A Taxonomy of User Behavior Model (UBM) Tools for UI Design and User Research

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Abstract. The engineering of user interfaces (UIs) increasingly relies on software tools that aid in ideation, design, evaluation, etc., but involve no real users. Particularly, user behavior models (UBMs) bear the potential to improve human-centered design processes, but their adoption in practice remains low. In this paper, we present a taxonomy for UBM tools that organizes and structures them along 7 dimensions – supported job, degree of automation, focus, interface data input, user data input, output of tool, and target interface platform. We also conduct an initial evaluation with 61 existing tools, providing insights into the current state of the field. Notably, none of the investigated tools work with user characteristics or reference interfaces as input, although this would appear very practical for real projects. Our results could support UI/UX researchers and digital design practitioners in searching for the tools and further enhancing them. Ultimately, our work represents a step toward understanding and overcoming the low adoption rate of ML-based UBM tools in the industry.

Keywords: Software Classification, User-Centered Design, Human-Computer Interaction, Machine Learning.

1 Introduction

In their work, engineers and designers rely on an actionable mix of existing knowledge in their respective fields and the understanding of the problem and the context at hand. Engineering of effective and attractive web user interfaces (UIs) necessitates finding out the website's target visitors' needs and characteristics during the user research stage. Rigorous knowledge for transforming these into a UI is drawn from the field of human-computer interaction (HCI), where it is increasingly operationalized as user behavior models (UBMs) [1].

In the broadest sense, UBMs in HCI are formal constructs that attempt to conceptualize, explain, or predict the behavior of human users with respect to particular interface designs without involving actual users. Many modern UI/UX engineering support software tools/systems/platforms are based on UBMs, at least to a certain extent (we shall call them *UBM tools* hereinafter), and they are in the focus of this paper. UBM tools can simulate or predict users' behavioral responses to novel designs, to optimize or inspire design features [2, 3], produce novel prototypes [4], perform quantitative analyses [5], etc. They have the potential to facilitate the development of successful interfaces of digital products, but they appear to have trouble gaining traction in the industry. In a recent survey of UI design practitioners, we found that the top reasons for non-using the AI/ML-based tools included *"never heard of those"* (91%) and *"I don't see the added value"* (21%) [6]. Thus, we concluded that the designers have little awareness on how exactly such tools could support them in their job.

In the current paper, we rely on the same collection of 61 UBM tools (see in [6]) to construct a taxonomy, which we then apply to classify them. In this way, we hope to facilitate the identification and differentiation of UBM tools for practitioners and researchers, and to provide a starting point for better understanding the gap between research and practice in this area. We structure the remainder of the paper as follows. Section 2 summarizes related research and outlines the taxonomy development process. In Section 3, we present our novel taxonomy and classify the considered UBM tools. In the final section, we discuss our findings and potential directions for future work.

2 Related Work and the Taxonomy Development Process

A wide range of disciplines apply behavior models in one way or another, including Psychology, Biology, and Economics. In HCI, behavior models typically aim to explain or predict the response of human users to specific interface designs, which is why the HCI community commonly refers to these models as "user behavior models" (UBMs) [7]. They generally output (predict) a certain interaction quality parameter, for a particular UI (or its prototype) and a certain user group [1]. Our definition of a UBM-based tool is: *software which can, based on previously learned user behavior, instantly (more or less) and automatically produce a visual design, prototype, analysis, or validation*.

In that sense, UBM tools are a specific category of design support tools, whose overarching goal is to facilitate the development of interfaces that optimize the user experience by providing designers insights into user behaviors and their interaction with an interface without involving actual human users. This shall not be contrasted with the involvement of real users – in IT industry, with its constrained budgets and schedules that hinder thorough implementation of the prescribed user-centered design process, the real alternative is relying on no user data whatsoever. Strictly speaking, the name *"user-less"* tools that we used previously [6], is not entirely embracing: theoretically, a UBM tool can supplement its operation with a real user data, in addition to the learned behavior.

