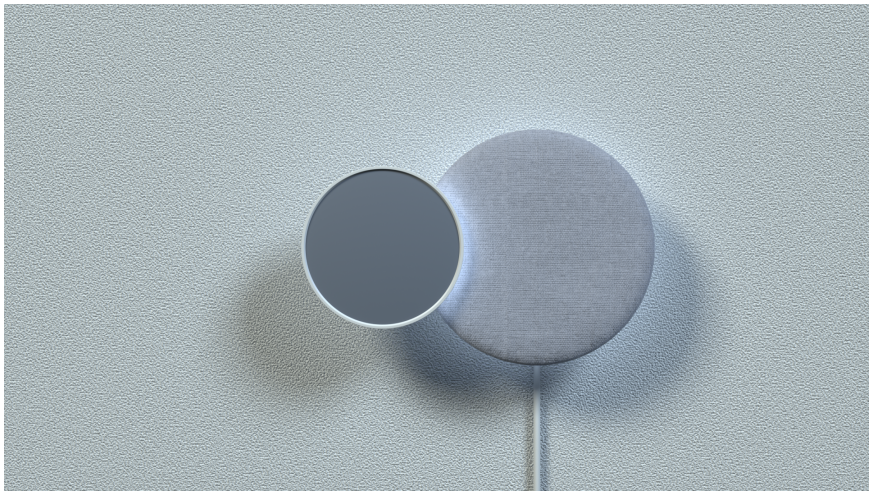
Grey Bigger Unified Sensor Box: In room in daylight



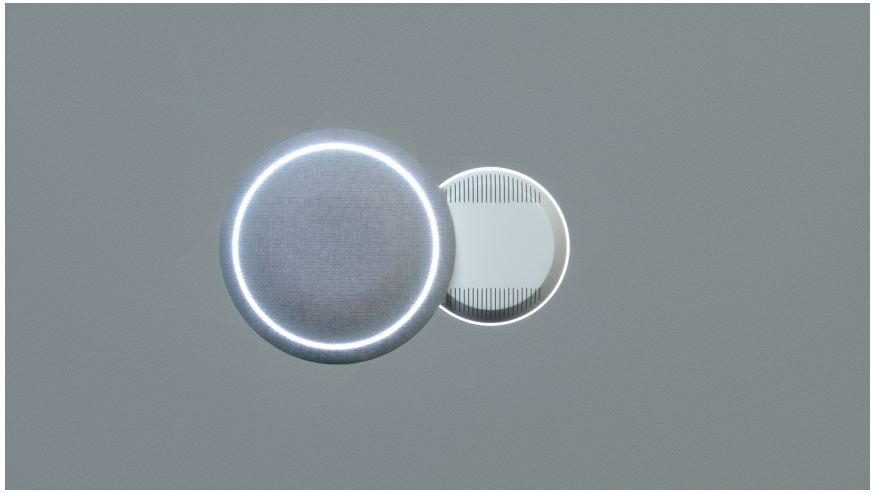
Grey Bigger Unified Sensor Box: In room in daylight



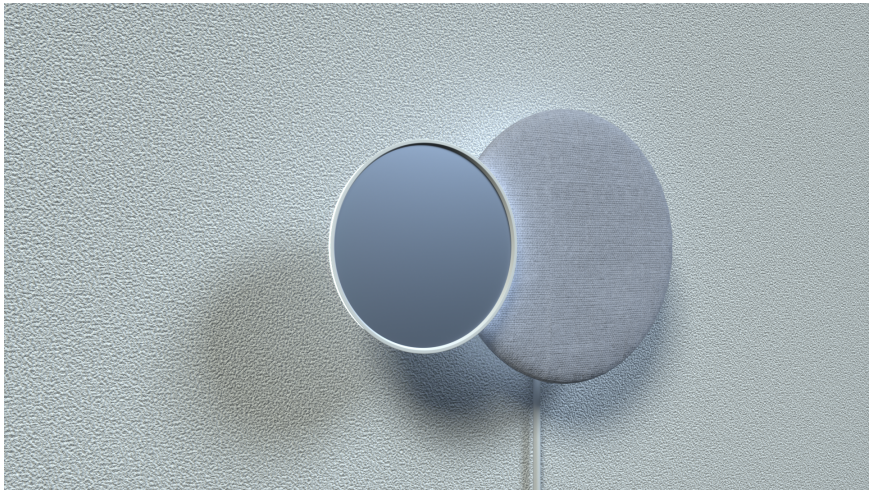
Grey Smaller Unified Sensor Box: Front Wide



