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P2P Mapper: From User Experiences to Pattern-Based Design

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Original Research

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Abstract

User experience is an umbrella term referring to a collection of information that covers the user's behavior and interaction with a system. It is observed when the user is actively using a service or interacting with information, includes expectations and perceptions, and is influenced by user characteristics and application or service characteristics. User characteristics include knowledge, experience, personality and demographics. We propose a process and supporting software tool called Persona to Pattern (P2P) Mapper, which guides designers in modeling user experiences and identifying appropriate design patterns. The three-step process is: Persona Creation (a representative persona set is developed), Pattern Selection (behavioral patterns are identified resulting in an ordered list of design patterns for each persona), and Pattern Composition (patterns are used to create a conceptual design). The tool supports the first two steps of the process by providing various automation algorithms for user grouping and pattern selection combined with the benefit of rapid pattern and user information access. Persona and pattern formats are augmented with a set of discrete domain variables to facilitate automation and provide an alternative view on the information. Finally, the P2P Mapper is used in the redesign of two different Bioinformatics applications: a popular website and a visualization tool. The results of the studies demonstrate a significant improvement in the system usability of both applications.

Keywords: Personas, patterns, user experiences, conceptual design, user-centered design, design process

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INTRODUCTION

User-Centered Design (UCD) provides a general approach for interactive system design by making the end-user's experience and involvement a focal point of the design process. UCD principles have informed the development of different design methods. (Keinonen, 2009) proposed a framework to define and compare UCD approaches to traditional software development methods. Popular UCD methods include scenario-based design (Carroll, 2000), goal-directed design (Cooper, 1999), contextual design (Beyer and Holtzblatt, 1997) and participatory design (Ehn, 1988). These methods introduce techniques for evolving and documenting interactive system design at various steps of the process. For example, if a designer would like to model user experiences, tasks, and the context of use, relevant techniques include personas, task analysis, scenarios, workflow modeling, and context analysis. If a designer would like to build a prototype, conceptual design, or detailed design, relevant techniques include design guidelines, principles, style sheets, and patterns.

Although UCD methods share a common user-focused tenet, there exists a significant gap between current user experience analysis and modeling techniques, and the process of deriving a conceptual design based on user involvement (Iivari et al., 2009). Ethnographic and empirical techniques are generally used to collect relevant user data to describe user experiences. These experiences are then captured in narrative form, but the process of deriving a design from these narratives is ambiguous and based on guiding principles rather than a reproducible systematic method. Some techniques like storyboarding try to "walk" designers through relevant user tasks, but they only address a subset of user experiences. There is little reproducibility of solutions and traceability to user experiences. Often, the final system design is simply the result of the designer's background and knowledge rather than the result of following a well-established and standardized design method.

The need to enable a tighter fit between user experiences and design concepts is one of the main challenges in human-centered design (Figure 1). To advance the state-of-the art and narrow this gap, processes must be introduced to support designers in deriving conceptual designs from user experience descriptions. Such a process should be systematic, traceable, and practical, but should also leave room for design creativity when appropriate. In this paper, we propose a design tool and systematic process to tackle this problem.

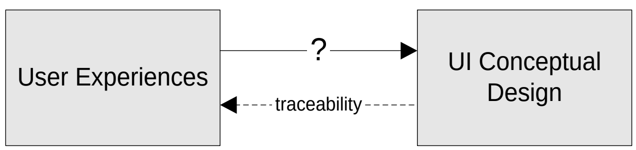


Figure 1: The Gap of Deriving a Design from User Experiences

Current interactive design methods based on the UCD philosophy provide a generic framework for design, including general suggestions, techniques and principles. They do not, however, define a process and provide tools to support the translation of inputs of the user analysis phase into concrete design solutions. We believe that the lack of clear specifications explaining and relating particular user experiences with design-level decisions is the primary cause of this gap. Currently, there is no way to systematically derive a concrete design from user experiences (Javahery, 2007) and no way to trace back a large part of the decisions that are made during the design. Thus, reproducibility of the process is compromised.

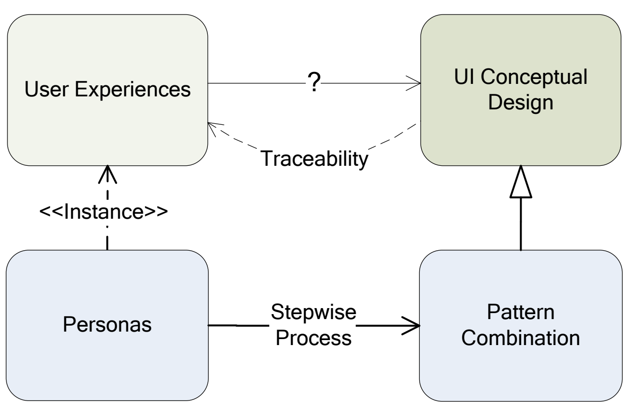


Figure 2: The Proposed Approach for Deriving a Design from User Experiences Captured as Personas

We believe that these limitations can be overcome by investigating the relations between personas and patterns (see Figure 2). In fact, we have described both as commonly used techniques to respectively capture user experiences and disseminate best practices in design. Thus, by defining a stepwise process with clearly described information flow and decision points, we can give designers the ability to make more enlightened, traceable design decisions and learn from comparable projects based on concrete information and non-anecdotal experiences.

Our objectives are:

(1) To construct or adapt one of the existing UCD variations to clearly define all of the steps bridging the gap between user experiences and a concrete design.

(2) To adopt the process and all artifacts used in order to facilitate automation.

(3) To define and implement a support environment that will reduce the burden placed on the user and still follow the process constructed in (1) and adopted in (2).

Furthermore, an underlying practical objective of our work is to provide a format to capture and represent both "user experiences" and a "conceptual design" in a rigorous manner, using a suitable combination of representational models and techniques. By using personas and patterns as the foundation for these representations, we can derive a pattern-oriented design from persona descriptions through a set of intermediate steps.

In the next section, we describe our two key concepts – personas and design patterns – and provide a synopsis of how these artifacts are used within the human-centered design community. After introducing the process of deriving design patterns from user experiences, we present an overview of the supporting P2P Mapper tool with details about the research methodology used for developing and validating the tool (first study) We then summarize a case study using the P2P Mapper to redesign a large information visualization portal (second study). Finally, we present results from a series of interviews with designers on initial impressions about the tool (third study).

WHY PERSONAS AND PATTERNS? SOME BACKGROUND INFORMATION

User experience descriptions and conceptual designs are two major artifacts of UCD. The concept of "user experiences" is still evolving in the field of Human-Computer Interaction (HCI) (Law et al., 2009). They are often captured in narrative form, and one way to represent them is as personas. There is currently no method to systematically derive concrete design solutions from user experiences; typically, the design is reliant almost completely on the designer's intuition. This is especially problematic for novice designers who lack the background and training required to make trade-offs, judgments and interpretations towards a usable design. The Persona to Pattern Mapper (P2P) tool uses personas and patterns as representational models to facilitate the design process. The resulting design is composed of patterns derived from a description of the persona.

The Persona: Engaging Users and Modeling Their Experiences

We use the concept of personas proposed by Alan Cooper as a tool to document and model the user experience. (Cooper, 1999) brought personas from marketing to design; so as to redirect the focus of the development process towards end users and their needs. His work emphasizes that personas are fictitious characters based on composite archetypes and encapsulating "behavioral data" gathered from ethnography and empirical analysis of actual users. Archetypes have been used in marketing research both as an alternative to and as an extension of traditional market segmentation and user profiling. Instead of modeling only "average" users, personas also take into account boundary cases. The underlying belief is that all consumers are a mixture of certain types of users.

Pruitt and Grudin (2003) encourage a "global" use of personas. This includes attempts to integrate personas in the software development process and to establish relationships with other data sets through the use of artifacts such as feature-persona matrices, foundation documents, and task descriptions (although the latter is mentioned, specific examples are not provided). In addition, a focus on ongoing qualitative and quantitative analysis is a central theme of their work. However, there is little discussion about what kind of detailed information is contained in their personas, how they are represented, and how they are mapped to actual data sets. Furthermore, it is unclear if and how precise interaction behavior is addressed in their personas.

Courage and Baxter (2005) defined a set of persona components in text format that can act as a guide in building personas. In Table 1, we adapted these components to better fit the requirements of our process.