Recently, advances in the field of Machine Learning (ML) have also spilled over into the domain of UBM tools, promising to make the lives of digital design and user researcher professionals easier automating pivotal parts of their jobs. At the most automated end of the spectrum, they could take over the entire design process and output an optimized user interface [1]. For example, researchers have shown that ML-based UBM tools can define design problems from online review narratives [8], generate interface prototypes based on sketches [9], construct behavioral personas from clickstreams and social media contents [10], and derive semantic representations of digital designs that inform user behaviors [11].

Despite their versatility and great promise to revolutionize the design work of practitioners, this new generation of UBM tools has not seen much practical usage and appears to belong predominantly to the academic realm [12]. One of the reasons for the non-usage that we can speculate about concerns the extensive upfront effort required to find a suitable tool and integrate it into existing design processes [13]. We believe that developing a taxonomy can provide a better overview of the UBM tool landscape with its different capabilities and purposes, facilitating researchers' and practitioners' navigation of the field.

Taxonomies related to software are manifold: many of them target specific subject matters and are created ad-hoc for practical purposes [14].The substantial stages in a taxonomy development process, based on [15, Table 1], are as follows:

1. **Planning:** Identify the business needs and the objectives of the taxonomy. Define the list of key users and survey the users’ needs.
2. **Identification and extraction of information:** Explore sources of information, extract the terms and identify the candidate categories.
3. **Design and construction of the taxonomy:** Define the first level of the taxonomy design (about 7 categories) and the subsequent levels.
4. **Testing and validation:** Validate the use to which the taxonomy is intended and apply the content of the taxonomy.

The two intended groups of our taxonomy users are: 1) digital design practitioners, who often have problems finding and recruiting real users, especially specialized ones [6], and would benefit from awareness of the UBM tools’ and the specific support they can provide, and 2) authors of design support tools, who need to position them in the market and invent new functionality, could analyze the competitors and identify unoccupied segments.

The sources of information were by and large the official websites of the tools, at which we arrived by sending queries to global search engines (details on the queries and the tools’ selection can be found in [6]). Overall, we collected 61 classification items, some of which are not individual tools, but series, e.g., *Clicks/CTR prediction* or *Browser web analytics plug-ins*. Like for lanthanides and actinides series in the Mendeleev’s Periodic Table, the properties of items within them are virtually indistinguishable in the context of UI/UX design. The full list of the collected items is available in the Online Appendix of [6] (https://github.com/heseba/UserlessDesignSurvey).

The technology for the actual design and construction of software taxonomies is not very well detailed, and a lot is left to the experts. The initial generation of the UBM tools taxonomy structure and the categories was done by the first authors of this paper, based on his 15-years’ experience in HCI and over 20-years’ experience in web UIs engineering. The process was largely top-down, but inspired by the list of the tools. The validation was performed by all the other authors, whereas the application of the categories to classify the 61 items was done by the second author of this paper.

In the first level, there were 7 categories, each of which got from 3 to 11 possible values (sub-categories), so the taxonomy structure turned out to be rather shallow. The categories were largely orthogonal, and each of the UBM tools would be simultaneously classified in each category. The values were not necessarily mutually exclusive, but in most instances only one of the values should apply to a classified item.

3 A Taxonomy of User Behavior Models-Based Tools

Most of the categories that we initially identified for the taxonomy were rather universal for software products in general: supported job, input and output, target platform, degree of automation. These were tailored for the considered domain: e.g., input was detailed into *Interface data input* and *User data input*, as per UBMs. The values in the second level of the taxonomy were also by and large made domain-dependent.

In this section, we present the taxonomy categories and values and demonstrate its application to classify the 61 tools. More complete taxonomy data can be found in the Online Appendix[1]. A reader shall not consider the classification that we propose to be strictly correct and complete. Instead, we welcome the tools' developers and the research community to make corrections to our initial classification.

Designer's/researcher's job. As any software made for professionals, the tools need to fulfill or support a certain task in the user's work process. Design and evaluation (assessment/ analysis/ testing/validating/checking) appear to be the most frequent ones in the digital design field, followed by ideation (Table 1).

Table 1. UBM Tools' taxonomy: by *Designer's/researcher's job*.