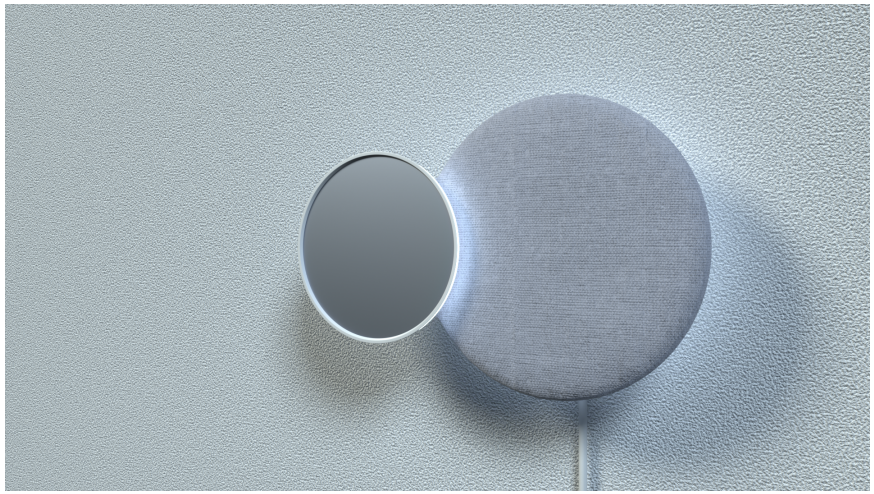
Grey Smaller Unified Sensor Box: Front



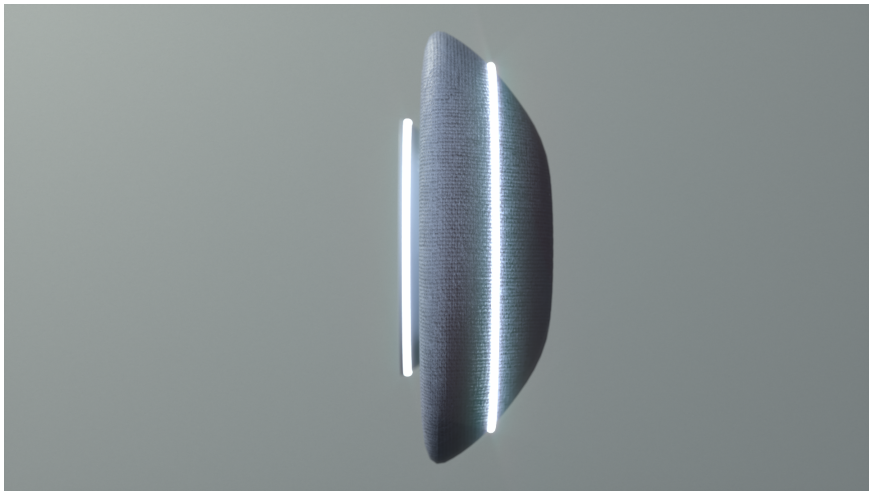
Grey Smaller Unified Sensor Box: Back



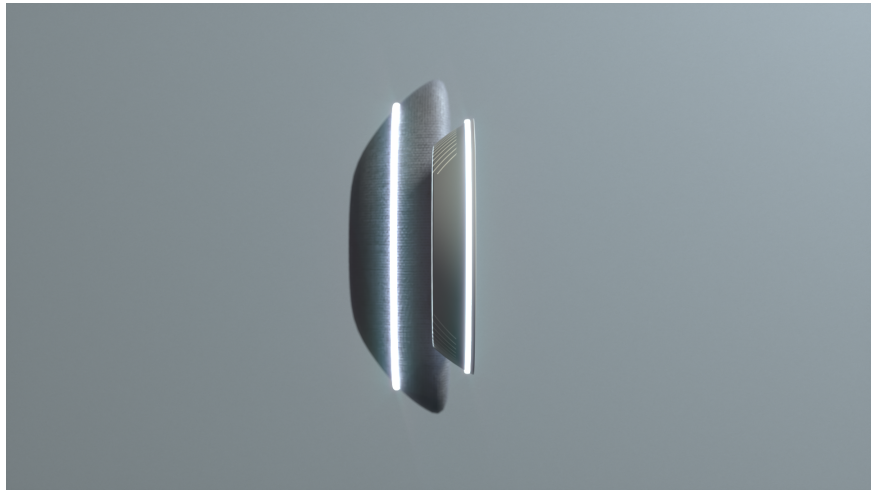
Grey Smaller Unified Sensor Box: Front Left