Table 1: Persona Components (Adapted from Courage and Baxter, 2005)

Persona Components	Description
Identity	First and last name, age and other demographic information.
Status	Whether the user is a primary, secondary, tertiary, or anti-user of the application. Typically, only primary and in some cases, secondary users are included.
Goals	Goals related to the application as well as personal and professional goals.
Knowledge and Experience	Knowledge and experience including education, training, and specialized skills. This should not be limited only to the application.
Tasks	Frequency, importance and duration of most important tasks related to the application.
Relationships	Information about user associates; this could give insight about other stakeholders.
Psychological profile and Needs	Information about cognitive and learning styles and needs such as guidance and validation of decisions.
Attitude and Motivation	Information about the user's attitude to information technology and level of motivation to use the system.
Expectations	Information about how the user perceives the system to work and how the user organizes information related to his/her task, domain or job.
Disabilities	Any disabilities, such as color-blindness, related to mobility, eyesight (wears contacts), etc.
Photograph	A photograph that fits with the name.

The following is an example of a persona for a mobile phone application targeted mostly to adolescents and young adults (Table 2). The application is a game called crazy shopper in which users like Anna Spinelli go to virtual rooms and receive points with every shopping purchase. Purchases include items categorized as clothing and fashion, household items, or electronics and gadgets. The goal is to be a "smart" shopper and attain a certain amount of points within a specific timeframe. Frequent players with high scores receive shopping incentives and gifts from sponsors.

Patterns: Capturing Reusable Design Blocks

In his two books, A Pattern Language and The Timeless Way of Building, the father of patterns, the architect Christopher Alexander, introduced the concept of design patterns as a "three-part rule that expresses a relation between a certain context, a problem, and a solution" (Alexander, 1977) (Alexander, 1979). Following the object-oriented software design community (Gamma et al., 1995), HCI practitioners investigated design patterns as one possible solution allowing them to reuse design knowledge with a focus on users and their experiences.

The HCI design pattern has been defined as a named, reusable solution to a recurrent user problem in different contexts of use. The context describes a recurring set of situations in which the pattern can be applied, for example, to the use of different computing platforms (Web, GUI, Mobile applications, etc.) (Javahery et al., 2004). Related patterns can be combined to form pattern languages, resulting in both a lingua franca for design (Erickson, 2000) and pattern-oriented design methods (POD). In POD, patterns are building blocks at different levels of abstraction which makes patterns extremely useful for designers when driving the UI design from user definitions (Javahery, 2007).

The pattern description is organized within a set of pre-defined attributes, allowing designers to, for example, search rapidly through different design solutions while assessing the relevance of each pattern to their design. Every pattern has three necessary elements, usually presented as separate attributes: context, problem and solution. Other attributes that may be included are the design rationale, specific examples, and related patterns.

Table 3 portrays the Overview and Detail, a pattern for visualization environments. Patterns are powerful design tools, simply because they can be implemented differently by the designer depending on variations in user experiences and usage context data. To illustrate, Windows Explorer and Google Maps demonstrate two different implementations of this pattern. In Windows Explorer, the user is provided with two views. One view presents a hierarchical overview of folders while the other displays the contents of the selected folder. In Google Maps, the user is also provided with two views of the data: an orienting view of the selected area presented as a corner map, and a detailed view of the same geographic location.

Table 2: Narrative View of the Persona Anna

Persona 1: Anna Spinelli		*"I just want to play for a few minutes when I am bored. I want to beat my friends and be the 'smartest' shopper"*
Identifiers	Adolescent, early adopter, female	
General Profile	Anna is an 18 year-old college student. She lives with her parents. She is in her first year of the Commerce program, and is involved in different extra-curricular activities like intramural soccer and the social club. She has a part-time job working at a local movie theatre. She loves to shop and hang out with her friends. She uses her mobile phone to keep contact numbers, records all important events in the calendar, and likes playing games on it.	
Goals	Professional: Succeed in school, and work towards a marketing university degree. Personal: Enjoy time with her friends and family. Application: Have fun for a few minutes, and then get back to studying.	
Scenario	Description	Anna has a 30 minute break between two of her classes. She is sitting in the college cafeteria with her friend Angy, who is sitting beside her studying. She is bored and doesn't feel like studying anymore, so she puts away her books and goes to the "games" option on her phone. She chooses *crazy shopper*. She gets frustrated because it takes so long to load. She really wants to beat her score from last time. She likes to move often from one virtual room to another, and have control over her surroundings. She likes to explore the different shopping items before deciding on an item to purchase. She plays the game for 10 minutes, but the beeping sound bothers Angy and she has to turn it off.
	Specific needs	Control, Efficiency, Exploration
	Features	Quick loading, scoring recall/tracking, rapid-key exploring, silent mode (visual indicators)
	Interaction details	Anna gets easily frustrated if system takes too long to respond. She is very competitive and wants to keep close track of scores. She likes to explore first before selecting an item to purchase. She engages in short playing times, but frequently (daily).
Demographics	She is an 18 year old female, with a student income and financial support from parents. She has a part-time job which allows her to pay for social and personal expenses not related to school.	
Knowledge and Experience	Anna is a college student and a native English speaker. She has average experience with computers and is an advanced mobile phone and game user. She has been playing mobile phone games for 2 years now, but only started to play *crazy shopper* a few months ago.	
Psychological profile and needs	She needs to be in control, and is a fast learner (high learning speed). She needs basic (low) guidance and no validation of decisions.	
Attitude and Motivation	She has a positive attitude to IT, and somewhat of a high level of motivation to use the system.	
Special Needs	She has no disabilities but belongs to a special user group, *experts*.	

Table 3: HCI Design Pattern

Title	Overview and Detail
Context	The dataset is large, too large for all the details to fit in a single view, and there is a need to view details about subsets of data items. The data can be viewed at one or more levels of abstraction, e.g. directories and files within a directory, aggregated document content and detailed document content, etc. Alternatively, the dataset may be large and continuous but only a subset can be viewed at any one time, e.g. map data.
Problem	How to display the entire contents of a large dataset at once, allow users to explore the dataset, and at the same time show details about subsets of items.
Solution	Show an overview of the entire dataset together with some visual indication as to which part of the dataset is currently being viewed. Show details about subsets of items in a separate view. The overview can be a scaled version of the main view, i.e. a spatial zoom, or some other representation, i.e. a semantic zoom. Since the overview tends to display a higher number of data items than any more detailed view it is necessary to use simple glyphs that minimize clutter, maximize use of screen space and portray the data attributes most relevant to the task.
Examples	Windows Explorer and Google Maps
Other Attributes	Forces, Related Patterns, Design Rationale

OVERVIEW OF THE P2P MAPPER AND RELATED RESEARCH METHODOLOGY

Our first study was exploratory, and led to the prototyping of the P2P Mapper tool. We wanted to further investigate our ideas around the development of a rigorously-defined process with tool support. To motivate this, we developed and used an initial framework employing personas and patterns. We applied this framework to the redesign of a Bioinformatics website, documenting each step manually, iterating when necessary, and suggesting improvements. We then performed a comparative usability study to evaluate the new design of the site and assess whether the process helped to facilitate the design process and improve system usability.

The First Study: Modeling the Process

Initially, our research team, composed of researchers and a group of ten industry designers from the Usability Professional Association Montreal chapter, suggested an informal process. The process consisted of three major stages: Persona Modeling, Pattern Selection, and Pattern Composition, a step in which patterns are combined to create a conceptual design. The process was then used in a proof-of-concept study we conducted with a biomedical information portal, the NCBI Website (www.ncbi.nlm.nih.gov).

The goals of this study were to (1) evaluate whether the use of personas and patterns result in more usable systems, (2) understand in detail the process that links personas with patterns while designing, and (3) understand the limitations of the process and the improvements required.

We started with a usability evaluation that included 39 end-users; 16 at the pre-design stage, and 23 at the post-design stage. Pre-design evaluations consisted of psychometric and heuristic techniques to construct personas and identify usability issues with the current design. We then used these personas, as well as accrued usability results, to construct a design approach based on patterns. We prototyped a new design based on this approach. To test this new design, we then carried out a comparative randomized study with the original site and used the following evaluation techniques: think-aloud protocol, task-based evaluation, structured questionnaires, and open-ended interviews.

The study provided us with an experimental infrastructure to test our ideas about relating personas and patterns. First, we found that applying the framework facilitated our design activities, allowed us to incorporate sound UCD principles into our design, and afforded guidance to an often ad-hoc process. Because the starting point was creating personas, the focus of the design activity was directed to the users early on. Furthermore, personas are a relatively lightweight user model, and we did not require a user or cognitive modeling specialist for their creation. By developing personas iteratively using empirical evidence, it allowed us to determine more precise interaction behavior and detect usability problems with the application; these points were essential in selecting HCI patterns. In this vein, the framework follows the reuse paradigm through the use of these patterns, enabling us to make design decisions based on best practices. Notably, in current practice, there exists no commonly agreed upon UI design process that employs patterns and their languages as first class tools. It was our intention to further develop the framework to overcome this problem.

