UCD | User Interface | Terminal

Technology Reports

Special Articles on User Interface Research—New Interface Design of Mobile Phones—

User Interface Development from Conceptualization to Prototype Evaluation through UCD Processes

The recent rise in demand for terminals with attractive UIs that users find appealing is creating a need to study UI designs from the user's standpoint. NTT DOCOMO therefore studied a typical series of UI development processes from conceptualization to prototype evaluation, and determined how these processes are improved by incorporating the development approach known as UCD. Evaluations of the developed UI verified that UCD-based development processes are an effective way to create an advanced, easy-to-use UI. These UCD-based development processes also provided valuable information on how to plan, implement and run studies on UIs designed to provide users with easy-to-use products and services.

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1. Introduction

In order for a service to be popular, it is necessary that users clearly recognize the value of the service at a glance, and that the service is attractive enough for them to try it out, and engaging enough for them to continue using it. The key to achieving this goal is the User Interface (UI). The UI is the bridge between user and mobile terminal, and a well-designed UI can greatly increase the number of times users access a particular product or service.

Since the user is the final arbiter of whether a product or service is appealing and/or easy to use, it is crucial to always keep the user in mind during development. One way to do so is by applying a development methodology known as User-Centered Design (UCD)[1].

UCD-based development is one way of minimizing the common pitfalls of product/service providers, developers and designers–issues such as failure to address user needs, or UIs that are difficult to use. Such shortcomings often arise from putting technology before user needs, or from the preconceptions of product creators[2].

We applied the UCD for the design of mobile UIs, ranging from its conceptualization to prototype evaluation, and validated the usefulness of the methodology. We also acquired various skills

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to plan/conduct UCD development processes, while balancing user benefits with marketability.

Our UI study was carried out to meet the following two design goals:

- To design an advanced UI that appeals to users
- To design a UI that actual users find useful and usable

To attain these goals, we divided the UI development processes into two phases - a conceptualization phase and a prototyping phase. We executed these phases in sequence, applying the UCD methodology in the form best matched to each.

This article provides an overview of UCD, describes how we incorporated it into UI development processes, and presents the results.

2. UCD Processes

UCD is a user-centered development approach. It considers the user's standpoint throughout all processes of development to ensure that users will find the developed product or service attractive as well as easy to use. There is an ISO standard[3] that defines the development processes for the UCD approach by systematizing the methodologies and techniques used to implement it. This article refers to these development processes as the UCD processes.

The UCD processes consist of the four steps below (**Figure 1**).

1) Understand and Specify the Context of Use (Step 1)

Understand the characteristics of intended users, tasks and the environments in which the product or service will be used, and specify them. Observation, interviews and questionnaires are some of the methods used in this step.

2) Specify the User and Organizational Requirements (Step 2)

Explicitly specify the requirements in terms of both user and organizational standpoints in relation to the context of use stated in the previous step. Define the focus areas for UI conceptualization, and define the UI requirements in the form of use cases.

3) Produce Design Solutions (Step 3)

Devise concrete solutions to address the defined requirements. Create visual representations of these solutions using sketches, movies or working prototypes.

4) Evaluate Designs against Requirements (Step 4)

Evaluate the solutions devised in Step 3 to determine how well they meet the requirements set in Step 2 in the form of use cases. Using test subjects who match the target user profiles, check whether the solutions devised for the requirements are correct.

As previously described, we divided UI development into two phases (conceptualization and prototyping). Each phase's UCD processes were carried out by following the four steps shown in Fig. 1.

The conceptualization phase consisted of tailoring the study's UCD processes for optimal conformance with a study of an advanced UI. Some of the work done in this phase consisted of conducting user surveys on UCD while gathering information from within NTT DOCOMO. These activities gen-

