The [Connected] Home is Where the Heart is:
User Interface Design for Smart Appliances

Keeping up with the latest trends in user interface (UI) and user experience (UX) development while maintaining a consistent branded look and feel across your entire product line can help create legions of dedicated customers. The challenge for manufacturers is that different technology approaches are often used for various products, increasing the development time and the maintenance burden. To show you how you can create next-generation user experiences, we have used the latest trends in UI/UX to design and develop four oven demo prototypes covering four product ranges. The prototypes reuse code across the devices and follow best software and hardware architecture practices to illustrate how you can shorten your time-to-market.

**Next-Gen UX.
Limitless Scalability.**

Contents

1. Executive summary

user interfaces
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distinction in a
very competitive
market

In the last 10 years, the white goods market has become a stimulating research and experimentation field for UX/UI designers, developers, and practitioners. Domestic appliance manufacturers have started focusing on providing a sophisticated interaction system to their end-users.

This trend is fuelled on the one hand by users wanting to find a feeling of **familiar and "smartphone-like"** interaction when interacting with a device; and on the other hand, **embedded technologies** become increasingly more powerful, accessible, and scalable. The thrust of these two forces implies exponential growth of possible applications for user interface systems, in sectors ranging from kitchen appliances to washing systems, from products for home sports to the entire home automation.

User interfaces are becoming a **means of distinction** in a very competitive market and appliance manufacturers are leveraging them to increase their recognizability and create brand recognition. In addition, user interfaces are also becoming a way for companies to differentiate their products within **different segments**: this implies the design of interfaces that are different yet linked by consistent essential components in terms of style and recognizability.

Another upcoming trend is the increasing need for **integration between** "**real-world systems"** (e.g., household appliances) **and "virtual interactions".** A concrete illustration of this concept is represented by the combination of objects (and interfaces) and mobile applications; a smooth integration between these systems seems to be a promising design field and an opportunity to develop **appealing, reliable, and innovative interaction systems**.

These trends are becoming even more prominent due to various external factors. For example, the COVID-19 pandemic has changed routines in terms of daily life and propensity to purchase while the semiconductor shortage has limited production in some industries. These combined with other external factors could radically affect the production and market of consumer goods.

The emergence of these trends is challenging appliance manufacturers to develop strategies to address scalability while managing costs and risks, not only on the hardware side but also on the software side.

This paper describes how the Qt software development platform was used to design and develop an Oven interface project with these considerations in mind. Most of the graphics, interaction modalities, and software have been exploited and reused to deploy four prototypes targeting different market segments¬ while keeping high user experience standards and a unified look and feel across the different models. The four prototypes (1 **Low-End** embedded board/display, 1 **Mid-range** embedded board/display, 1 **High-End** screen simulating a "Kitchen

Hub," and a mobile **Companion App** running on different Operating Systems) are described highlighting the common elements

The document also presents relevant trends in the white goods domain, focusing on technological, functionality, UI aspects, and provides a systemic analysis of the application market. The design methodology is presented as well. We call it Design once, deploy everywhere since it demonstrates how this flexible approach based on User-Centered Design, combined with the appropriate Qt framework, can reduce development time and costs. In addition, the results of a usability test conducted with real users are presented. This approach, widespread in Human-Machine Interaction (HMI) studies, has been used to iteratively improve the prototypes through the responses collected from potential customers.

Design once, deploy everywhere.
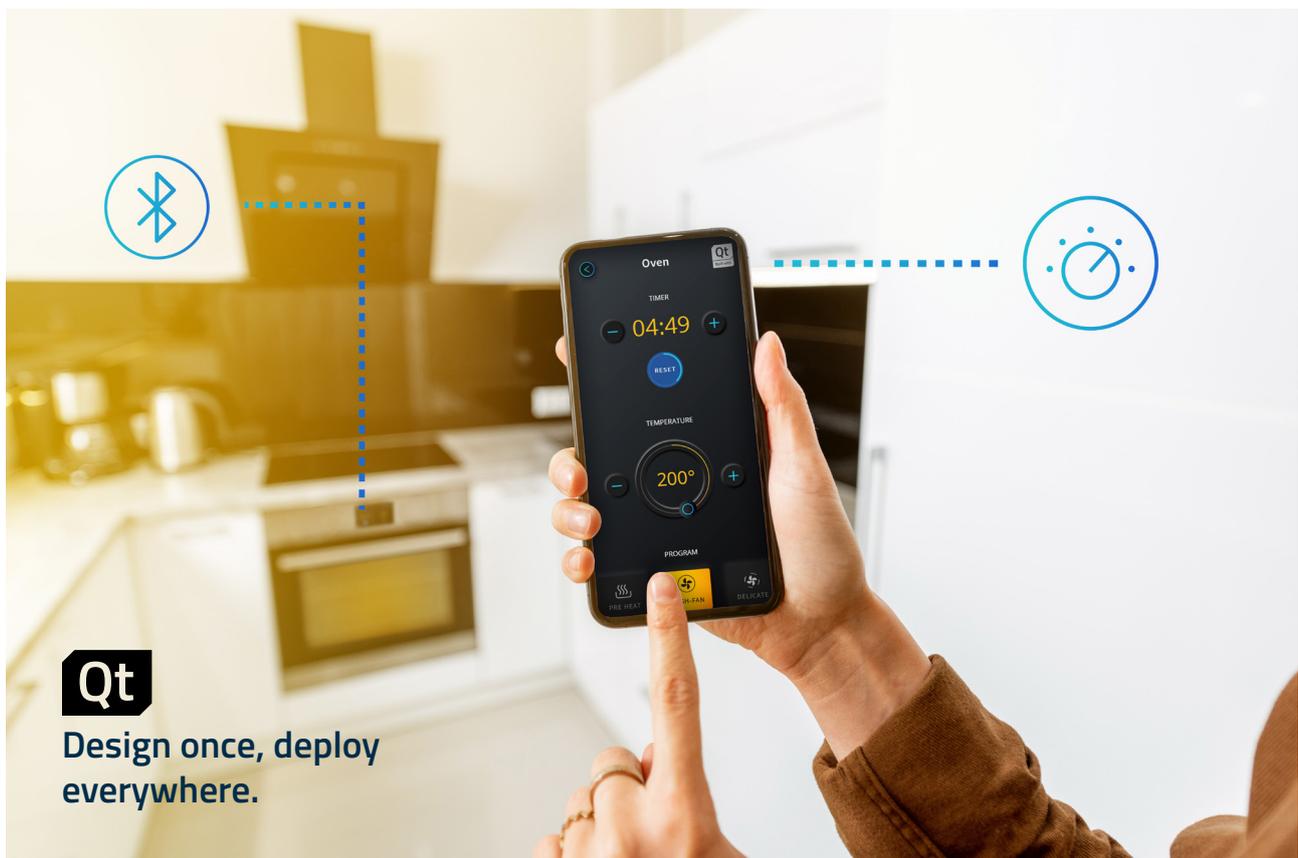
2. Latest trends in UI for consumer electronics

The development of a new interaction system always starts from a deep analysis of the most relevant trends and features available on the market. As already stated, the domain of HMI design for consumer electronics, and white goods specifically, is rapidly evolving.

Continuous innovations are carried out at different levels; among them the following **three categories of trends** shall be highlighted:

Trends at the **technological level** (e.g., displays and control unit)

Trends on the **graphical level** (for visual UIs)

Trends at the **feature level**, with new functionalities and applications enabled by the technological advances and changes

From the UX/UI perspective, we highlighted five main trends to consider, as a combination of the innovation raised from these categories:

1   **Moving towards mixed interaction**
Mixed interaction through voice and gesture combined with visual aid and classic touch controllers.

2   **Advanced personalization**
Different from customization, it makes the user feel that the content has been created especially for them.

3   **UX/UI simplification and optimization**
Moving to less-thinking actions toward a natural behavior to increase user satisfaction and accessibility.

4   **Animations and transitions**
Mobile-like animated interactions, smooth and pleasing transitions for user encouragement, and help in navigation.