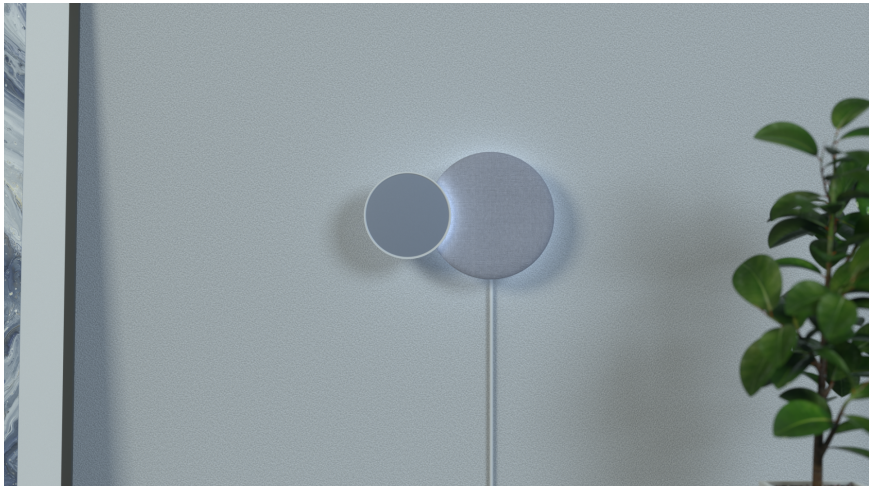
Grey Smaller Unified Sensor Box: Front Right



Grey Smaller Unified Sensor Box: Right Side



Grey Smaller Unified Sensor Box: Left Side



Grey Smaller Unified Sensor Box: In Room

Living Room Model Components: **CPU, Screen, Sensors**: Humidity, Temperature, Smoke, CO, Lidar, IR, Light



Purple Unified Sensor Box: Living Room

Bedroom Model Components: **CPU, Screen, Sensors**: Humidity, Temperature, Smoke, CO, Lidar, IR, Light



Grey Unified Sensor Box: Bedroom

Kitchen Model Components: **CPU, Screen, Sensors**: Temperature, Smoke, Lidar, IR, Light