Secondly, after applying the "Persona to Pattern" framework to the NCBI site, we carried out comparative usability studies with the original and newly-designed site. We wanted to determine if using the framework helped with system usability. We used principles of software usability measurement based on ISO 9126 standards. The results were positive for both quantitative and qualitative measures. In particular, users had a statistically significant decrease in task duration with the new site, and novice users indicated an increase in satisfaction. For total task time, we noted an overall improvement of more than 55%. Moreover, when we considered average satisfaction ratings of both designs, we found that users were almost two times more satisfied with the new design as compared to the original design. As expected, our qualitative results with expert users were also positive but more mixed because they had extensive experience with the original site.

Thirdly, there were some limitations we needed to address. The framework was a first step toward using the techniques of personas and patterns together. We noted that links made between user experiences and design solutions were based on narrative and qualitative data and assessed manually so that the "best" pattern within a specific context was selected. Any further development of our framework should include identifiable and discrete steps, and not be subject to extensive interpretation by the designer. This would require some formalization of the information contained in both personas and patterns; which we will discuss in subsequent sections. We also realized early on that we would refer back to the personas for additional information both during the selection of appropriate patterns and for pattern-oriented design. At times, the amount of additional information contained in the basic persona description was lacking. Therefore, the enhancement of persona descriptions with interaction behaviors, scenarios, and goals was necessary.

The Prototype: Key Functionalities of the P2P Mapper

Based on our first study, we documented the P2P process in detail, gathered requirements around tool support, and developed a prototype. The P2P Mapper prototype is organized around five views; three are used for key activities and the other two provide complementary information.

The first view (Figure 3a) is used for data entry and to review persona and user information. It presents a customizable view of all the textual information and allows for easy access to user variables (described in the next section). In the second view (Figure 3b), clustering results are represented using color and a special encoding method in which users are grouped around a persona object and distinguished based on color. In this view, it is possible to drag and drop users from one cluster to another. In the fourth view (Figure 3d), clustering results and pattern information is presented. This view presents an ordered pattern list for each persona and detailed information on any chosen patterns. The third and fifth views are complementary (Figures 3c and 3e). The third view presents user and persona information in tabular form. It is mostly intended for expert use, specifically in cases when some modifications to the user format have been made and need to be verified. The fifth view is a basic trace of the Pattern Selection logic. It presents all hierarchically organized operations in the same order as they were executed by the tool.

All of the views can be customized and reorganized. In fact, the tool uses the floating windows interaction paradigm used in Visual Studio 2005 and many other software applications. In addition, the user and pattern information is generated dynamically from the corresponding XML file. This facilitates future evolution of pattern and user/persona descriptions without a need to change the tool.

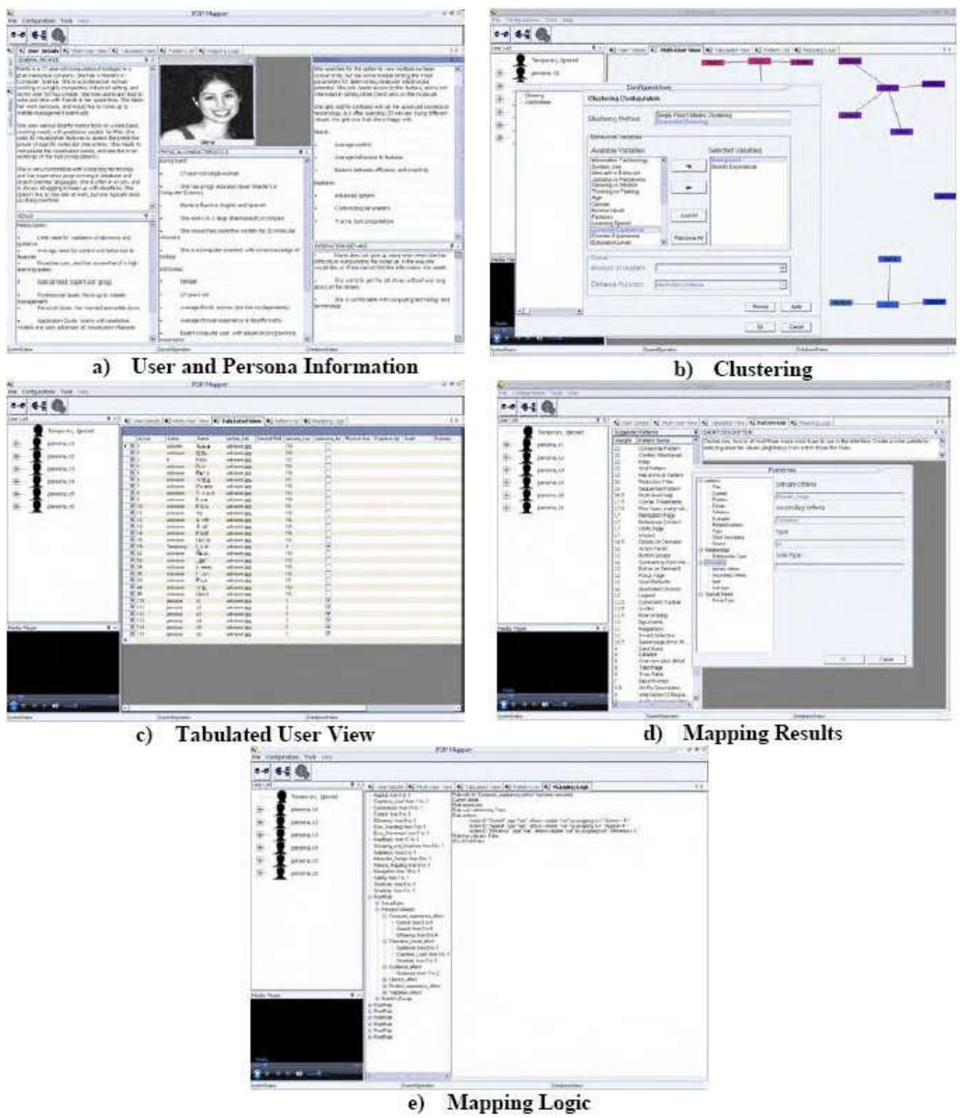


Figure 3: The Key Components of P2P (Persona to Patterns) Mapper User Interface

The Variables: Defining User Experiences

Persona descriptions are informal and not suitable for machine processing. We therefore needed to construct a model that was both human and machine readable to include formalizations (input for tools) while keeping their intuitive narrative nature (input for designers). As such, we further extended the textual persona components (see Table 1) to include variables for machine processing (see Table 4).

A literature analysis on cognitive styles and user models developed in HCI (Card et al., 1983) provided us with an initial set of variables describing the cognitive behavior of users. These variables were refined through semi-structured interviews and online focus groups with HCI and cognitive psychology experts. The range of values (scale) for each variable was selected based on the most commonly accepted format used by the experts in the field.

Table 4 summarizes our final set of variables, grouped into five different categories that cover a range of user and behavioral characteristics: (1) Demographics, (2) Knowledge and Experience, (3) Psychological Profile and Needs, (4) Attitude and Motivation, and (5) Special Needs. All variables have a name, a description, and a limited range of values. Each variable is defined on a binary, 5-point or 7-point scale. For example, variables like gender are binary with possible values being “male” or “female.” Variables such as domain experience are defined on a 5-point semantic-differential scale: 0=none, 1=basic 2=average, 3=advanced and 4=expert. Similarly, some variables, such as age, educational level and income, have been defined on 7-point scales (0 to 6) following commonly accepted standards in demographics. Finally, two variables in the proposed set (Disabilities and Special Groups) can contain an array of values.

Table 4: User Variables

User Variable	Description	Range of Values
1. Demographics		
Age	Age group or range	toddlers, children, adolescents, young adults, mature adults, seniors, elderly[1]
Gender	Gender	male or female
Income level	Family income, where low income defined as < 50% of median[2]	low to high
2. Knowledge and Experience		
Computer experience	Where basic experience is working knowledge of office systems	none to expert
Domain Experience	Experience in technical or business function supported by product	none to expert
Education level	Formal training and education	none, elementary, highschool, vocational, college, undergrad, advanced
Linguistic ability	Knowledge of product language	none to fluent
Literacy	Ability to read, write, use numbers, and handle obtained information	illiterate to fully-functional literacy
Product Experience	Experience with product or with similar software products	none to expert
3. Psychological Profile and Needs		
Behavior to features	Behavior and interaction style towards software features	feature shy to feature keen
Control	Amount of control user needs when interacting with the product[3]	low to high
Guidance	Amount of guidance required when interacting with the product[3]	low to high
Initiative taking	Initiative taking habits of user when interacting with the product[3]	reactive to proactive
Learning speed	Rate this user’s learning abilities in general (slow learner/fast learner)	low to high
Learning style	Primary learning style of user	3 categories: auditory, visual, kinesthetic
Learning support	Learning support required when interacting with the product[3]	low to high
Validation of decisions	Validation of decisions required when interacting with the product[3]	low to high
4. Attitude and Motivation		
IT attitude	Attitude to information technology in general	negative to positive
Motivation level	Motivation to use the system	low to high
5. Special Needs		
Disabilities[4]	Physical or intellectual disabilities	Vision (colorblind, low vision, none), hearing, physical/motor, learning/cognitive
Special Groups	Belonging to a special user group	Children, seniors, novice, expert, low literacy

The user variable categories help ensure that all aspects of the user experience have been covered in the proposed format. While a given variable may overlap with existing ones, a designer must ensure that it describes some essential new aspect that cannot be deduced by applying basic logic from already available variables. For example, a user with low computer and domain experience generally requires high levels of guidance. However, a high level of guidance may also be needed for users with expert experience because of other personal factors. This variable may overlap with others but still describes a unique facet of a user that cannot be easily deduced.