5   **The introduction of 3D elements**
3D graphics and elements to engage users and present objects virtually to create immersive experiences.

2.1.   Technologies and Displays

Compact and minimal display

Displays for embedded applications are more and more relying on small yet sophisticated displays, able to show with a high resolution a wide range of colors with a good level of details.
These compact screens are now used also in low-end and mid-range systems.

Vivo Screen 4.3 and the Vivo Screen Max 6,3 LCD mounted on SMEG ovens

Large touch-screen display

Larger screens are also becoming more and more widespread. These screens are now controlled by low-power, high-performance electronics, that have become more cost-efficient with a reduced size in the last 10 years.

7" touch-screen Full HD display mounted on GE Profile 30
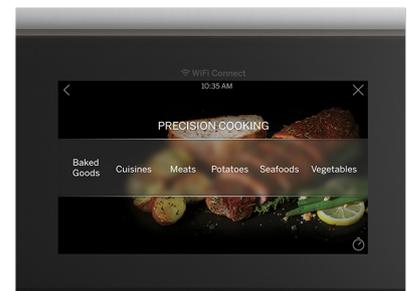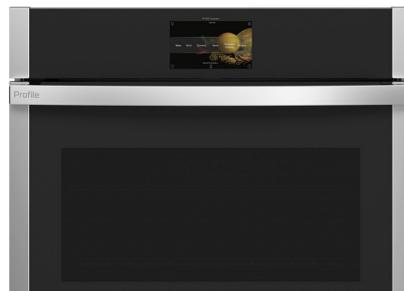
Kitchen hubs

Alongside traditional display systems, home hubs that control multiple devices while maintaining consistent display modes and style are becoming more popular in recent years.

GE 27 touch screen and ventilation combo, are able to control and monitor all the kitchen appliances, and are integrated with the most popular home automation systems (e.g., Amazon Alexa and Google Home).

2.2. Graphical trends

Neumorphism
Also called New skeuomorphism, is characterized by minimal design, plastic extruded look, mimicking physical textures such as plastic and metal.
The main benefit of this style is the modernity, which brings a new feel to the interface and makes it stand out. However, it may have some drawbacks in terms of visibility and accessibility.

Example of neumorphism

https://dribbble.com/shots/11660750-Smart-Oven-App-Soft-UI

Glassmorphism
It is characterized by soft shadows, layers, and floating elements.
It brings depth to UIs, through the combination of transparency, vivid colors to highlight the blurred transparency and a subtle, light border on the translucent objects. It is strongly suggested to obtain a mobile-like look and feel.

Example of glassmorphism

https://dribbble.com/shots/14695232-Glassmorphism-trend-for-2021-glass
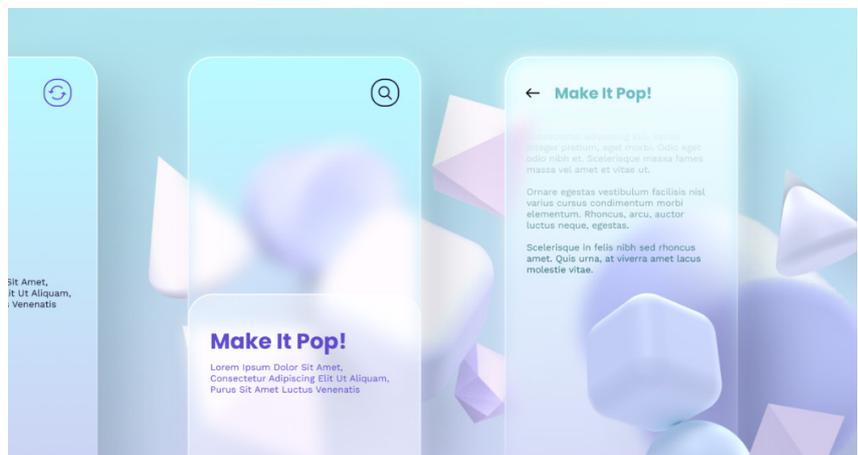
3D Elements

This trend, which is not new at all, is also more accessible also for embedded systems running on low-power CPU/GPU.
Applications include icons, product representations, and transitions.

Example of 3D model

Typography and microcopy

Fonts and typography, in general, are becoming more and more important.
This implies a more expressionistic use of the characters, with great care given to the type of application in which the font is used.

In addition, studies of character readability and the relationship between reading time and comprehension effectiveness affect the match between fonts and applications.

Example of typography

https://dribbble.com/
shots/2249414-Splash-
Screens
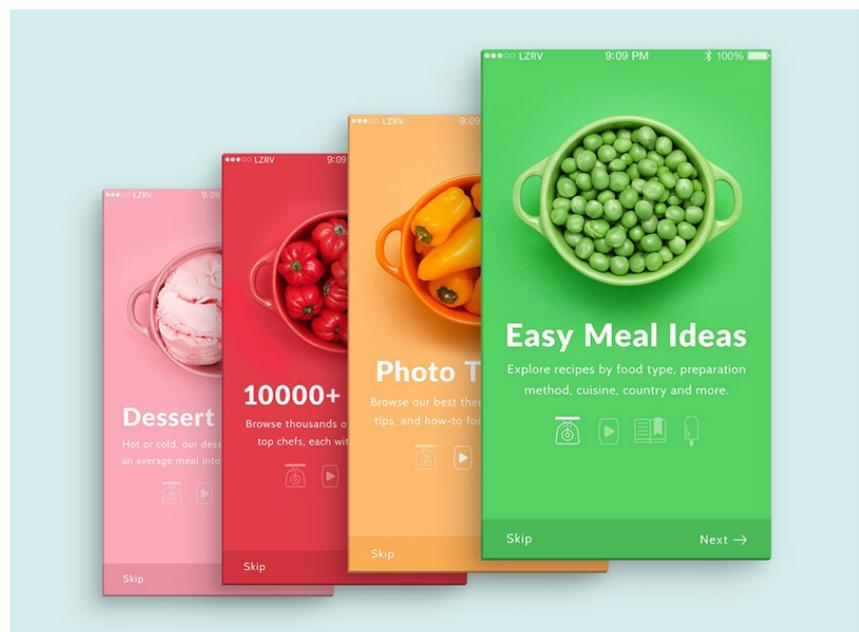
Dark Mode / Adaptive Brightness

Dark mode has been made popular by apps, and is expanding into other domains like consumer electronics.

It is characterized by high contrast design, to maximize readability and give a modern look.

Anova Oven Interface
Example of dark mode
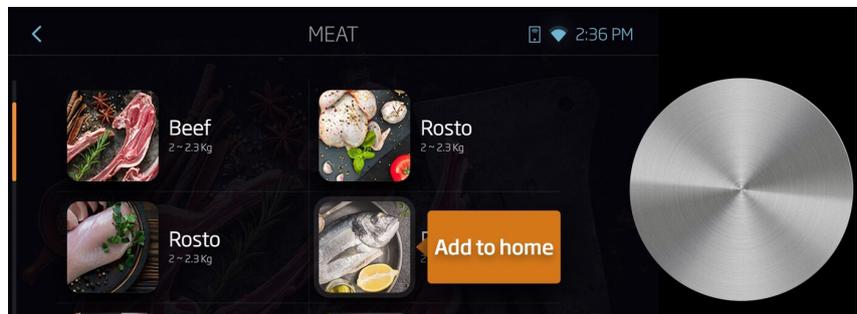
Mobile looking

In general, the mobile app style is expanding across all other industries. People are used to visual systems that replicate the design intent and style of their most familiar models.

Animation, transitions, and UI with a look and feel of an app can also be found in home appliances, thanks to electronics able to process complex graphics.

This trend is expected to be further extended in the following years.