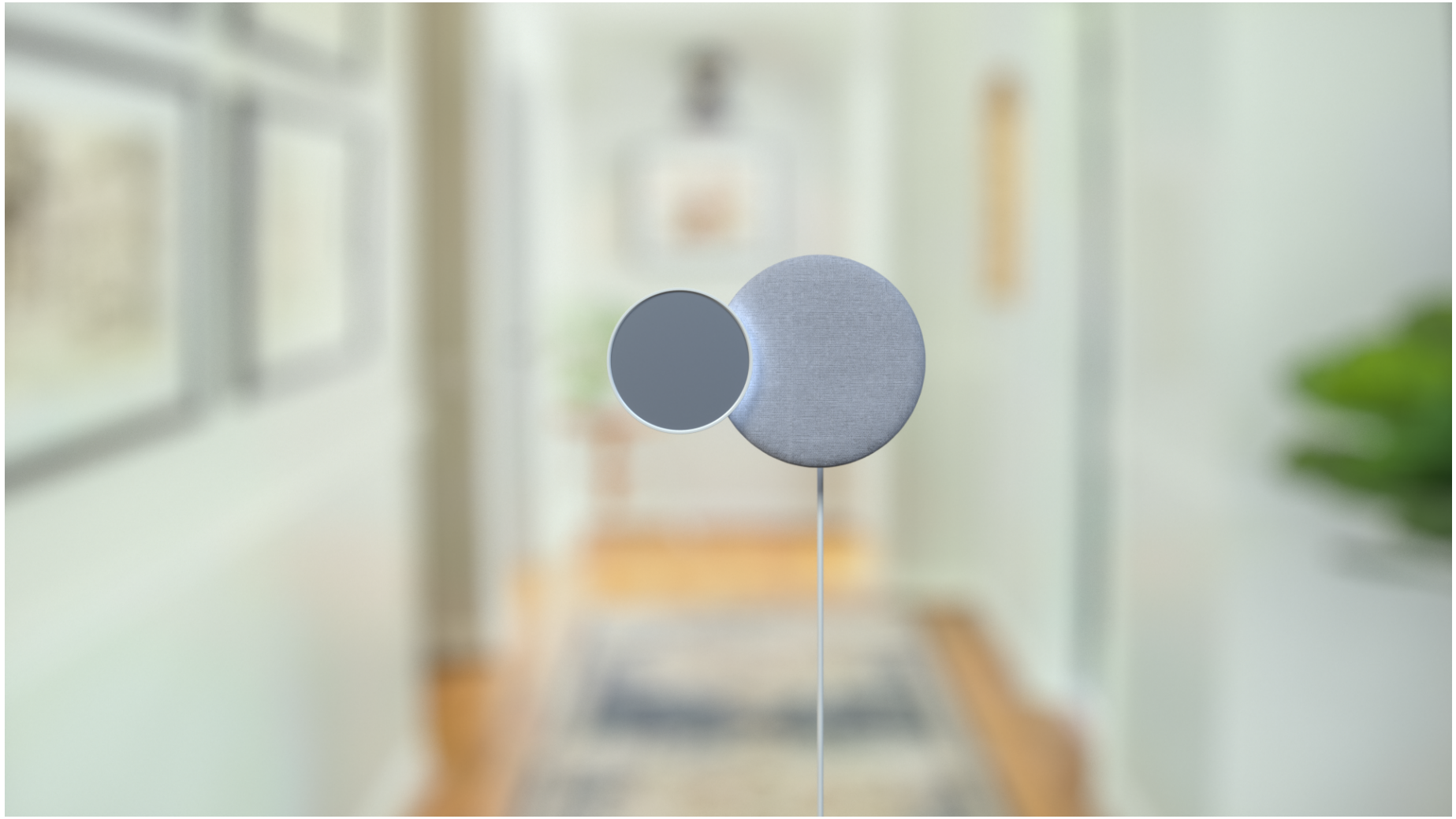
Green Unified Sensor Box: Kitchen

Bathroom Model Components: **CPU, Sensors**: Humidity, Lidar, IR, Light



Purple Unified Sensor Box: Bathroom

Hallways Model Components: **CPU, Screen, Sensors:** Humidity, Temperature, Smoke, CO, Lidar, IR, Light