The set provided above is not complete and may not be even sufficient for a large variety of projects. However, it is a first step towards a clearly defined discrete format that moves away from simple raw textual descriptions. We have performed a large analysis of available information from a variety of sources including literature (Kirakowski and Corbett, 1993) (Aaker et al., 2004) (Law et al., 2009) and hands-on expertise accumulated by a range of specialists in the field. This resulted in a set of variables that describe commonly identified facets of users or personas. The resulting format satisfies our objectives by providing an alternative description of users and personas that can be later incorporated in and analyzed by software tools.

P2P MAPPER IN DETAIL: DERIVING DESIGN PATTERNS FROM PERSONAS

The P2P Mapper guides the designer through the three major steps of the process: (1) persona creation, (2) pattern selection, and (3) pattern composition (Figure 4). The result is a conceptual design.

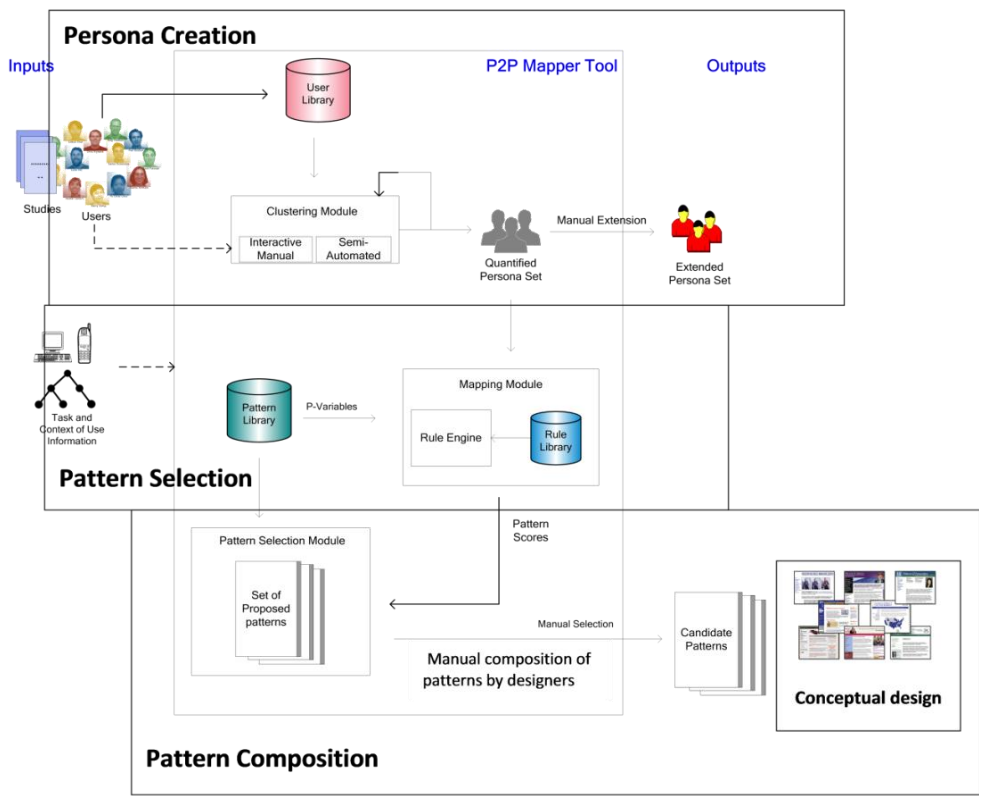


Figure 4: A Detailed Description of the P2P Mapper Process

Persona Creation

A prerequisite to this step is gathering information about the users of the system. Once this is done, user and behavioral characteristics are entered into the tool. The output of this step is a set of quantified personas (selected list). For validation purposes, this list of personas can always be compared with a list of external personas proposed by a panel of experts.

The following activities are required for persona creation:

- Understand the users of the system. An initial understanding of users based on different types of studies such as domain analysis and field observation are necessary. This activity results in a detailed description of user attributes. Examples of attributes include computer and application experience, domain knowledge, profession, age, and learning style. This information is entered into the P2P Mapper.
- Clustering users to create a set of quantified personas. Users are grouped based on the values of the attributes. Two clustering techniques are used. Manual clustering is done by an expert sorting users into defined groups, while semi-automated clustering exploits a classification algorithm that groups users based on a selection of attributes. We may group users based on what we initially believe to be the most important attributes; for example, age, work environment and application experience. We may also exploit attributes that cause differences in interaction behavior. For example, we may consider the fact that older users were less comfortable with site navigation, industry users were driven by deadlines and demonstrated an increased need for control, and novice application users exhibited information overload.

The resulting quantified persona set may be larger than needed and not the most optimal. Therefore, further user studies and expert designers may help determine the most significant user groups and identify user attributes captured in the corresponding personas. At this point, the designer has a better idea of the users, and a set of participants can be identified for further empirical studies if so desired. Studies can include psychometric tests, usability evaluation and interviews on a prototype or similar application. Results from these studies can be used to both enhance the persona set, and directly inform design decisions.

Enhancements to the personas can include scenarios, which are stories about the persona in a specific context of use. They typically include information about the individual user, task or situation, the user's desired outcome or goal, task flow details, timeline, and envisioned features. Initial steps consist of first including user needs and interaction behaviors in the persona descriptions.

The set of quantified personas is iterated as many times as needed to fit the context of use. During the various iterations, personas may be added or omitted. Additions occur when designers need to include an important attribute that will conflict with existing personas. Omissions occur when two personas vary in attributes that are not important for the designer to capture. Therefore, only one of the two personas is retained.

Pattern Selection

This step consists of associating patterns with users and their needs. HCI patterns include valuable information about users and their experiences, as well as usability and design principles. This information is typically included in the context or forces attribute of the pattern. Before candidate patterns can be selected, the designer needs to choose an appropriate pattern library. Pattern libraries are typically organized according to domain of application such as visualization and navigation, or platform such as the Web, mobile, and desktop. Welie provides an example of the possible categorization of patterns (www.welie.com/patterns).

The selection of candidate patterns is based on persona specifications, and entails finding associations between user attributes within the personas and the forces that constitute a pattern. Based on the contextual information entailed in pattern descriptions, we can draw direct associations between certain user categories and patterns. Examples include patterns for color-blind users, novice users, children, and users with disabilities. An example of a pattern for a novice user, the wizard pattern, is illustrated in Table 5. We can also establish a more complex association between user needs and usability principles. From persona descriptions, we derive information about needs (e.g., a user's need for guidance) and associate them with usability principles inferred from the pattern description. For example, the wizard pattern also addresses the guidance usability principle which in turn satisfies the user's need for guidance.

To adequately support our process, we extended traditional pattern descriptions in two ways. First, we included supplementary attributes that designers need for both the pattern selection and pattern composition steps: a short description of the pattern, which includes keywords from the context, problem and solution, and relationships with other patterns. Secondly, we associated each pattern to a set of pattern variables (P-variables) suitable for machine processing. This set of P-variables has the following information: (1) primary criteria, which is the main design principle that the pattern addresses, (2) secondary criteria, the secondary design principle that the pattern addresses, (3) pattern type, which is the type of library this pattern belongs to, typically organized by domain, and (4) special needs, which refer to any special user needs that this pattern addresses. The value of each P-variable belongs to a discrete and finite domain (see Table 6).

The P2P Mapper uses a rule-based scoring technique for pattern selection. To allow for computation, user variables are associated with patterns through a set of dependencies. We determined the nature of these dependencies and their relative weights based on expert input. The scoring technique comes from ideas gathered from a recommender system (Kim and Kim, 2003), where suggestions are made based on a computation of the confidence of the result (i.e., the score). That is, if a persona is described by a set of values, the confidence of a pattern suggestion is the sum of all confidences of the rules that have been used to compute that result. We use a similar approach in which the confidence of each rule is determined empirically and their summation is used to compute scores, resulting in a final recommendation.