Qt Smart Oven UI -
Example of mobile
like interaction to
browse recipes (touch
horizontal scroll)
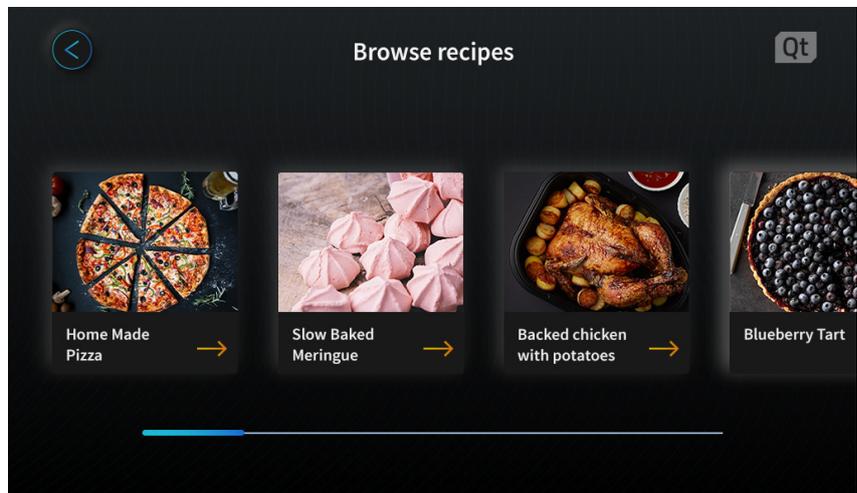
2.3. User Interaction trends

Touch screen Interaction
Digital touch screen displays with enhanced graphics and UI are spreading to the appliance industry as well.
Modern ovens and other home appliances are often equipped with touchscreen displays that replace the traditional mechanical controls.

App and Hub
The trend of virtually extending the embedded displays with a companion mobile app, able to allow a natural interaction is becoming more frequent. Also kitchen hubs, able to control all the kitchen equipment and interact with other digital services (YouTube, Spotify, Amazon Alexa, Google Home, etc...) will become increasingly popular in the next years to come.

Guided cooking
Step-by-step recipes and instructions are widely considered one of the most popular applications for innovative appliances.

Increased Connectivity and Social Interaction
Connection with other home appliances (e.g., fridge, mixer, etc.) and interaction with other people on cooking-related topics (e.g., virtual cooking experience, tutorial, masterclass, remote cooking) is a key trend in home appliances.

Qt Smart Oven App UI

3.   Methodology

3.1 Design system

The design system has been developed following two key points: responsiveness and re-usability.

Responsiveness
The aim was to create an interface that would adapt to three different target screen sizes (plus one mobile app) without scaling, but rather re-disposing the graphical elements to fit each target display.

To do that we started by creating a wireframe of the interface as a reference scheme for the design system behavior.

Oven UI responsive concept

Oven UI wireframe concept
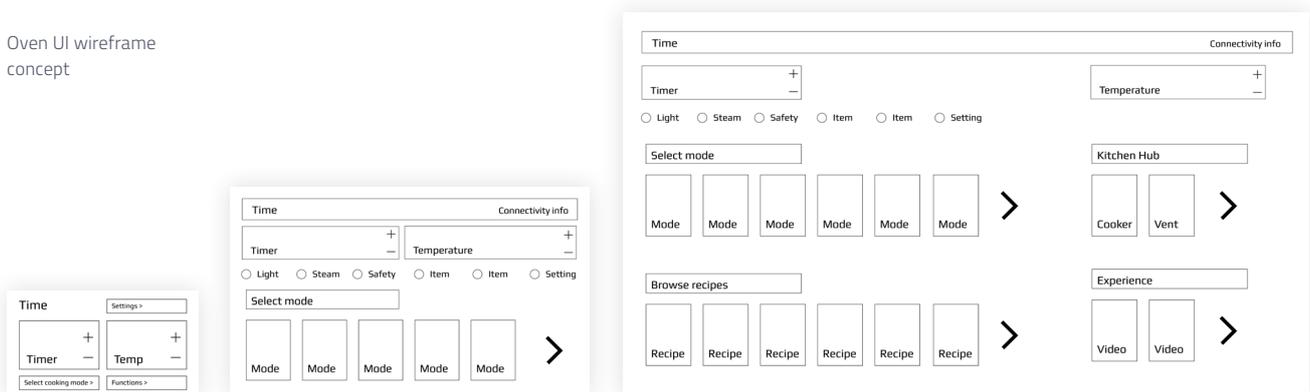
Re-usability

All the UI graphical assets, such as buttons, indicators, icons, sliders, etc... have been created only once and then placed throughout all the different target displays.

Oven UI graphical assets
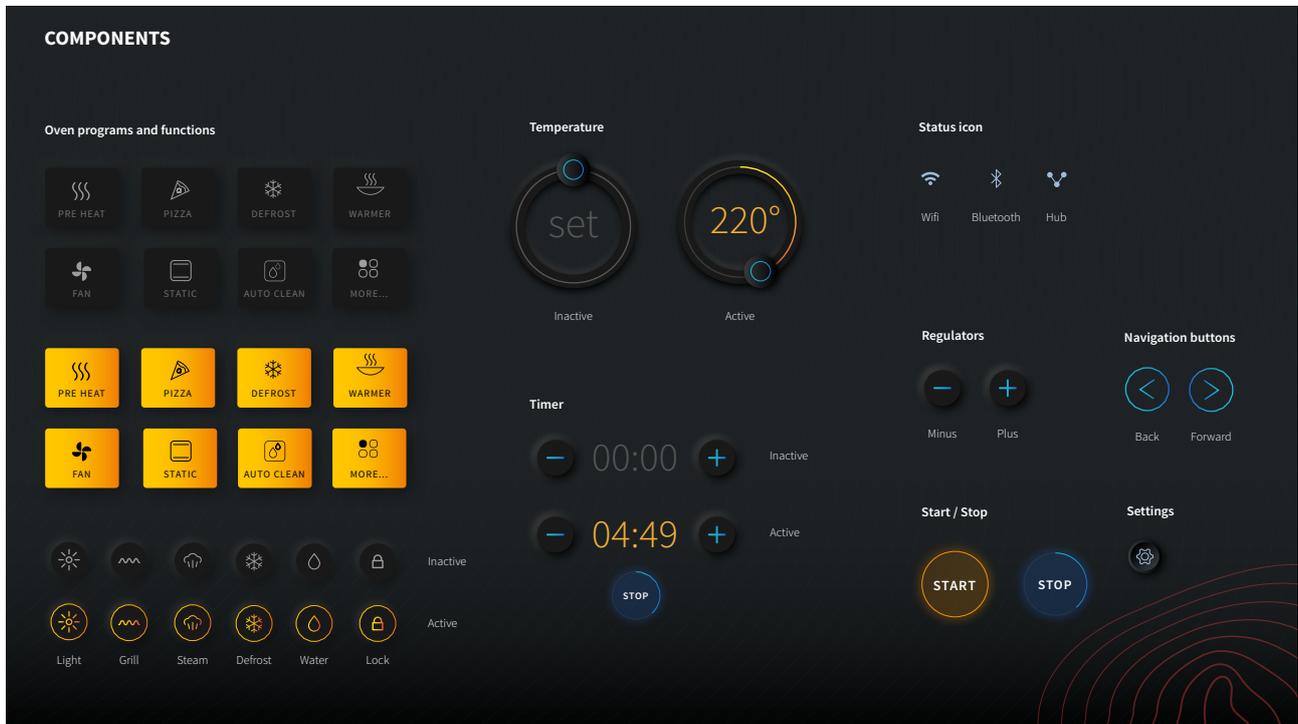
Same elements on different target displays
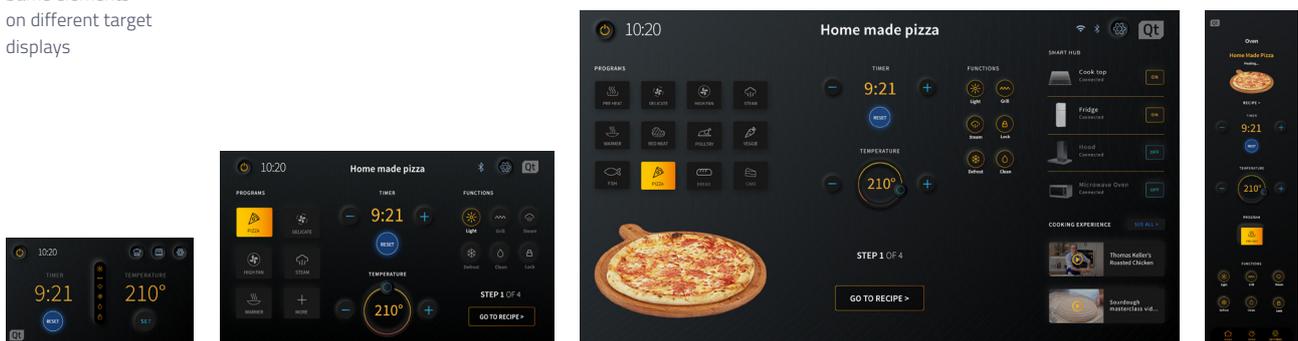


Low-end

Mid-range

High-end

App

3.2. Features

Key features have been identified to promote Qt value proposition, enabling oven manufacturers to reduce their bill of materials (BOM) and create astonishing graphical UIs.