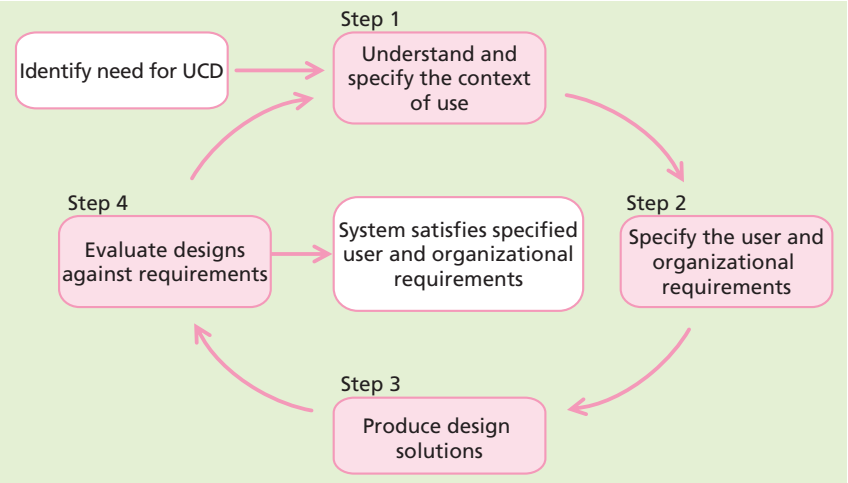


Figure 1 UCD processes as defined in ISO 13407

erated multiple visual representations of the advanced UI, and helped ensure the development approach would conform to NTT DOCOMO's business model. The UI we selected to advance to the prototyping phase was one that clearly demonstrated advanced design, and offered promising service development potential.

We began the prototyping phase by creating a detailed archetype of actual users and use cases, and redesigning the UI as needed. We then recruited test subjects matching the target user profiles to evaluate the UI, letting us verify that it combines advanced design, convenience, and ease of use.

3. Conceptualization Phase

The goal of the conceptualization phase was to visualize several candidate UI concepts having user appeal and advanced design. Our study followed the four steps below, corresponding to the UCD processes shown in Fig. 1.

- Step 1:
  Gather information about NTT DOCOMO's business strategy, and conduct user surveys.
- Step 2:
  Synthesize the gathered information, and determine multiple focus areas.
- Step 3:
  Visualize several UI concepts.
- Step 4:
  Screen the visualized UIs to select the UI to advance to the prototyping phase.

3.1 Surveys (Issue Exploration)

Step 1 consisted of gathering information on the NTT DOCOMO business model, then conducting user surveys designed for the users and their context of use that will exist in a timeframe of three years. They were carried out by observations, interviews, and a combination of both.

1) Stakeholder Interviews

We conducted individual interviews with a total of ten stakeholders involved in major decision-making at NTT DOCOMO. These interviews were designed to provide information on the company's business strategy and requirements for future products and services.

2) Expert Interviews

We interviewed a total of seven external subject matter experts. These interviews were designed to provide information on current and future trends in specific areas such as business, design and technology.

3) Cultural Immersion

Designers and fieldwork[*1] specialists carried out "cultural immersion" surveys in ten Japanese cities, mainly through observation. These surveys studied local environments classified as public spaces. Their objective was to gather information on designs the market is receptive to, and on the behavioral characteristics of people in public spaces.

4) Contextual Inquiry

This survey technique consisted of observation in homes or other private spaces, and interviews. These surveys were designed to understand the users, including contexts such as individual lifestyles, value systems, behavior patterns and living environments.

We selected twelve survey respondents that we identified as market trendsetters in areas such as social trends, lifestyle or technology. We selected these respondents assuming that the information obtained from them at the time of the surveys would be helpful for our study of advanced UIs.

This article refers to the information gathered from our surveys as survey findings. Our survey findings served as the information used in the next step of the study (**Table 1**).

3.2 Defining Focus Areas

Step 2 consisted of synthesizing the findings obtained from the survey results, and defining them as high-level requirements for the UCD processes. **Figure 2** shows the general flow of procedures in this step, from synthesizing/interpreting survey results to setting the focus areas.

As shown in Fig. 2, similar or repeated findings are grouped into patterns. These patterns can be considered key characteristics that are independent of specific users or contexts, and are somewhat able to be generalized. They

*1 **Fieldwork**: In fields such as cultural anthropology, the term fieldwork denotes surveys carried out in the field to enable direct observation of the people or objects surveyed, or interview respondents.

Table 1 Survey findings (selected examples)

Survey method	Survey findings (selected examples)
Stakeholder interviews	UIs have to be considered as closely coupled with products and services
	Open terminals require supporting unique aspects to the Japanese market
	New form factor, different from conventional mobile terminals, should be explored
Expert interviews	Mobile users access social networking services several times per day. Each access usually takes several minutes
	I want to see something new which is not a (conventional) mobile terminal
Cultural immersion	Various forms of architecture have layers such as shoji screens, bamboo fences, perforated metal or translucent glass
	Seniors sometimes use magnifying glasses to view mobile terminal screens
	Some warning signs are too much to read (stickers at tops and bottoms of escalators)
	Mobile users often adorn their terminals with decorations and accessories
Contextual inquiry	I'm addicted to a quiz game found in arcades. I don't feel I'm wasting my money (100 yen per game) because the games are educational to increase general knowledge (an extreme social user)
	Appointment books are obsessively neat and even color-coded (multiple extreme fashion/social users)
	I wear different nail varnish colors depending on occasions and my moods (an extreme fashion user)