To summarize, we distinguish between three major selection criteria, based on a pattern's: (1) domain of application, (2) direct association with specific user attributes, and (3) inferred association to usability requirements. To illustrate, let us use the wizard pattern again, but within the context of the NCBI site (our first study). One of the personas of this site was a novice user who needed guidance and simple navigation. We could have selected this pattern for our design since it is applicable for: (1) web applications, and (2) novice users with basic product experience, and/or (3) users who need guidance.

The set of selected patterns should be iterated as many times as needed until the designer is satisfied with the pattern set. As further design information is synthesized, patterns will be added or omitted from the selection.

Table 5: Wizard Pattern for Users with Guidance Needs (Welie, 2003)

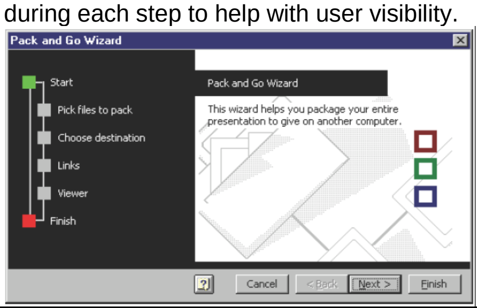
Title	The Wizard
Context	This pattern can be used when a novice user needs to perform an infrequent complex task consisting of several subtasks in a linear order where decisions need to be made in each subtask. The number of subtasks must be small, typically between 3-10.
Problem	The user wants to achieve a single goal but several decisions need to be made before the goal can be achieved completely, which may not be known to the user. A guiding principle here is that the user needs guidance.
Solution	Take the user through the entire task one step at the time. Let the user step through the tasks and show which steps exist and which have been completed. When the complex task is started, the user is informed about the goal that will be achieved and the fact that several decisions are needed. The user can go to the next task by using a navigation widget (e.g., a button). If the user cannot start the next task before completing the current one, feedback is provided indicating the user cannot proceed before completion (e.g., by disabling a navigation widget).
Examples	The user wants to package a presentation so that the presentation can be given on another computer. Several relevant decisions need to be made and the wizard helps the user make these decisions. The current position in the task flow is highlighted during each step to help with user visibility. 
Related Patterns	Two Panel Selector, Titled Sections, Responsive Enabling, Responsive Disclosure, Good Defaults

Table 6: Pattern Variables

Pattern variables	Values
Criteria	Shortcuts/accelerators, feedback, error prevention, error handling, grouping & structure, navigation, consistency, minimalist design
Pattern type	Web, GUI, mobile, visualization
Special needs	Colorblind, low vision, no vision, hearing disability, physical/motor disability, learning/cognitive disability, children, seniors, novice, expert, low literacy

Pattern Composition

During this phase, a pattern-oriented design (POD) is generated by composing the set of selected patterns. The P2P Mapper assists the designer by providing a support environment where selected patterns and their relationships can be viewed and also modified if desired. A valuable advantage of patterns and their associated languages is their generative nature, meaning that they can essentially be combined together as building blocks and even "plugged in" to an overall structure, resulting in a comprehensive design. In order to effectively apply patterns, we need to have an understanding of when a pattern is applicable during the design process, how it can be used, and how and why it can or cannot be combined with other patterns. We therefore define two essential elements related to composing a pattern-oriented design: (1) using a POD model for design structure and as a guide in stepwise design decisions, and (2) exploiting pattern relationships for incremental design generation.

The POD model holds information about the overall design structure, including a breakdown of the structure into different design facets. For example, in the Usability Patterns-Assisted Design Environment (UPADE) Web Language (Javahery, 2003), a website is organized according to architectural, structural (page managers and information containers), and navigation support patterns. In addition, the pattern language follows certain rules with regards to pattern documentation and language structure. Such a POD model can act as a guide in stepwise design decisions, where patterns are composed according to each facet separately and then combined in an overall design. Secondly, we should exploit relationships between patterns. One of the pattern attributes is "Related Patterns," which includes alternative or complementary patterns that we may want to consider as part of our design. As noted in Table 5, the wizard pattern is related to the responsive disclosure pattern according to which the display of a step is delayed until the user finishes the previous one. Pattern interactions and dependencies are very useful, contributing to an incremental generation of the design.

THE SECOND STUDY: DESIGNING WITH THE P2P MAPPER

We used the P2P Mapper tool to redesign a tool called Protein Explorer used to visualize biological data. We followed the process outlined above by entering all user information into the tool, iteratively clustering users, and populating the resulting persona descriptions. The tool provided an ordered pattern list for each persona, which we then used for our conceptual design by combining a subset of the suggested patterns. We then carried out a validation study, which consisted of building a fully functional prototype based on the new design and performing usability evaluations. Similar to the NCBI exploratory project (study 1), we conducted a comparative randomized study using task-based evaluation and open-ended interviews. The goals of the study were to: (1) assess the applicability of using the P2P Mapper process and tool within the context of a design project, and (2) to evaluate whether its use had a positive effect on system usability.

Protein explorer is a web-based (Java-script and HTML) information portal targeted towards biomedical research (see Figure 5). It is generally used for the prediction and analysis of complex molecular structures such as proteins, DNA etc. The tool uses a large set of data extracted from various heterogeneous information databases and Web servers. This tool uses a description file containing all structural information about a given molecule, which is fetched from web resources such as the Protein Data Bank (PDB).

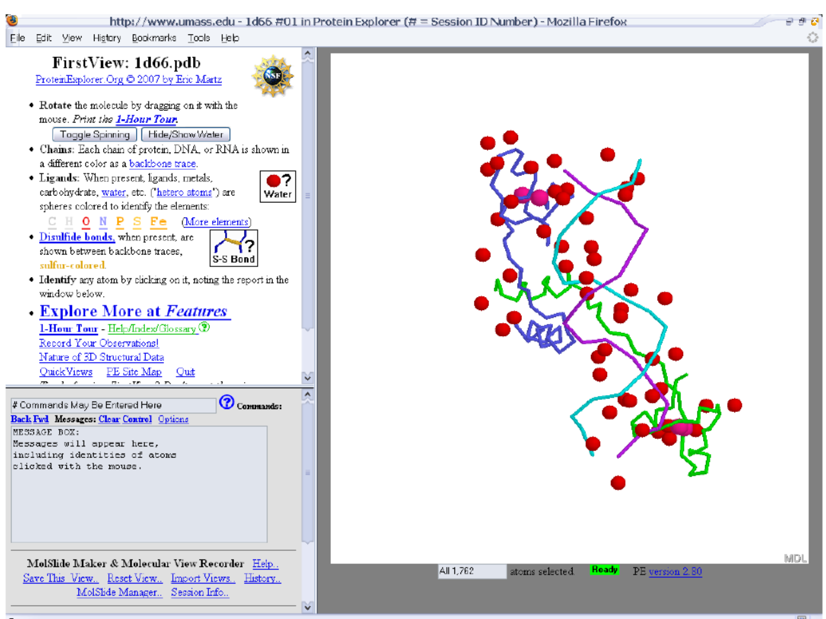


Figure 5: Protein Explorer – Original Version

We selected a sample of 22 users from biology, medicine and other related fields. To better understand our users, we carried out usability inquiries in the form of field studies and user observations on two Bioinformatics visualization tools, Cn3D (Cn3D, 2005) and ADN-Viewer (Hérisson et al., 2005). For each participant, a complete set of user variables was recorded (see Tables 4 and 7). Some user variables, such as education level, were recorded based on an initial questionnaire administered to participants. Others, such as learning speed, were recorded during user observations. Furthermore, we noted information about goals and interaction details for each user, and typical scenarios for a subset of the most representative users. This information was applied later to our personas.

Table 7: Aggregate Description of 22 Participants of PE Pre-Design Phase

User Variable[5]	Mean	SD
Age	3.33	0.62
Computer Experience	2.91	1.15
Domain Experience	2.09	1.38
Education Level	5.55	0.51
Bioinformatics Experience	2.00	1.20
Product Experience	1.68	1.36
Gender	Male count	Female count
	8	14

Clustering

Following our process, a key sub-step is clustering. The designer must select a small set of the most influential user variables which become the basis for grouping users.

We noted differences in interaction behaviors and dependencies based on specific user variables. Examples are: (1) Users with medium and high domain experience were more feature-keen. (2) Users with significant product experience had higher expectations in terms of both features and performance, and were reluctant to learn a new design paradigm. This was especially apparent with individuals who came from computational backgrounds. (3) The biologists needed more control when interacting with the tool. They were extremely dissatisfied when processes were automated. They wanted to understand how the automation worked. Biologists had a more experimental problem-solving strategy, where they followed a scientific process and were repeat users of specific features. It is important to note that as part of our study protocol, we did not carry out any empirical studies or pre-design analyses (including task model creation) with the original Protein Explorer tool, but with similar visualization tools. This was to ensure that the new design was only developed based on our process, without any possible positive “side-effects” due to the re-iteration and/or the discovery of usability issues with the original version of the tool.