They have been chosen among the most relevant features identified in the Trend analysis which has led to the selection of hardware components (display, connectivity modules, etc..) to actually implement the features in the different demos.
The selection of hardware components in each demo, has also led to the selection of the embedded board to support them.

Oven UI design features

LOW-END

Basic UI design
Qt for MCUs

- ☑ Modern aesthetics
- ☑ Custom icons
- ☑ Textures
- ☑ Smooth transitions
- ○ Photo / images
- ○ 3D Micro animations
- ○ Video

MID-RANGE

Improved UI design
Qt for MCUs

- ☑ Modern aesthetics
- ☑ Custom icons
- ☑ Textures
- ☑ Smooth transitions
- ☑ Photo / images
- ☑ 3D Micro animations
- ○ Video

HIGH-END/APP

Advanced UI design
Full Qt framework

- ☑ Modern aesthetics
- ☑ Custom icons
- ☑ Textures
- ☑ Smooth transitions
- ☑ Photo / images
- ☑ 3D Micro animations
- ☑ Video

Board selection

LOW-END

Qt for MCUs
STM32F7508
No connection
4.3" 480x272px Touch Display

MID-RANGE

Qt for MCUs
i.MX RT1176
Bluetooth & Wi-Fi
7" 1200x600px Touch Display

HIGH-END

Full Qt framework
Raspberry Pi 4 4GB RAM
Bluetooth & Wi-Fi
15.6" 1920x1080px Touch Display

4. Oven demo

4.1   Qt for MCUs on low-end control unit

Hardware specifications

Qt framework	Qt for MCUs
Board	STM32F469I
Connectivity	No connection
Display	4.3" 480x272 Touch Display

UX Design

The low-end display is set up directly on the oven control panel. The size of the display and its resolution are optimized to save space without compromising usability. The gestures included in the low-end interface are touch and slide.

UI Design

The graphical components of the interface are designed with a touch target 45 - 58 pixels wide which allows the finger to fit snugly inside the target. The edges of the target are visible when the user taps it. This provides them with clear visual feedback that they're hitting the target accurately.

To include all oven demo features in the interface, some of the functionalities and options have been divided into different screens so that all the components result in a comfortable touch target surface.

# Low-end Qt Oven demo screens

Idle screen
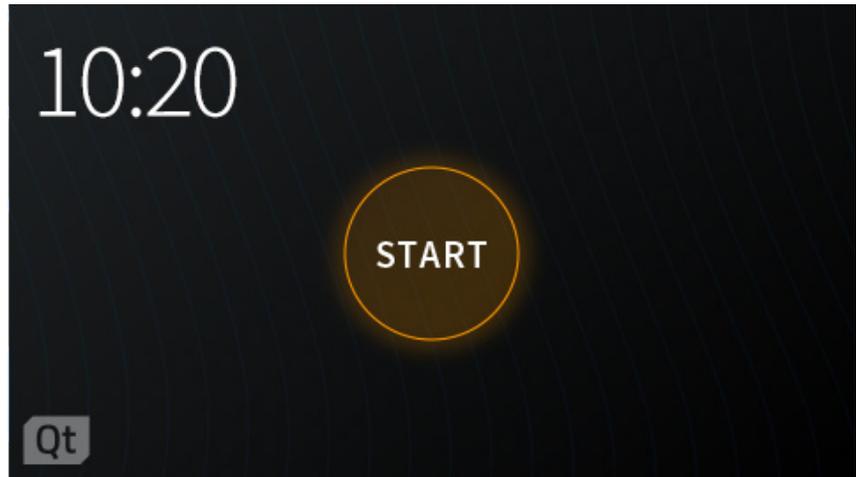
Dashboard with active program

Oven function with active and inactive buttons
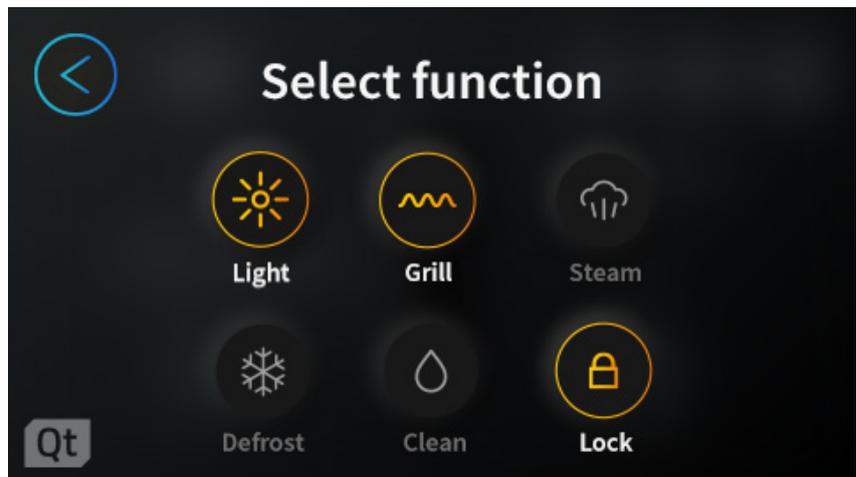
Low-end Qt Oven demo screens

Program screen with
horizontal scroll
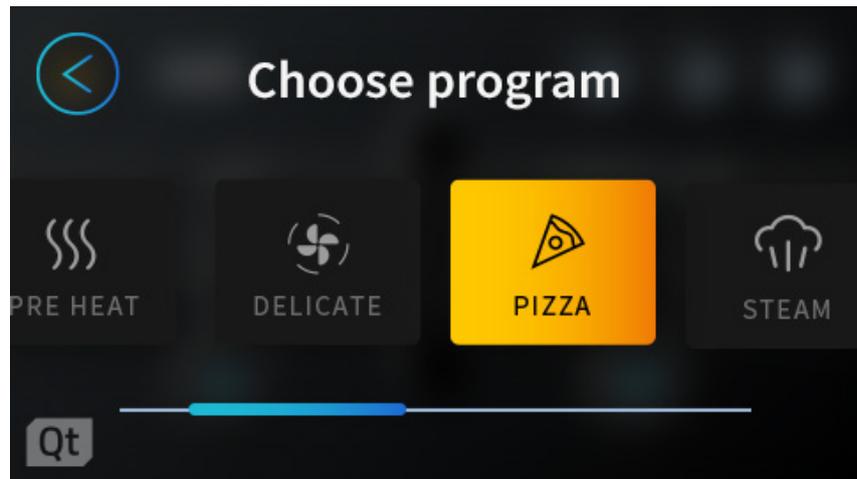
Set timer screen
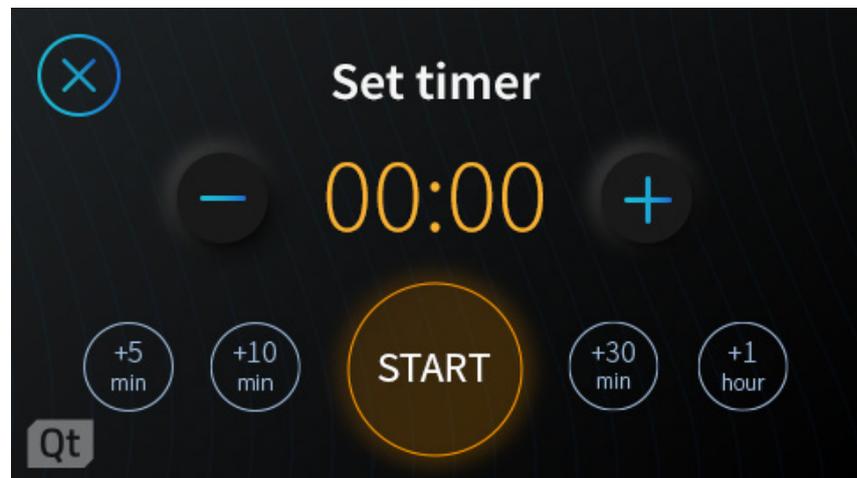
Set temperature
screen