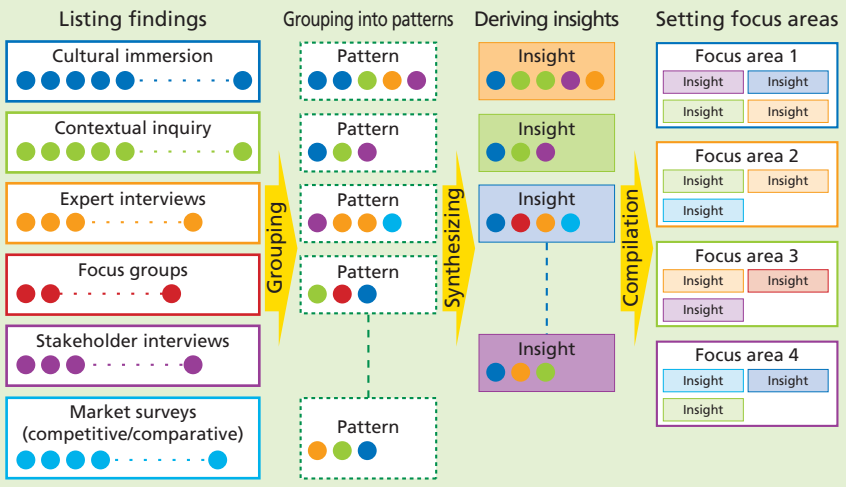


Figure 2 General flow of procedures used to define focus areas

indicate possible requirements that might need to be met.

Through further analysis and study, we distilled these isolated patterns into a list of 'insights' that we ultimately used to generate the focus areas for creating ideas. **Figure 3** shows some examples of focus areas we derived and the insights they came from.

3.3 Visualizing UIs

Step 3 consisted of visualizing UI concepts by following the previously defined focus areas while referring to the survey results gathered in Step 1. We brainstormed a variety of ideas around the focus areas. Then, we combined and expanded on the ideas we came up with to make them more concrete, ending up with a total of five visual representations in the form of sketches and movies. **Figure 4** shows two of these visual representations.

The final winner among the five concepts we created was Streams UI, chosen for its advanced design, technical feasibility, concept clarity and service development potential, among other benefits. We decided to advance Streams UI to the next phase (prototyping), for detailed design work and user evaluations.

4. Prototyping Phase

The goal of the prototyping phase was to specify the target users and their context of use, then prototype and evaluate the UI. The evaluations were designed to check whether the UI provides convenience and ease of use under the anticipated contexts. We also checked whether overlooked issues could be revealed through the evaluation.

Focus areas	Corresponding insights
Streams What does it mean to activate mobile phones with a constant stream of people, rich-media, and information?	Streams of information Streams of people
Specialization How can we enable multi-tasking through multi-devices in the mobile ecosystem?	Specialty stores Many specialized devices

Figure 3 Example focus areas and corresponding insights

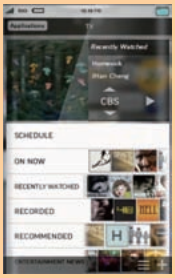
Streams UI	Tablet
A UI designed for users who consume large amounts of information on a mobile terminal Streams of contents, which are always in motion, represent information being updated continually	A specialized device designed for young women who carry around large paper appointment books, linked to networks and mobile phones
Aggregated streams displaying all new and/or unread contents  Music player	A diary from which application users can upload data directly to their blog The device design evoking a keen sense of having a "personal organizer"

Figure 4 Example UI visual representations

We defined the core value of the selected UI (Streams UI) as its ability to allow users to consume a large amount of information on a mobile phone, and crafted various use cases that should meet the value. The prototyping phase was studied to follow the steps below.

- Step 1:

  Extract findings corresponding to Streams UI's core value from the results of the user surveys conducted during the conceptualization phase.
- Step 2:

  Define users and their context of use based on the extracted findings, and specify requirements for Streams UI in the form of hypothetical use cases.
- Step 3:

  Create a UI prototype that presents a solution for the use cases.
- Step 4:

  Evaluate the UI prototype whether it is a sufficient solution for the use cases in terms of its convenience and usability.