Therefore, as a result of our field studies and psychometric assessments, we clustered users based on the domain experience and background variables. We used the clustering tool from our P2P Mapper Environment to perform this step. Domain experience was a user variable from our persona model and therefore pre-defined in P2P Mapper. To make clustering manageable, we restricted the domain to three values: Low (0 and 1), Medium (2), and High (3 and 4). Background was an additional variable which we added as a parameter in the tool; its values were defined as being either “biology” or “computer science.” The P2P Mapper provides the flexibility to add additional user variables that are not pre-defined.

Iterative clustering yielded a set of six clusters (Figure 6). We then analyzed the behavior of each cluster in comparison with other clusters. The reduced volume of information allowed us to find additional information. More precisely, we found that the interaction behavior of biologists with low domain experience was the same as computer scientists. Therefore, one of the groups was sufficient in order to construct a persona. Moreover, when we re-examined the group of computer scientists with low domain knowledge we found that these users need and tend to use a simpler tool. Capture of scenarios and goals demonstrated that Protein Explorer will not be used by these types of users. As a result, we eliminated two of the six groups from the study.

After analysis of the resulting four groups, we found that age, which was not considered in the previous clustering exercise, was also an important factor in influencing user behavior: Older users (45+) were more anxious when interacting with the system, and were less comfortable manipulating the visualization. They had a high need for validation of decisions, would often ask their assistants or others to help them in performing more complex tasks, and were feature-shy. As age increased, the expectation for tool support increased and users had more difficulty with learning the application.

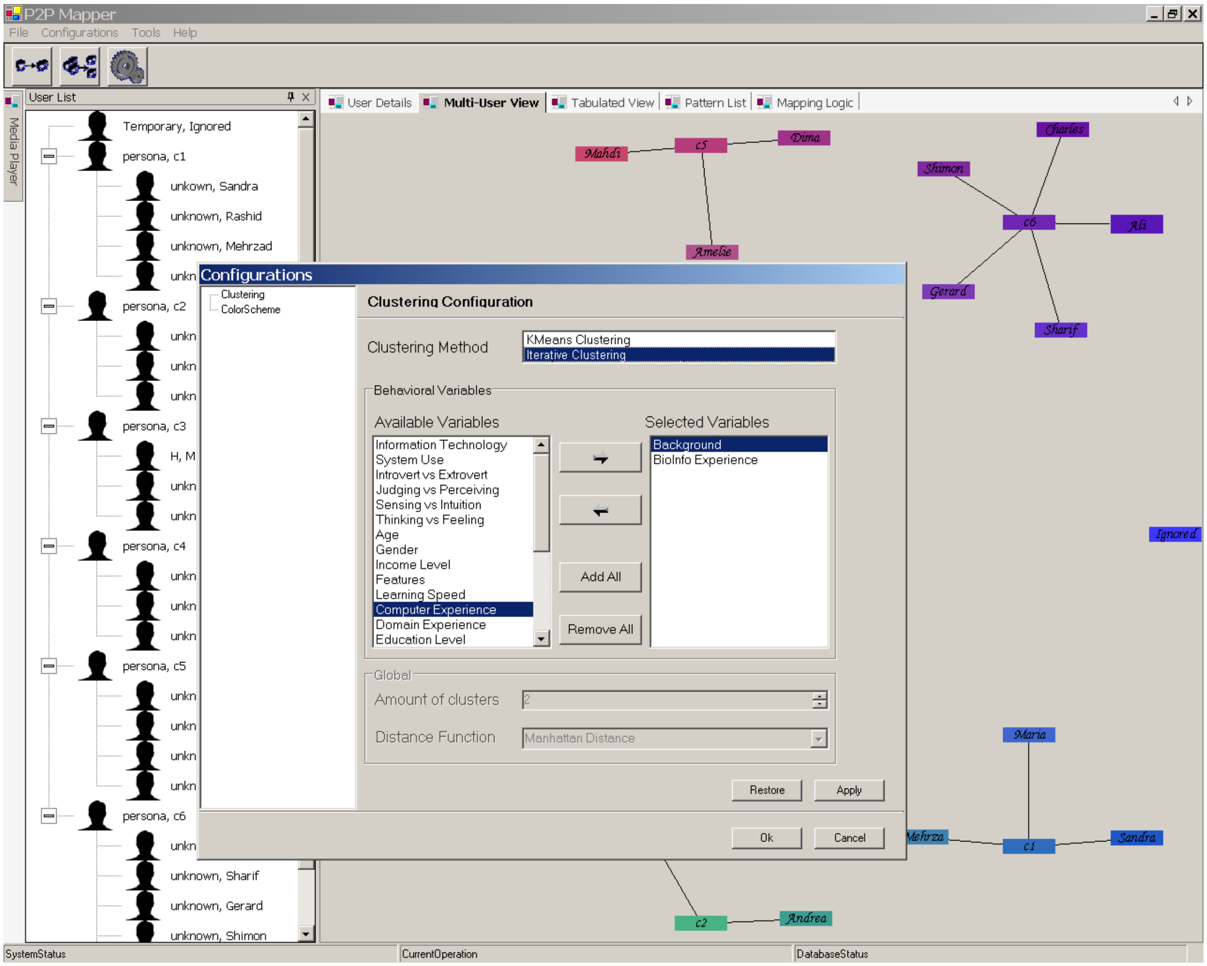


Figure 6: First Iteration Clustering in P2PMapper Tool

The second iteration of clustering was performed on the four remaining clusters with the age variable as an additional condition. Although the maximum number of possible clusters was actually 28, some age groups were not present in the user sample. Therefore, the tool produced only eight clusters (C1-C8). Once again, we compared the behavior of users across clusters. We eliminated five out of the eight clusters because their attributes and behaviors were contained within other clusters. For example, C1, C3 and C4 (all computer users, but with variations in domain experience and age) were removed because their functional needs were satisfied by C2 (young computer user with medium domain experience). When considering individuals with a computer science background, age and the variation between medium and high domain experience did not seem to notably influence interaction behavior.

The tool provides a skeleton structure for each persona and populates the discrete variables of the persona based on user values in its cluster. In order to bring to life our personas, we constructed the following based on original user descriptions:

- Martha Aviles, a young bioinformatics professional working in industry (see Figure 7),
- Zhang Hui, a senior Parasitology professor, and
- Sue Blachford, a mature adult and medical practitioner with limited experience in Bioinformatics

Pattern Selection and Resulting Design

We identified a set of five variables for pattern selection: (1) special need, (2) age, (3) behavior to features, (4) control and (5) domain experience (see Table 8).