4.2.   Qt for MCUs on mid-range control unit
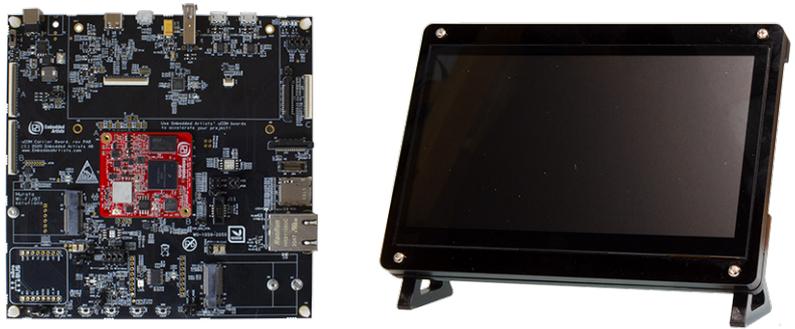
Hardware specifications

Qt framework	Qt for MCUs
Board	i.MX RT1176
Connectivity	Bluetooth & Wi-Fi
Display	7" HDMI Display

UX Design

The size of the mid-range display allows to include more function inside the same screen. Compared to the low-end, the user has to do fewer taps to reach the same feature. Gestures included in the mid-range interface are touch, slide, and swipe.

UI Design

As mentioned above, in the mid-range version the display is bigger than the low-end one. This leads to fewer screens with more options.

In this version of the demo, there is also a Light Screen Mode available.

Mid-range Qt Oven demo screens

Dashboard with active recipe mode

Recipe list
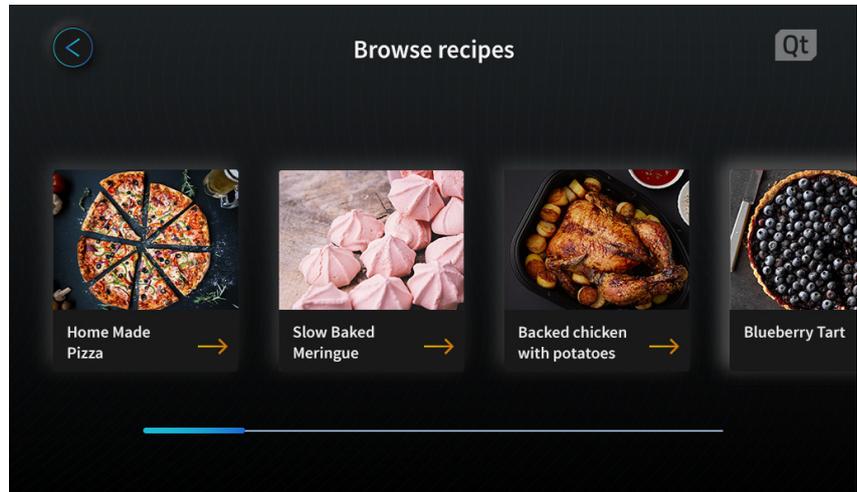
Recipe overview (supporting GIF animation on the right)
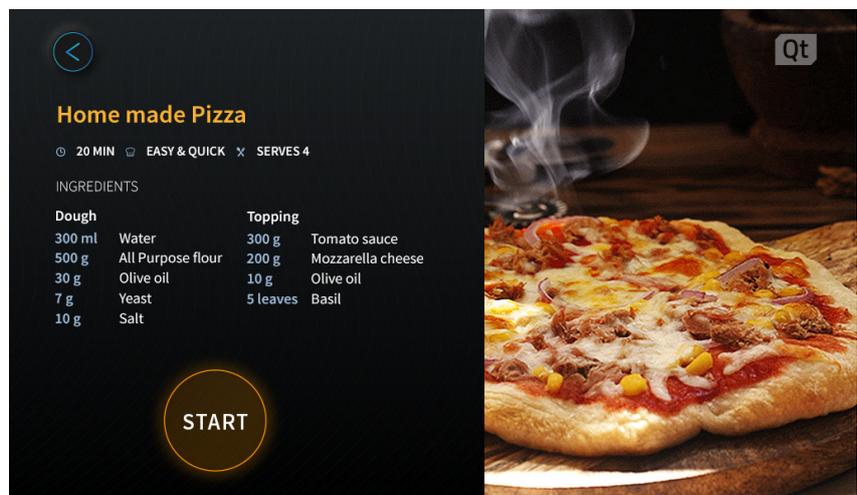
# Mid-range Qt Oven demo screens

Recipe step
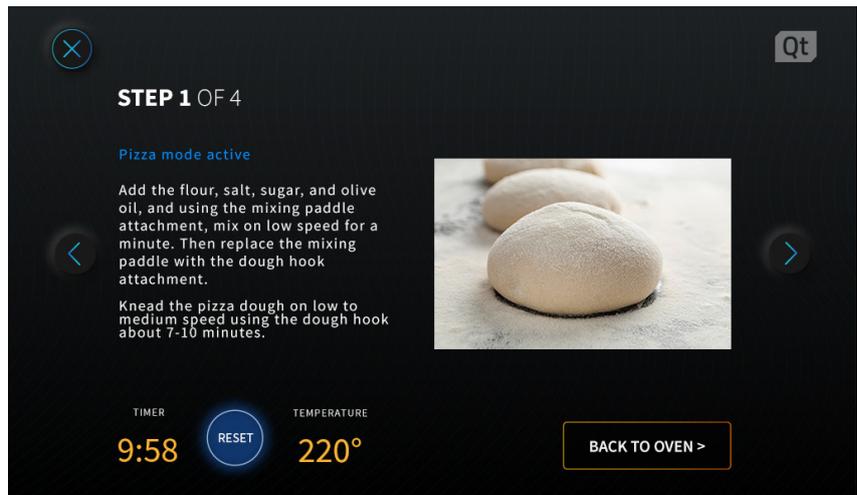
Settings screen
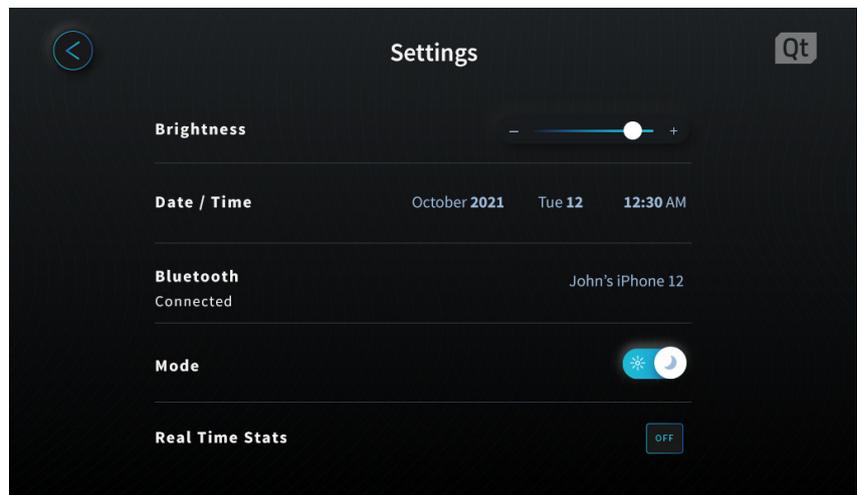
Dashboard on light mode
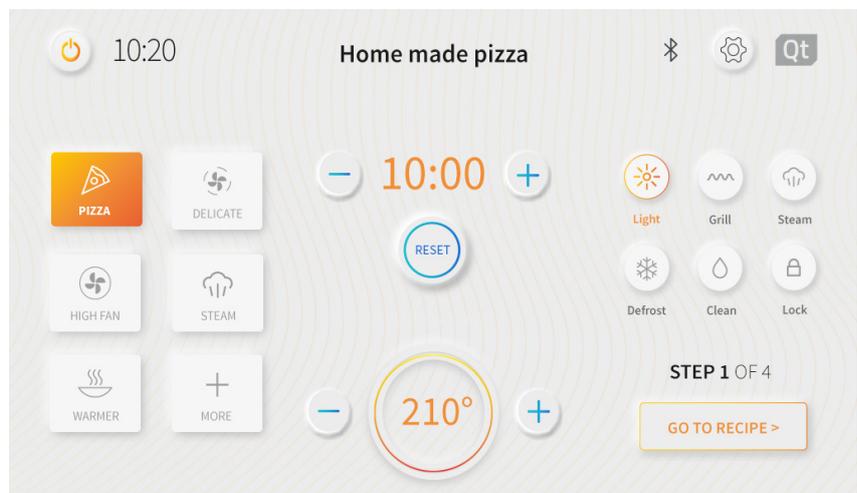
4.3. Qt's full framework on high-end control unit