4.1 Defining Detailed Requirements

Step 2 consisted of setting the UI's requirements for the target users and their contexts of use. We used the persona method to define the target users and the scenario method to define the use cases. The methods were as follows:

1) Create Personas

A persona is an artificially crafted archetype of a target user to define the characteristics of target users when designing a product or service. Personas can be used to overcome preconceptions or misconceptions the design team might have, and can help designers devise concrete solutions by addressing individual persona needs[4]. To create the personas, we used NTT DOCOMO's user segment

analysis materials, along with the results of the user surveys carried out during the conceptualization phase. Each persona was given attributes such as name, job, address, family members and other profile information; personality, needs, products owned, and services used. We took steps to ensure that the background information generating the user needs of each persona was clearly described, in a form such as "since working as a system engineer keeps him busy, he wants some time to relax."

2) Create Use Cases

We created use cases using the scenario method. We linked Streams UI to various behaviors of personas under specific contexts of use, and compiled a brief narrative (scenario) for each. This process enabled us to define in detail how each persona uses the UI, and how the UI meets the persona's needs.

Figure 5 shows an example of a Streams UI use case and interaction, created using a scenario. It is a hypothetical use case for a persona of someone who is busy in the morning. The screen displays an alarm along with a list of the information the persona should want to check when he/she wakes up. This use case was generated by linking the value provided by Streams UI (the ability to present a large amount of information) to routine activities likely for the persona with certain characteristics.

Whether Streams UI can provide actual users with convenience or other value was checked later by the user evaluations of Step 4.

4.2 Creating the UI Design and Prototype

Step 3 consisted of creating a Streams UI design and prototype to provide solutions to address the requirements (hypothetical use cases) defined in the previous step.

As part of the UI design work, we needed to define the screen layouts and interactions (the behavior of the UI in response to each user operation). Therefore, we created a set of paper prototypes, simplified sketches of the UI and then carried out a heuristic evaluation[*2] and revised the paper prototype before creating an actual working prototype. **Table 2** shows the check items we used in our heuristic evaluation. They are the same as Nielsen's ten usability heuristics[5], excluding two unneeded items.

The revised paper prototype worked as specifications used to create the actual prototype. We implemented the final working prototype using a Flash®[*3] application running on a PC.

Figure 5 Information provided by alarm screen

Table 2 Check items used in heuristic evaluation

1	Is the system always keeping users informed about what is going on, through appropriate feedback within reasonable time?
2	Is the system speaking the users' language, with words, phrases and concepts familiar to the user?
3	Is there a clearly marked "emergency exit" to easily return the user to the previous state in case he/she makes a mistake?
4	Is there a consistent set of rules (in operative structure and interface) from beginning to end in the system?
5	Is there a careful design which prevents a user error from occurring in the first place?
6	Are there designs in place so that the user doesn't have to remember information while using the system?
7	Are there shortcuts or can users tailor frequent actions so that expert users can use the system efficiently?
8	Are unneeded dialogues eliminated, and is the design minimalist and aesthetic?

*2 **Heuristic evaluation**: An evaluation method conducted by UI specialists, usability experts, etc. to identify usability problems based on their knowledge and expertise.

*3 **Flash®**: A trademark or registered trademark of Adobe Systems Inc. in the United States and other countries.

4.3 User Evaluations

Step 4 consisted of using the created prototype to evaluate the use cases and UI. The evaluations were conducted by test subjects closely matching the previously defined personas.

1) Evaluation Method

The user evaluations conducted during the UI prototyping phase were designed to accurately evaluate interactions. The prototype therefore needed to have nearly the same operation and appearance as the final UI, but since we anticipated making frequent revisions, we needed an evaluation/development environment enabling rapid UI development.

To meet these requirements, we created an evaluation environment consisting of a PC and a mockup resembling a mobile phone. The mockup was a peripheral device connected to the PC. The mockup display acted as an external display for the PC, and the keypad, touch-screen, etc. acted as external input devices. Since the mockup supported both inputs and outputs with same form factor, evaluations conducted using it are almost equivalent to test subjects. In terms of the UI implementation, on the other hand, a standard Flash application running on a PC can be used, which is much easier than implementing the same UIs into an embedded device.

Photo 1 shows the touch-screen mockup's evaluation environment. To support a wide range of possible UIs to be explored in future, the mockup was equipped with devices such as pressure sensors on the sides to enable functions such as grip force detection.

Photo 1 Mockup with touch-screen

We screened possible test subjects to carry out the evaluations, and selected twelve subjects corresponding to the previously defined personas. The evaluations were conducted by a combination of observation, interviews and questionnaires. **Photo 2** shows an example of how test subjects carried out user evaluations. The test subject in this photo is evaluating the UI under a simulated context of use–operating the mobile phone while walking to a train station.