Value	Tools
Design (generative)	MenuOptimizer, GRIDS, UIZard Design Assistant, Material Design guidelines, 10 more tools
Evaluation	Usability Smells Finder, Qualidator, USEFul, WaPPU, AIM, CogTool, Cogulator, WAVE, ViCRAM, 27 more tools
Other (ideation, reference)	Paper2Wire, Sketch2Code, WebRatio, 8 more tools

Degree of automation. Classically, depending whether the transformation of the input to the output is done with involvement of a human (*Semi-automatic*) or without it (*Automatic*). *Instrumental* corresponds to software that supports certain intermediate operations (technical aid, computation, code generation, etc.), while most of the work is supposed to be done by the user (Table 2).

Focus. This category is the most domain-specific one and involves both theoretical interaction aspects known in HCI and practical goals of UI engineering (Table 3).

[1] https://github.com/heseba/UBMToolsTaxonomy

Table 2. UBM Tools' taxonomy: by *Degree of automation*.

Value	Tools
Automatic	Paper2Wire, WaPPU, AIM, Zyro Heatmaps, UIS Hunter, W3C Validator, VisualMind AI, 15 more tools
Semi-Automatic	MenuOptimizer, GRIDS, UIZard Design Assistant, Test.ai, Tricentis Tosca, Eggplant
Instrumental	Figma, Cogulator, Selenium, Appium, TestComplete, Ranorex Studio, IBM Rational Rhapsody, 25 more tools
None	Material Design guidelines

Table 3. UBM Tools' taxonomy: by *Focus (interaction aspect or goal)*.

Value	Tools
Technical (correctness of code, URIs, etc.)	Browser web analytics plugins, Web Vitals, Test.ai, W3C Validator, SortSite
Motor behavior	CogTool, Cogulator, KLM Calculator
Visual perception	GRIDS, AIM, ViCRAM, VisualMind AI
Cognitive (e.g., readability)	MenuOptimizer, WaPPU, Zyro Heatmaps, Eye-gaze/ROI prediction, CogTool, Cogulator, KLM calculator
Subjective/emotional	AIM, VisualMind AI
Marketing	Clicks/CTR prediction
Simulation	Selenium, Katalon, iMacros, Robot Framework, Capybara, Cucumber, Twist, Ranorex Studio, 6 more tools
Accessibility	Qualidator, WAVE, AChecker, SortSite, Level Access WebAccesibility, Color/Contrast checkers
Guidelines / patterns / standards	Usability Smells Finder, Qualidator, USEFul, Material Design Guidelines, UIS Hunter
Other	Adobe XD, Figma, Sketch, JustInMind, Balsamiq, Origami Studio, Sketch2Code, UIZard Design Assistant, CaseComplete, AXIOM, Mendix Studio, 9 more tools

Interface data input. This category corresponds to one of classical input components for a UBM, which can be of different types (Table 4). This input is optional, as some tools are not concerned with a particular UI or require the user to create it.

Table 4. UBM Tools' taxonomy: by *Interface data input*.

Value	Tools
Code	Usability Smells Finder, WaPPU, AIM, Test.ai, AChecker, SortSite, Selenium, Katalon, Twist, ViCRAM, 22 more tools
Image	Zyro Heatmaps, Eye-gaze/RoI prediction, UIS Hunter
Model	Cogulator, KLM Calculator, IBM Rationa Rhapsody, WebRatio, CaseComplete, Appian, AXIOM, Mendix Studio
Prototype	MenuOptimizer, GRIDS, CogTool

Sketch	UI-image-to-GUI-skeleton, Paper2Wire, Sketch2Code, UIZard Design Assistant
A reference interface	-
None	Figma, Axure, Mockplus, uizard.io, InVision, Balsamiq, JustInMind, Material Design Guidelines, 3 more tools

User data input. Some representation of the target user, (e.g., such *User characteristics* as age or gender obtained from user research) is another classical input for a UBM (Table 5). Some UBM tools do not explicitly ask to input a user data, but cover all users or contain implicit knowledge (e.g., about the significant visual factors).

Table 5. UBM Tools' taxonomy: by *User data input*.