Hardware specifications

Qt framework	Full Qt Framework
Board	Raspberry Pi 4 4GB RAM
Connectivity	Bluetooth & Wi-Fi
Display	Gechic OnLap M505T 15.6" Touch Display

UX Design
The size of the high-end display allows to include all the features of the smart oven application in the main dashboard screen. The high-definition touch-screen device is conceived to become a kitchen hub, controlling and regulating all the appliances in one place with simple and quick and straightforward gestures. With the possibility of the Wi-Fi and Bluetooth connections it is possible to switch from the smartphone to the high-end display easily and to browse the internet (YouTube in the demo) to find useful recipes and tutorials.

UI Design
With many functions featuring on the same screen, the elements have to be clearly identified in a hierarchy: main oven functions are central and bigger, active buttons are brighter while inactive buttons are darker.

High-end Qt Oven demo screens

Dashboard with
active recipe mode
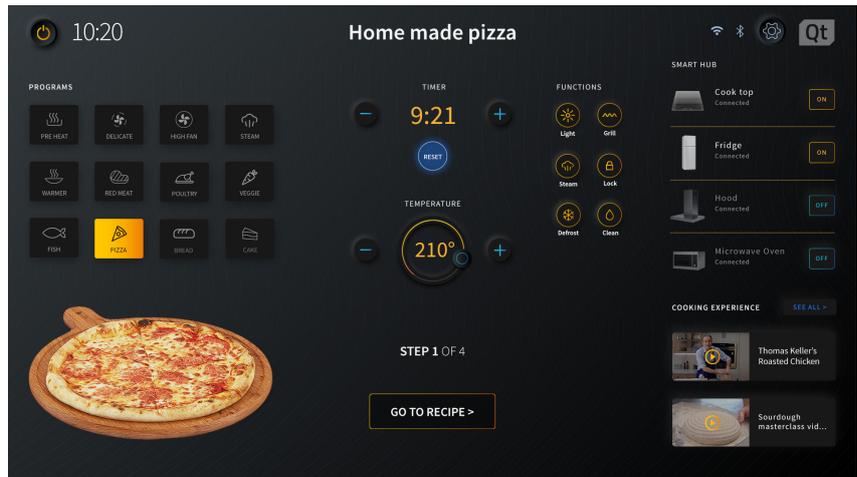
Cooking experience
video list

Video player (from
YouTube)
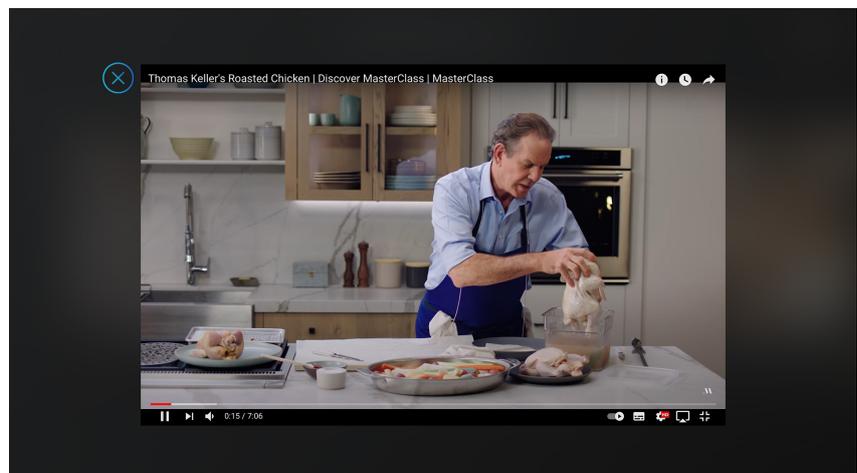
4.4. Qt's full framework for companion app

Hardware specifications

Qt framework	Qt's Full Framework
Device	Motorola G 5G with Android 10
Connectivity	Bluetooth & Wi-Fi
Display	2400 × 1080px

UX Design

The primary purpose of the companion app is to keep an eye on the status of the oven while cooking. But more than that: the app allows to add some key trend features in the experience of living a smart kitchen (and home) such as suggested recipes and connection with other apps (Google Health for instance).

UI Design

The app interface maintains the same look and feel of the overall design system allowing the user to switch seamlessly between devices.