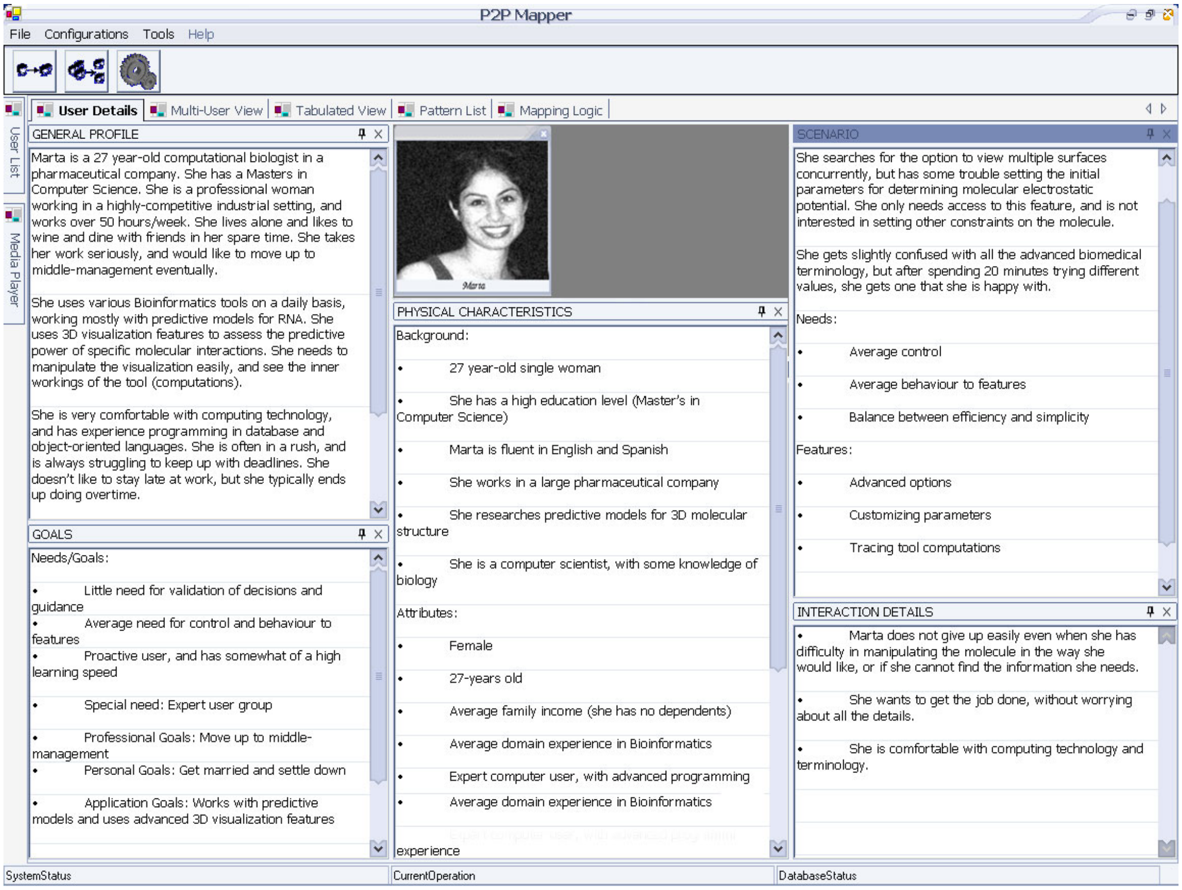


Figure 7: Persona Martha Aviles in P2PMapper tool

Table 8: Selected User Variables and Values[6]

Persona	Special Need	Age	Behavior to Features	Control	Domain Experience
Marta Aviles	Expert	3	2	2	2
Zhang Hui	Colorblind	5	4	4	4
Sue Blachford	Novice	4	0	0	1

We then used the tool to compute the scores for all patterns currently available in the library. As explained earlier, the tool computes a score for a pattern based on a set of rules and particular values of input variables. A higher score indicates a higher estimated applicability of the given pattern for the current persona. This process is automatically repeated for each persona.

The results obtained from the tool were compared in order to assess the possible evolution of the design. Each persona resulted in a different set of patterns. Zhang and Sue had the greatest variation in pattern ranking, whereas Marta contained patterns from both personas. Given the environment and the application at hand, we decided that a compromise solution would best fit our purpose. Moreover, we had a set of technological limitations related to the development platform chosen (Java/HTML). Based on the above, we selected 12 patterns (see Table 9).

The selected patterns were combined in order to create a conceptual design and then an implementation (Figure 8). It is important to note that we followed the process we defined; thus, we did not attempt to fix usability problems directly. In fact, we attempted to accommodate our personas with the best design possible by reusing best practices encapsulated in patterns. The only requirement we had was to keep the same "look and feel" for the design, including the use of several panes.

Table 9: Set of Selected Patterns for Protein Explorer Redesign

#	Name	Short Description
1	Button Groups	Present related actions as a small cluster of buttons, aligned either horizontally or vertically. Create several of them if there are more than three or four actions.
2	Card Stack	Put sections of content onto separate panels or "cards," and stack them up so only one is visible at a time; use tabs or other devices to give users access to them.
3	Good Defaults	Wherever appropriate, pre-fill form fields with your best guesses of the values the user wants.
4	Legend	Data are encoded in a form of visual objects that are then organized in a scene.
5	Multi-level Help	Use a mixture of lightweight and heavyweight help techniques to support users with various needs.
6	Details on Demand	Hide details of data items and present them on demand as Datatips or in a separate display.
7	Tool Tips	On mouse over an object, give an accurate and short phrase or sentence in close spatial and temporary proximity to the target.
8	Convenient Toolbar	Assist the user to reach convenient and key pages at any time throughout the Website.
9	Action Panel	Instead of using menus, present a large group of related actions on a UI panel that is richly organized and always visible.
10	Command History	As the user performs actions, keep a visible record of what was done, to what, and when.
11	Filter	Provide filtering facilities in order to reduce the number of visual objects displayed or assist the user in finding and focusing on specific items.
12	Reduction Filter	Provide facilities filtering out unwanted items from the display, where the display consists of a number of visual objects.

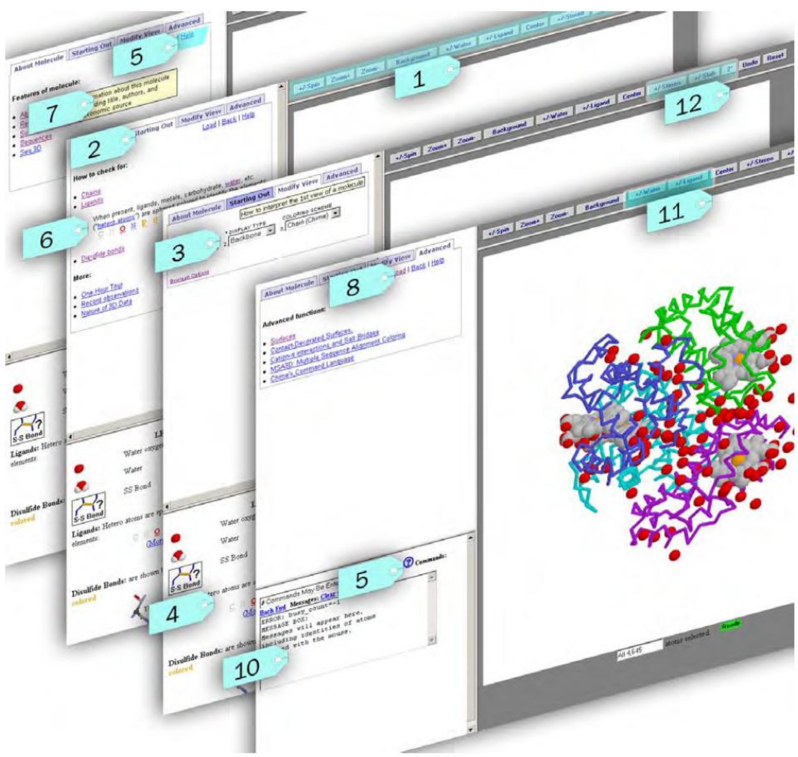


Figure 8: PE Prototype

Evaluation of PE design

We used a sample of 15 end-users from the biomedical-related fields for usability testing. Our sample was a subset of the users that participated in our pre-design activities. Although some of our users had experience with bioinformatics visualization tools, none of them had any experience with the Protein Explorer. This was advantageous for us, since there was no transfer of learning effects from expert users. Furthermore, participants were unaware of which version of the tool (original vs. new) they were using during the sessions. An aggregate description of the user demographics, as user variables, is presented in Table 10.

We performed task-based evaluations and open-ended interviews to compare the original design with the new design. Our goals were to evaluate task duration, success rate, and user satisfaction. Open-ended interviews included general questions about impressions of both versions of the tool (any differences, likes and dislikes) and specific questions about the user interface (navigation, etc.). Tasks were designed in conjunction with a biomedical expert. End-users of the tool typically follow a scientific process when performing tasks (i.e., the exploration of a particular molecule). We therefore designed each task as part of a scientific process. One example of a task is “exploring the hemoglobin molecule,” which includes sub-tasks such as loading the structure, modifying the view, determining its taxonomic source, and viewing surfaces such as molecular electrostatic potential.

Table 10: Aggregate Description of 15 Participants of PE Testing Phase

User Variable[7]	Mean	SD
Age	3.27	0.55
Computer Experience	3.00	1.07
Domain Experience	2.13	1.30
Education Level	5.60	0.51
Bioinformatics Experience	1.73	1.03
Product Experience	1.73	1.22
Gender	Male count	Female count
	4	11

We used a within-subjects protocol, where each user performs under each condition; in our case, each user tested both designs, the Original Design (Design O) and the New Design (Design N). The advantage of this protocol is that there is less of a chance of variation effects between users, and we can obtain a large data set even with a smaller number of participants. In order to reduce the effect of learning, we varied the order of the designs (Dix et al., 2003) per participant; some users started with Design N, others with Design O. Furthermore, we varied each of the two scientific processes per design type. We logged task times and failure rates and recorded the entire user experience, including facial expressions, with both designs.

Qualitative data were obtained from open-ended interviews with all users, carried out after task-based evaluations with both versions of the tool. The results revealed that the most common comments about the usability of the original version from end-users were as follows: (1) it is overloaded with content in the control pane; (2) the provided information is not filtered adequately, requiring users to spend lots of time reading irrelevant information, (3) navigation between pages is difficult, resulting in confusion when trying to reach the load page; and (4) manipulation of the visualization pane is difficult because it is unclear where the features for the visualization are located. Furthermore, we recorded the sessions and used the think-aloud protocol with users. Our observations indicated a high level of frustration during users’ interaction with the original version of the tool.