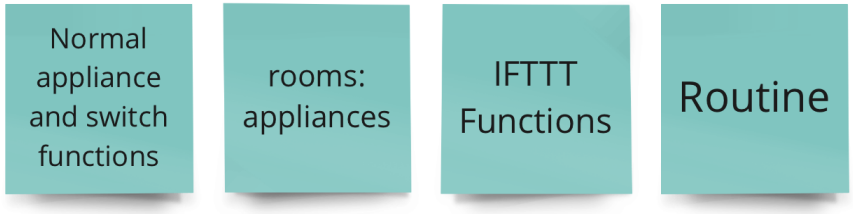


Grey Unified Sensor Box: Hallways

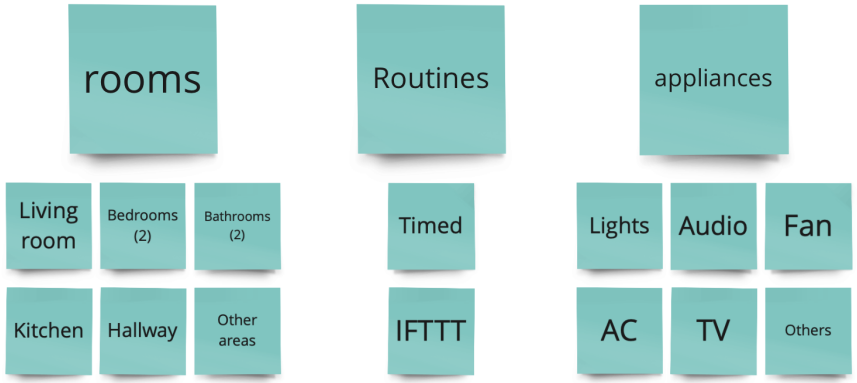
App Design

Ideation and Framework

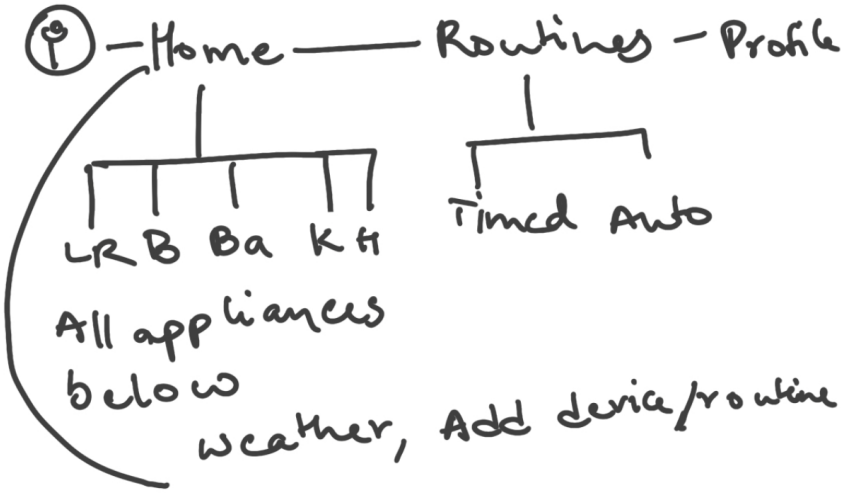
Different functionalities needed in the app were mapped out. Then an information arcitchture was created, then wireframes.



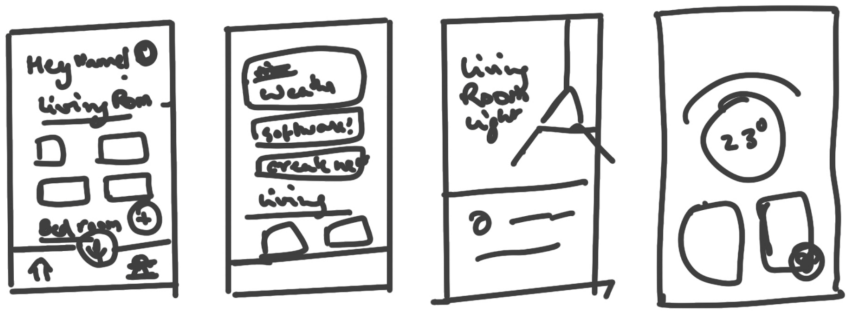
Grey Unified Sensor Box: Hallways



Grey Unified Sensor Box: Hallways



Information Arcitechture



Ideation

Final Concept

Concept Explanation

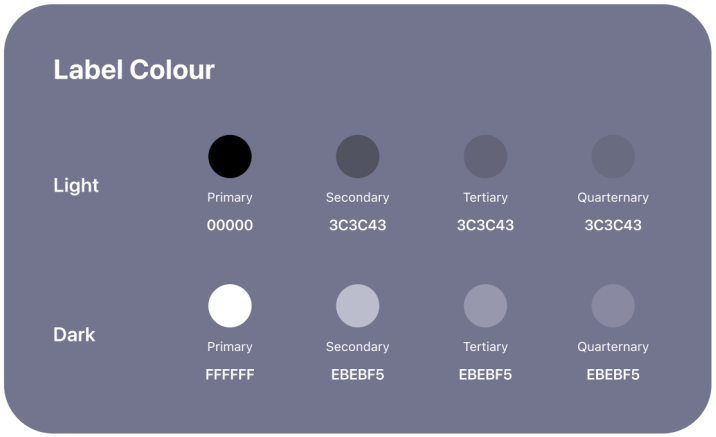
The app is designed to control all appliances and set routines (scheduled or automatic). It works with the unified sensor box.

Concept Detailing

Design system for the app is visualised below.