Companion app demo screens

Home screen with active program
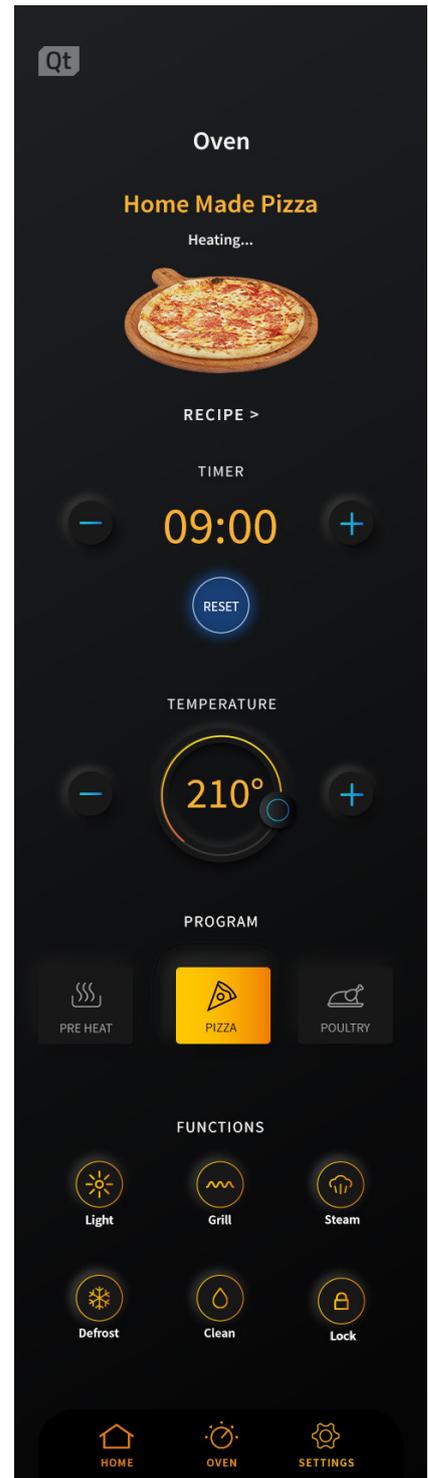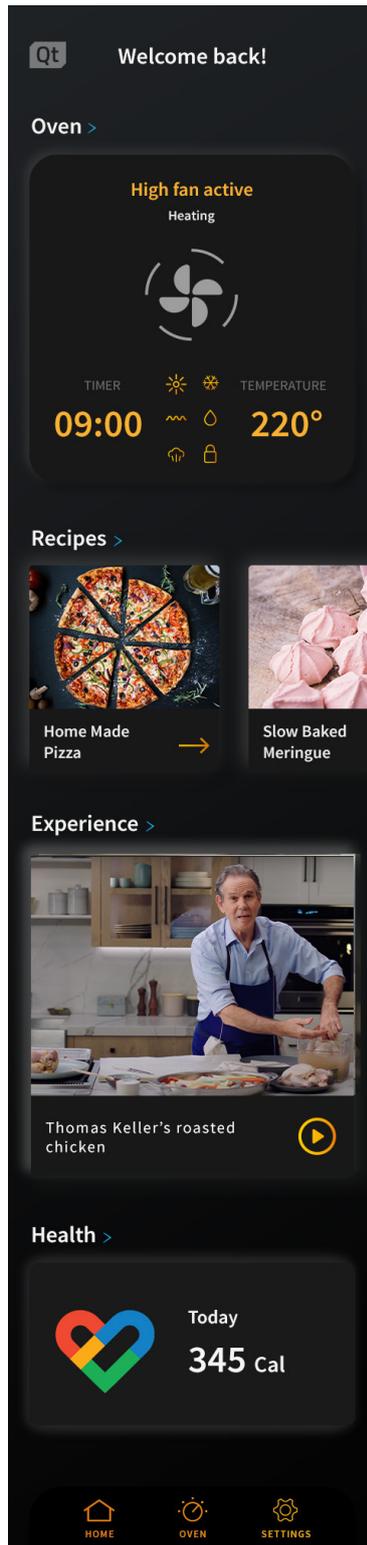
Oven screen with recipe mode

Companion app demo screens

Recipe detail
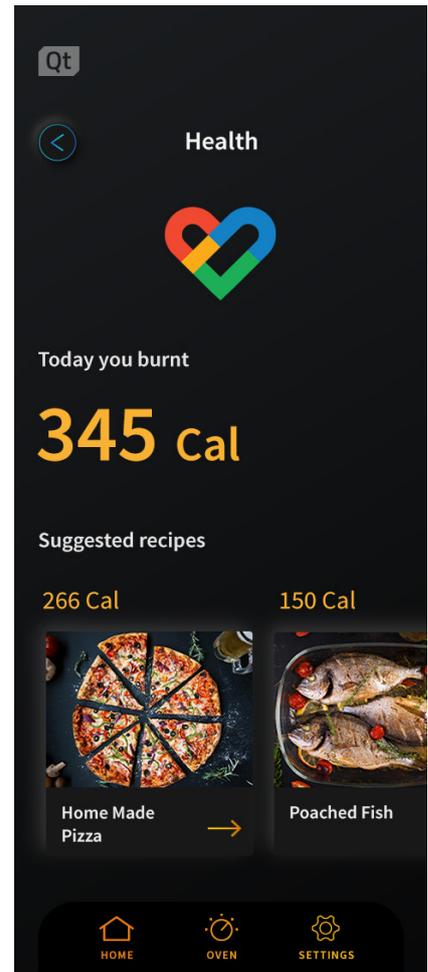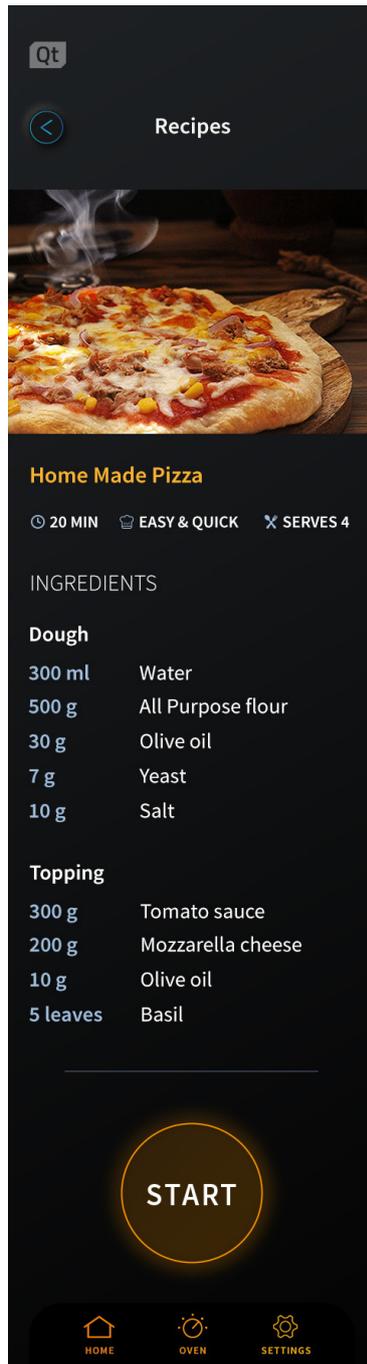
Heath screen with
suggested recipes

4.5. Development specifications

Workflow

Starting from trends research highlights and UI UX best practices, the actual demo design and development workflow has been set up to be straightforward and time-saving in terms of graphical and codebase assets.

The software tools that have been chosen to reach such results have the characteristic of being compatible with each other, allowing designers and developers to interact with the project on different levels (graphical and code), working directly on the files, and reducing/zeroing the needs for specifications Importing designs from **Photoshop**, **Sketch**, **Figma**, and third party tools directly into the prototypes can accelerate the workflow. In this case, we will address how the team used Photoshop to create the electronics.

UI asset
The graphical assets have been designed starting from sketches with Adobe Illustrator in vector format. The UI elements, such as buttons, sliders, shapes, icons, etc., have then been imported into Adobe Photoshop as advanced objects and arranged into artboards with the same size and final layout of the target display resolution.

UI export
One or more layers define each object in the Photoshop file, each layer that has been created can be exported, selected and edited afterward with Qt Design Studio. The Qt Bridge for Photoshop has been used to export the PS assets in PNG format along with a metadata file readable by Qt Design Studio.

Qt Design Studio import
From Qt Design Studio, the graphical assets are imported from previous steps. This will create declarative QML files for all the various screens previously designed with Photoshop ready to deploy.

Deploy
Finally, for compilation and deployment, low-end and mid-range targets make use of Qt For MCUs tool-chain, while the companion app needs Qt for Android and the High-end target make use of Qt for Device Creation and the Boot to Qt software stack.

5. User perspective

In the user-centered design approach, the involvement of real users from the preliminary design phase plays a crucial role.

This method allows to obtain feedback from a relevant sample of potential customers very early, and **tailor the design choices around the needs** collected in a structured way.

It is now widely acknowledged that this approach (although it requires testing the system in a preliminary form) can **reduce total design costs** compared to the traditional waterfall design model, mainly because it requires less re-work, and reduces the risk of launching a product on the market that is not optimized or does not meet the users' needs.

However, to ensure that the modifications required by the users are easily integrated into an incremental prototype, the system shall be designed in a way that allows to perform graphical and logical adjustments effortlessly.

In this sense, the **Qt platform facilitates the update of the prototypes** just by replacing the graphical assets as simple building blocks in the Qt toolchain.

The following paragraphs describe the test performed with real users and the main actions taken to integrate the improvements required.

5.1. Test Methodology

The Oven UI test has been performed only when the main concept and assets were available. The main scope of the test was to evaluate the users' satisfaction (including both aesthetics and usability factors) and the Acceptance of the Oven User Interface. These indicators have been selected as the most appropriate among the known KPIs in the UX/UI scientific literature.