The most common comments about the usability of the new prototype from end-users were as follows: (1) it is easier to locate information because of the structure; (2) the organization of features and tools follows more closely with the scientific process in bioinformatics, (3) the interface is simpler and users feel more in control when interacting with it, and (4) the use of tabs makes navigation easier. Furthermore, during the recorded sessions, users seemed calmer and more comfortable during their interaction with the prototype.

13 out of 15 users indicated that they preferred the design of the new prototype compared to the design of the original tool. Simplicity and “feeling more in control” were cited as the most important reasons. Interestingly enough, one of the two users who indicated his preference for the original tool also cited “simplicity” as a reason, but in terms of the new prototype being too simple, while the original version keeps all the information “handy.” The other user indicated that the fonts are too small and the colors a bit confusing on the new prototype.

We analyzed the quantitative data from the task-based evaluation using the ANOVA statistical analysis method. We specified two independent variables (variation of the design type and variation of the design order) and two dependent variables (task time and failure rate). A main goal of using our process is to improve system usability; therefore the following hypotheses were formulated:

- The P2P process will result in a statistically significant improvement of task times when comparing Design O with Design N.
- The process will result in a statistically significant improvement of failure rates when comparing Design O with Design N.
- The effect of transfer of knowledge will be statistically insignificant.

We performed an ANOVA two-factor with replication test in order to verify the effect that transfer of knowledge had on our results. Moreover, this test was used to verify if there was any interaction between two varying factors: (1) the order in which the user tested the designs (O/N or N/O) and (2) the design type tested (O or N).

Task Duration

The results demonstrated that variation of the order in which the user tested the design had no influence on the task times ($p>0.05$). This means that the users were unaffected by transfer of knowledge from one design to another. In addition, the combined effect of both variables had no statistically significant impact on the task times ($0.05<p<0.10$). Finally, the second factor (design tested) was the only one that had a statistically significant effect on the task times: $F=35.71$, $p=3.62E-06$, $\eta 2=0.55$ (Table 11). This indicated that there was a statistically significant improvement in task time with Design N when compared to Design O. On average we noted an improvement of 52%.

Table 11: ANOVA Two-Factor with Replication Test Results for Task Times

Source of Variation	F	P-value	F crit.	η2
Testing order	2.024175	0.167682	4.259675	0.03
Design tested	35.70645	3.62E-06	4.259675	0.55
Interaction	3.182445	0.087084	4.259675	0.05

Given the results presented above, we concluded that task times were improved with Design N and transfer of knowledge was effectively reduced to a statistically insignificant level.

Failure Rates

The test results demonstrated that there was a statistically significant improvement in failure rates in Design N when compared to Design O. In fact, the second factor (design tested) has $F=28.03$, $p<0.05$ and $\eta 2=0.49$. Moreover, the test indicated that there is no statistically significant interaction between the two factors when considering their effect on failure rates ($p>0.05$). Similarly, the test also demonstrated that the order under which the users have tested the designs has no statistically significant effect on the failure rates ($p>0.05$) (Table 12).

Table 12: ANOVA Two-Factor with Replication Test Results For Failure Rates

Source of Variation	F	P-value	F crit.	η2
Testing order	4.03333	0.55991	4.259675	0.07
Design tested	28.03333	1.97E-05	4.259675	0.49
Interaction	0.833333	0.37039	4.259675	0.01

Therefore, we can conclude that failure rates were improved with Design N and transfer of knowledge was effectively reduced to a statistically insignificant level.

THE THIRD STUDY: DESIGNER'S EXPERIENCE WITH P2P MAPPER

In addition to the two studies detailed in this paper, we conducted a series of interviews with designers to find out how they currently use personas and patterns in their projects. These interviews provided us with initial feedback on how to improve the process and refine the P2P Mapper tool.

In total, 16 designers from 7 different companies were interviewed, representing a range of backgrounds, experience levels, and roles with respect to design. During each interview, the designer was asked to choose a recent project that was completed or near completion and to walk the interviewer through the entire project, explaining what they did with patterns and personas. The designer was asked to show examples of personas that were produced, and to explain their understanding of patterns and personas with respect to the design process as a whole. In many cases, we were able to obtain mockups of the design produced as well as the list of patterns and personas considered. Projects discussed ranged from a company site to a Web-based customer management system to a large ERP system.

We also asked the same designers to use the P2P Mapper and rate its ease of use. They rated it above average (6 out of a scale ranging from 1 to 10). However, they rated the usefulness high (9 out of 10). This seems to indicate that, despite the shortcomings of the current implementation in terms of performance and effective interaction, designers felt that the basic concepts were on target. Also, the designers gave a fairly high rating (8 out of 10) when asked to rate the P2P Mapper in terms of its ability to facilitate communication with design team members.

CONCLUSION

To build a tighter fit between user experiences and design concepts, we propose a novel design process and tool explicitly involving users. In current practice, deriving a conceptual design from user experiences is based on loosely-defined guidelines, giving rise to a significant “gap” between user requirements and design outcomes. This is especially problematic for novice designers, who cannot rely heavily on their design experience. Our process is based on two core design techniques, patterns and personas, which we have enriched with “engineering-like” concepts such as reuse and traceability. The process consists of three steps: Persona Creation from raw descriptions of user experiences, Pattern Selection which includes rule-based identification of relevant patterns, and finally, Pattern Composition, in which a design is created by combining patterns.

Details of the process are in part extracted from our experiences during the first study in which a design prototype was built using personas and patterns as the primary design directives. This empirical study was carried out with 39 end-users; and the main purpose was for process discovery and investigation. The application of interest was a Bioinformatics website, which scientists use as a portal to access different analytical tools. The new design was built using our proposed process, which included a set of initial rules for Pattern Selection. It was compared to the original design, and resulted in significant improvements in terms of usability. Based on this study, we refined our ideas around a systematic process which incorporated personas and patterns, and an associated support tool called the P2P Mapper. Using knowledge elicited from HCI experts, we incorporated a clustering step into the tool as part of persona creation, and a set of rules (extended from our initial set), to select patterns from persona specifications. Furthermore, we proposed more formal representations for personas and patterns amenable for tool support.

As part of the second study, we tested our process and tool in the redesign of a Bioinformatics visualization application. The goals of the study were to assess the applicability of using the process and P2P Mapper tool within the context of an HCI project, and to evaluate whether their use leads to more usable systems. We first used clustering to create three personas, which were derived from a set of clusters automatically suggested by the P2P Mapper. The next step consisted of using the P2P Mapper to generate a list of candidate patterns. From the list, we selected applicable patterns based on our understanding of the users. We composed the patterns into a conceptual design, which was then implemented into a fully functional prototype. Our prototype was compared to the original tool, resulting in significant improvements in terms of usability measures. Quantitative results based on testing with 15 users indicated both a statistically significant improvement in task duration and failure rates. Furthermore, qualitative results indicated a greater degree of satisfaction with the prototype for 13 out of the 15 users.

We would like the P2P Mapper tool to work with existing design tools to fit more naturally into the entire user-centered design cycle. This includes generating storyboards and other design artifacts that can be imported by other tools (Mockups, prototypes, etc.). As part of the third study, we are investigating the designer's experience with the P2P Mapper and are using the feedback collected to improve the tool. We plan to explore new visualizations and interactions dealing with these additional design artifacts. For example, it would be desirable to allow the designer to identify task patterns from personas and use these patterns to derive design prototypes. We plan to extend the composition mechanisms of patterns to support the creation of a large variety of designs (Web, GUI, mobile applications) while allowing designers to specify their own reusable components and patterns. These components can be as simple as a new kind of widget or as complex as an entire design model.

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[1] toddlers (0-4 yrs), children (5-14), adolescents (15-19), young adults (20-34), mature adults (35-59) seniors (60-74), elderly people (75 and over)

[2] middle point on scale defined as the national median, and high income as per bracket for a particular country (i.e. in Canada, greater than $100,000)

[3] or with similar products

[4] users can belong to more than one group

[5] Age and Education Level are based on a 7-point scale with a range from 0 to 6. Computer, Domain, Bionformatics and Product Experience are based on a 5- point scale with a range from 0 to 4. See The *Variables: Defining User Experiences* Section for additional details.
[6] Age is based on a 7-point scale with a range from 0 to 6. Behavior to features (feature shy to feature keen), need for control (low to high) and domain experience (none to expert) are based on a 5-point scale with a range from 0 to 4.
[7] Age and Education Level are based on a 7-point scale with a range from 0 to 6. Computer, Domain, Bionformatics and Product Experience are based on a 5- point scale with a range from 0 to 4. See The *Variables: Defining User Experiences* Section for additional details.

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