To evaluate the UI, each test subject operated the mockup along evaluation scenarios, crafted from the use cases. We observed how the test subject operated the UI, asking the subject questions when needed.

2) Evaluation Results

Table 3 shows the subjective evaluation results regarding the overall reception and some individual functions. All these results were obtained using the Semantic Differential (SD) method[*4] with a five point scale. Streams UI received a mostly positive overall reception, suggesting that its advanced design came across to the targeted users as an attractive feature, and that it was evaluated as fairly easy to use.

We also evaluated the convenience of individual functions for hypothetical use cases defined using our personas and scenarios. We verified that the UI provides adequate solutions for the needs of the test subjects' own contexts, for each of the major use cases. Responding to the alarm screen shown in Fig. 5, for example, one test subject commented, "I like how I can check the

*4 **SD method**: A technique used to quantify the subjective impressions of evaluators.

Photo 2 User evaluation under a simulated context

Table 3 Evaluation results using SD method (five point scale)

Category	Question	Average score
Overall evaluation	Would you consider the UI innovative?	4.6
	Would you use the UI if available on your mobile phone?	4.5
	Would you recommend the UI to your friends?	4.4
	Would the UI encourage you to switch your phone models?	4.0
	Would you feel the UI easy to use?	4.0
Evaluations of individual functions	How would you rate the presentation of information in the alarm screen? (See Fig. 5)	4.75
	How would you rate the streams display to check new/updated information? (See Fig. 6)	4.75

weather right away without getting out of bed in the morning, letting me decide what to wear that day."

Although the evaluation results were positive, we found that one of the use cases we anticipated was not correct–the screen used to receive new/updated information (**Figure 6**). This screen displays several different types of content, such as e-mail, news stories and the music currently playing. Since the content scrolls from top to bottom and automatically disappears off the screen, we had thought that users would also tolerate unnecessary information the screen might contain. But several comments we received showed we had been wrong–one subject said, "I want more precise control over the displayed content," while another said, "I want to be able to show the scrolling content to friends and acquaintances, so I don't want it to include private information." This feedback provided valuable information for use in improving the prototype UI, and suggested we had revealed overlooked issues when defining the requirements.

5. Speculation

We verified that UCD can be incorporated into development processes to create a UI concept and prototype, and that the prototype UI actually provided the targeted users with advanced technologies, convenience, and ease of use. Our user evaluations verified that the hypothetical use cases we anticipated were mostly correct, and that overlooked issues, if existing, could be found through evaluation.

Regarding usability, it is possible to evaluate the working prototype on the mockup that simulates appearance and interaction of actual handsets. Since the prototypes can be developed as standard Flash applications running on PCs, the mockup also works as a rapid prototyping environment, which is suitable during the prototyping phase to iterate evaluation/revision cycles for further refinements.

However, there still remains the risk of ending up with a service or UI that doesn't match the provider's product concept or business model in case of simply applying UCD into development processes, which benefits users. Through the activity, to avoid the issue, we tried to address the risk and have accumulated expertise to plan and conduct UCD-based processes. For instance, we split the study into two phases for quality assurance. During the conceptualization phase, the main focus was to create several UI concepts that

*This is provided only in Japanese at present.

Figure 6 Screen used to check new/updated information

were then screened from a viewpoint of technical/business feasibility before getting into the prototyping phase. Consequently, we have been able to manage the risk of proceeding with the prototyping phase on UI concepts with low feasibility. Another example is the stakeholder interviews conducted during the conceptualization phase. Through the interviews, we have successfully identified various criteria from organizational perspectives that should also be taken into account for the concept screening, such as "support for needs specific to the Japanese domestic market." As described, the study gave us the knowledge and the expertise needed to balance user benefits and marketability–an important consideration when utilizing UCD in development.

6. Conclusion

This article has described our work on creating a concept and prototype for advanced UI using UCD, and the results of user evaluations on one of the UIs.

We will keep working on creating various UI concepts and prototypes together with other internal and/or external members, moving towards attractive, usable products and services, leveraging our knowledge and expertise on UCD.

REFERENCES

[1] D. A. Norman: "The Design of Everyday Things," Doubleday, 1988.
[2] D. Saffer: "Designing for Interaction," New Riders, 2007.
[3] ISO 13407: "Human-centered design process for interactive systems," 1999.
[4] A. Cooper, R. Reimann and D. Cronin: "About Face 3: The Essentials of Interaction Design," Wiley, 2007.
[5] J. Nielsen: "Usability Engineering," Morgan Kaufmann, 1993.