Moreover, additional factors have been considered; for example, UI assets (i.e. the icons) and Basic Functions (e.g. Timer and Recipes) have been tested to collect feedback and suggestions for improvements. Finally, Dark / Light modes have been tested to evaluate the usefulness of having both modalities.

To measure these indicators, standard techniques, and questionnaires have been selected and administered to the users. For example, for the User Acceptance, the Van der Laan questionnaire [1] has been used, while the aesthetics and the other subjective items have been measured with a 5-point Likert Scale [2]. Furthermore, market-oriented parameters (i.e., the willingness of the users to buy and to pay the system) have been tested to collect insights on the added value provided by the interaction system to the final product.

Additionally, the thinking aloud technique [3], which asks users to comment distinctly what they are doing and what motivates their steps, has been used to collect qualitative comments.

Twelve users (7 females and 5 males) have been involved in the test. The requirement asked to participate was to be familiar with oven systems and experience modern visual interaction systems. A small sub-cluster of 4 experts (namely professionals in UX, marketing, and copywriting) has been created to compare the results against the overall sample and check possible differences.

5.1. Test Results and Re-design

From the User Acceptance point of view, the system has been **strongly accepted by the users**. In particular, the overall Acceptance score was +1,44 (where the interval is between -2 and +2, and the acceptability threshold is considered at 0). Regarding the single parameters used to evaluate this metric, users found the system as **Useful** (+1,67), **Assistive** (+1,67), **Pleasant** (+1,58), and **Desirable** (+1,50)
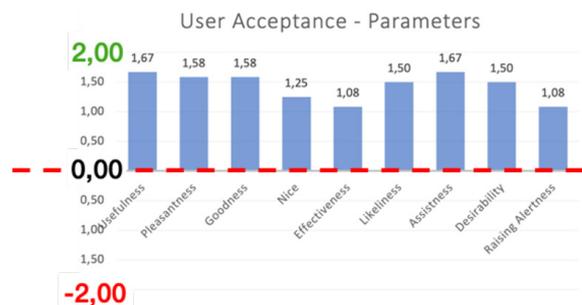
Regarding the single icons assets, the scope of the test was to measure the **usability and satisfaction of the main visual**s, to improve those that did not reach the acceptability threshold. This was particularly relevant, since the HMI of an oven is usually installed in small displays, where there is not so much space to provide additional details on the icons and the programs. For this reason, the pictograms shall be as much self-explanatory as possible.
Most of the UI assets have been well perceived and considered as pleasant and easy to be understood. Some assets were under the acceptability threshold and have been re-designed.
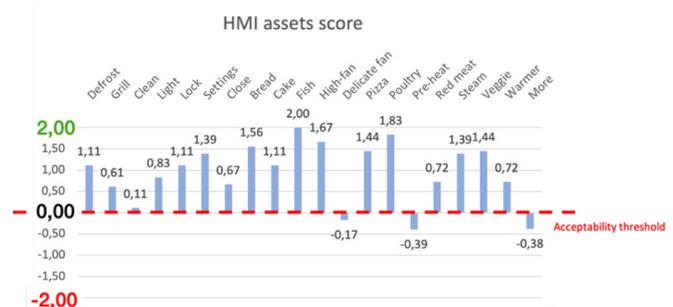
Dark Vs. Light mode

The possibility of having different lights modalities in a user interface is an increasingly common feature. The test comparing the Dark and Light modes has been split in two parts: subjective feedbacks on the Legibility and the Pleasantness of each mode was collected, and the Reading Time for long text paragraphs (i.e., a recipe) was measured.

Concerning the subjective factors, **Dark mode has been considered slightly more readable than the Light mode (+2,00 against +1,67), while no differences have been noticed in** pleasantness (+1,50 for both versions). Also reading times were quite similar (24,68 seconds in average for Dark Mode vs 25,49 seconds for Light Mode).

In general, users found as useful to have the possibility of switching among the two modes (feature that is in fact available in the mid-range prototype).

Dark / Light Mode - Subjective results


Dark / Light Mode - Reading time (s)
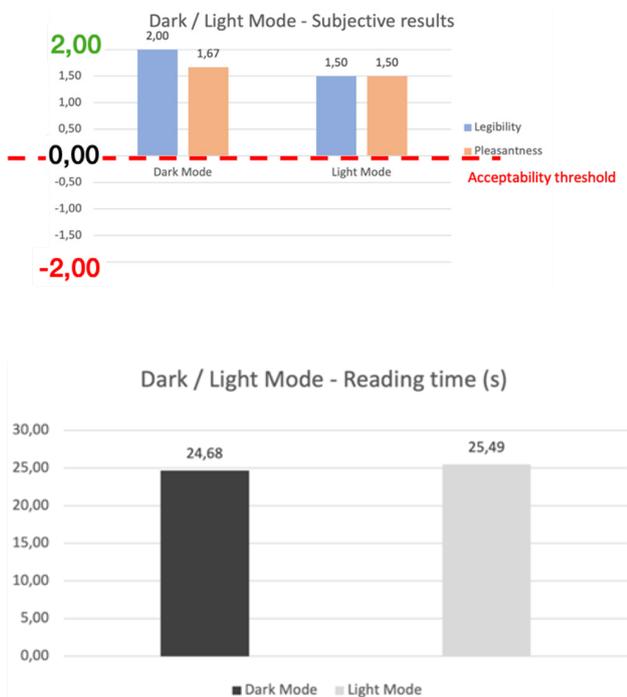
Market-oriented parameters

Regarding the market-oriented parameters, it has been noted that users were **strongly willing to buy** an oven equipped with the UI under analysis (+1,75). Users would pay on average 687,91€ for an oven equipped with that interface, and would pay 154,58€ for the display / UI if it would be offered as an "Optional".

These results confirm the original hypothesis about the role of user interfaces to reinforce an appliance brand identity and a parameter that can influence the customers' decision to select and purchase a product.

Willingess to Buy

Willingness to Pay (€)

In general, no significant differences have been found between expert and generic users. However, the qualitative comments provided by the experts have been considered in a special way to provide suggestions to designers and developers.

Conclusions

To summarize, the main insights collected in the test **confirmed the validity of the design approach** (e.g., the general design style, the use of dark/light modes, the interaction modalities, etc.), and **allowed to timely improve the weaknesses**. The tools provided by the Qt toolchain facilitated the update of the prototype, without intervention at the software development level, with a significant saving in terms of time and effort, confirming the crucial added value provided by the Qt platform to the design and development of user interfaces.

6. High performance, tiny footprint

6.1. General considerations

Consumer device manufacturers have traditionally viewed software as secondary to hardware. They must now revisit this perspective, as well as their traditional development approaches since the software is now a prime value driver for the product development porfolio.

Using a modern approach to design for a product portfolio allows for designers to focus on the latest trends in UI UX and work with developers efficiently. Software engineers can work on one codebase rather than needing specialists for each platform. Successful software **teams can efficiently adjust and correct one project code** based on customer feedback. Companies can **elevate expectations** against competition and **reduce resource limitations**.

The value of using one technology solution to simplify the complex architecture of product lines allows for companies to cost-effectively manage brand consistency and knowledge transfer using one HMI solution.

References

[1] Van Der Laan, J. D., Heino, A., & De Waard, D. (1997). A simple procedure for the assessment of acceptance of advanced transport telematics. Transportation research. Part C, Emerging technologies, 5(1), 1-10.

[2] Forrester Consulting (2021). Smarter Product Development for Smarter Team. The Qt Company. https://www.qt.io/forrester-smarter-product-development-study . Page 9-13.

[3] Preedy V.R., Watson R.R., (2010) 5-Point Likert Scale. In: (eds) Handbook of Disease Burdens and Quality of Life Measures. Springer, New York, NY. https://doi.org/10.1007/978-0-387-78665-0_636

[4] Flaherty, E. G. (1975). The thinking aloud technique and problem-solving ability. The Journal of Educational Research, 68(6), 223-225.