Text Styles

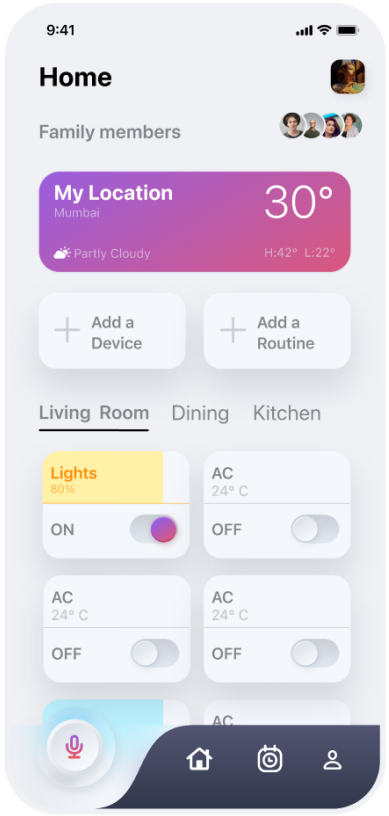


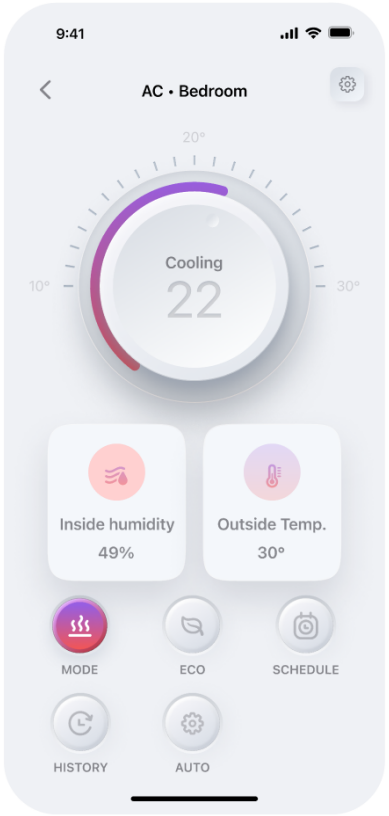
Label Colours

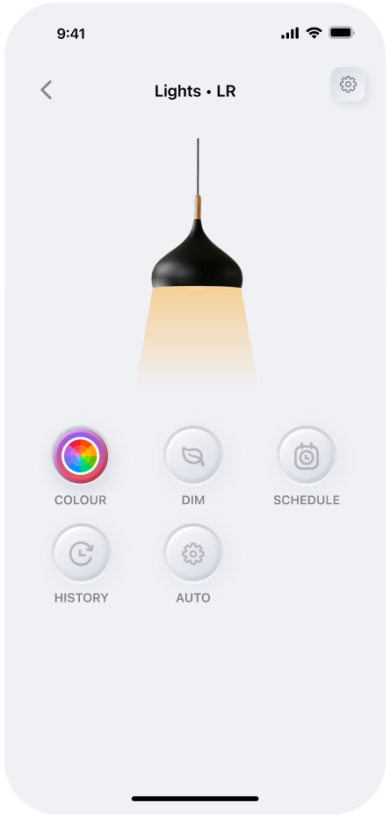


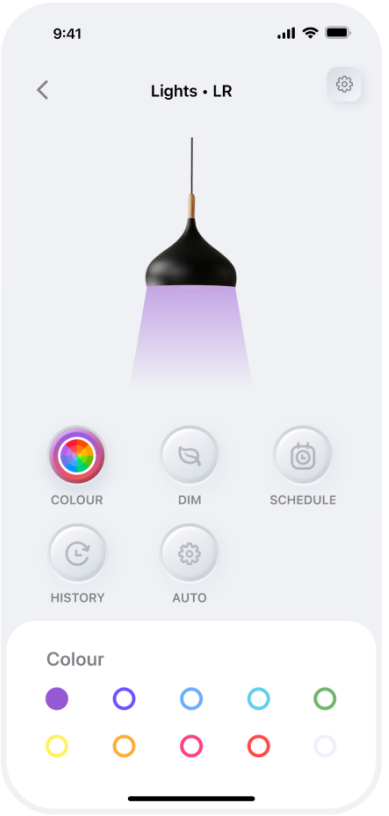
Colour Palette

Screens


9:41
Home
Family members
My Location
Mumbai
30°
Partly Cloudy
H:42° L:22°
Add a Device
Add a Routine
Living Room
Dining
Kitchen
Lights
80%
ON
AC
24° C
OFF
AC
24° C
OFF
AC
24° C
OFF
AC


9:41
AC • Bedroom
20°
Cooling
22
10°
30°
Inside humidity
49%
Outside Temp.
30°
MODE
ECO
SCHEDULE
HISTORY
AUTO


9:41
Lights • LR
COLOUR
DIM
SCHEDULE
HISTORY
AUTO


9:41
Lights • LR
COLOUR
DIM
SCHEDULE
HISTORY
AUTO
Colour

Conclusion

Problems in the design:

- The exact technical details might vary in reality depending on the engineering requirements of the box, thereby changing the form or system itself.
- The artificial intelligence method requires more fine-tuning.
- Sensors placement in the room needs to be looked into from an engineering perspective.

Difficulties faced:

- Considering the amount of technical knowledge required, more time would have allowed for better-rounded final designs.
- During the time the user interviews were taking place, COVID-19 proved to be a barrier for site visits.
- Procurement of exact sensors needed would have helped test the design.

Further Scope:

- Testing using exact sensors required with proper technical specifications.
- Holistic ecosphere for all smart home needs by designing more smart appliances keeping the system design in mind, native applications would have less latency.
- Deployment to conduct beta testing for the AI lidar system.

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