Value	Tools
User model	-
User interaction data/logs	Usability Smells Finder, Clicks/CTR prediction
User survey data	WaPPU
User characteristics	-
Other	XCUITest, UIS Hunter, CogTool, KLM Calculator, Cogulator, Selenium, Appium, Tricentis Tosca, Twist, 11 more tools
Implicit/none	Adobe XD, Balsamiq, Sketch, GRIDS, Paper2Wire, Qualidator, AIM, Appian, AXIOM, VisualMind AI, 23 more tools

Output of the tool. This category corresponds to the added value that the tool can provide to designers, user researchers, or even product managers (Table 6).

Table 6. UBM Tools' taxonomy: by *Output (added value)*.

Value	Tools
Errors/warnings/"smells"	Usability Smells Finder, Qualidator, USEFul, UIS Hunter, W3C Validator, WAVE, AChecker, SortSite, 5 more tools
Guidelines/recommendations	-
Interface metrics	Qualidator, WaPPU, AIM, ViCRAM, VisualMind AI
Usability/interaction metrics (time, error, subjective, etc.)	WebVitals, CogTool, Cogulator, KLM Calculator
Business KPIs (e.g., CTR, sales, subscriptions, etc.)	Clicks/CTR prediction
Code	IBM Rational Rhapsody, WebRatio, Appian, AXIOM, Mendix Studio
Interface-related image (e.g., heatmaps) or visualization	Zyro Heatmaps, Eye-gaze/RoI prediction
Interface model/prototype	MenuOptimizer, GRIDS, Sketch2Code, UIZard Design Assitant, 8 more tools
Simulated interactions	Selenium, Eggplant, Linux Desktop Testing Project, Robot Framework, Behat, Twist, Ranorex Studio, 7 more tools

User classification/profiling	-
Other	CaseComplete

Target interface platform. The interface platforms are different in the employed technologies and interaction modes and in the maturity of related HCI techniques (Table 7). Many design support tools promote themselves as specific to a certain platform.

Table 7. UBM Tools' taxonomy: by *Target UI platform*.

Value	**Tools**
Web	GRIDS, Usability Smells Finder, Qualidator, WaPPU, AIM, Web Vitals, W3C Validator, WAVE, Selenium, iMacros, Behat, WebRatio, ViCRAM, VisualMind AI, 10 more tools
Mobile	XCUITest, Appium, AXIOM, Mendix Studio
Desktop	MenuOptimizer, Linux Desktop Testing Project
Embedded (vending machines, kiosks, cars, etc.)	-
Hybrid	Zyro Heatmaps, Test.ai, CogTool, Cogulator, Katalon, Eggplant, Ranorex Studio, IBM Rational Rhapsody, 18 more tools
Other (AR/VR, voice, etc.)	-
N/A	CaseComplete

4 Conclusion

UI/UX design practitioners frequently perceive jobs that involve actual users as particularly costly and time-consuming, leading them to reduce this central component of the user-centered design methodology to a minimum [3]. This reduction, however, causes them to waste valuable time and resources developing designs that users eventually reject. Meanwhile, design support tools based on UBMs can provide insights into user interactions with an interface even in the absence of the actual human users.

In this paper, we have developed a 2-level taxonomy incorporating 7 categories and 48 values (sub-categories) in total, which we applied to classify the 61 items that we previously collected [6]. It provides a comprehensive overview of the existing landscape of UBM tools, allowing researchers and practitioners to navigate and identify different tools based on their capabilities and features. This can also help identify underpopulated segments and provide inspiration for developing new software features.

Our taxonomy and the associated classification yield some noteworthy insights: in particular, there are no tools that require *user characteristics* as inputs, although this data is readily available in real projects. Another input that surprisingly none of the identified tools accepts are *reference interfaces*, even though they are often of considerable use in the ideation phase of design processes, e.g., to produce slightly changed versions of a single design mockup or an existing website design. Finally, none of the existing tools focus on *embedded, AR/VR, and voice,* which reveals a clear opportunity in the market.

We would like to note several limitations of our work. First, **knowing** about a design support tool and **using** it is not the same, as we have previously learned from the negative correlation discovered in practitioners' survey [6]. Awareness that can be facilitated by the taxonomy is necessary, but not sufficient – ultimately, adoption of a design support tool would depend of the added value it provides. Second, our classification is far from being complete and perfect, as the collection of the tools had started in 2021, so the landscape might have changed somehow. Still, we believe that the proposed taxonomy categories and values have long-term validity and utility.

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