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INTERACTION AND FEEDBACK LOOPS IN USER INTERFACE FOR DIGITAL ENGINEERING DESIGN

Abstract *The article aims to review existing issues and look for novel ways of human-computer digital systems design and interaction. Such interaction takes place, as a rule, through an appropriate interface, which can be mechanical, digital, analog, with a touch screen, etc. For the end user of the relevant application or system, it is important how this interaction process will be implemented, presented, and programmed. That is, what controls, actions for interaction, and feedback mechanisms from the system to the user will be available. The research methods are based on the main methodologies of design and analysis of digital products with an emphasis on user experience, research of user requirements, the context of application use, and the presentation of the menu of interaction with a digital service. The article presents the results of a detailed description and modeling of the main process of user interaction with the feedback system (cyclic process). The context of using the application, the main desires and goals of the user when interacting, as well as the types of available options for interacting with the interactive system are taken into account. The seven-step process of user interaction presented in the paper includes functions, data, software systems and modules, appropriate software and hardware architecture, and methods of internal communication between cycle functions. A process of interactive interaction has been developed, which describes the full cycle from the beginning to the end of the user's work with any digital, analog, computing device, application, or service. This process can be used by designers, software developers, and scientists/researchers at the stage of planning a new interactive system or to improve an existing one.*

Keywords: *HCI, user interface, computer engineering, design engineering, design.*

Introduction. Software and digital information applications are used in every area of life. Hardware and technological advancements led to a great number of digital interactive devices and screens available to users around the world. Digital and analog devices are used not only by the general populace but by many professionals in all industries, from construction to aerospace engineers to mechanical engineering to military and health care, among many other industries. What users see and interact with, first of all, is the user interface or mechanical interface. The Human-Computer Interaction field is responsible for researching new ways and improving existing user-computer(user-devices) mechanics. The process of user-computer interaction happens in loops, and for every user action or series of activities, systems provide appropriate feedback. To take a step further interaction design is not just centered on, limited to input and output operations cycles, it affects the whole software/hardware/system. Digital human-computer interaction systems design can be classified as a type of engineering systems architecture and should be studied appropriately.

Analysis of research and publications. There are many prominent researchers and research work in the fields of HCI, UI research, and interaction engineering. The most common work in the area of HCI is user interface and interaction feedback loops [1-5]. Besides, fundamental studies have been carried out in the area of user interface design principles and design systems [6-9]. Emerging Technologies, such as VR, AR, and new touch interfaces require a new view of how the interaction loop operates [10]. Even though the area of HCI and interaction research is not new, many systems and possibilities were left unstudied or haven't received enough focus. Among them, the field of

digital design is focused on comprehensive system design that includes multiple simultaneous use complex interaction actions, and multi-device feedback.

Purpose. The research work aims to describe the HCI interaction loop, break it down into functional components, and present a robust model for interaction design context, interaction process, as well as the view on User Interaction – Feedback Systems, and States.

Methods. List of main HCI research methods, components, and interaction systems are listed in Table 1. Human-computer interaction is conducted using various mechanical, screen, and sound processing devices. Major interaction systems include digital electronic and electrical devices, used for input and output operation, data and signal processing modules. Each type of interaction has a corresponding sample system type, ranging from LCDs to touchscreen interfaces to found speakers and spatial sensors.

*Table 1 – User-Interface Interaction Classification**

Interaction Type	Components	Data	Example systems
Mechanical	Input Device Input Sensor Output Device Group of devices Processing Machine Singal Processing	Analog/Digital Signal Spatial coordinates Input/Output Type Input/output signal End-point comms. message Device control data	Electrical device Singal processors Transistors Programmable components Camera and motion recognition, tracker Touch screen device Mechanical control device
Text	Direct physical input/output Virtual Input/output	Screen size and type Language model Input/output text	BW screen LCD screen Paper/Magnetic Ink
Voice	Physical microphone/speaker Audio processing Audio recognition software	Signal data (wave) Recognition and sensory data Timer and buffer data	Sound wave signal converters Sound processing engine
Visual (CGI)	GPU Rendering Software	2D/3D Coordinates Geometry VFX and Animation sequences	Game Engine Modeling Software End-user application

** prepared based on author work and public research data [1-10]*

Data and programming functions are included in user, software, and hardware system design. Data types are broken down into categories based on interaction type, and listed in Table 1, column 3. List of the most common user-interface interaction functions (based on Table 1 Interaction Types), each of which can take input data and/or return result data:

- ProcessingEngine();
- ScreenRender();
- ViewMode();
- InteractionMode();
- MenuSystem();
- GetInput();
- SetOutput();
- StoreData();
- ConnectToDevice();
- SingalProcess();
- and others.

When developing and designing new interaction systems both scientists and industry specialists have a wide range of tools at their disposal. The most commonly used hardware and software solutions are listed in columns 1 and 2 of Table 2. HCI and Interaction design rely on many methodologies and patterns, as the product/applications design process starts with the Business and

product planning, followed by design and technology development (column 3 in Table 2). What the end-user gets is not some random number of signals or misc. messages, but specific text, and visual elements and has access to several possible menus and navigation panels (column 4 in Table 2).

*Table 2 – Hardware, Software, Methodology Classification in HCI**

Hardware	**Software**	**Methodology**	**Presentation**
Glasses: - VR - AR - MR	Software development suits and stacks: - native platform - cross-platform - use case specific	Business and Product development: - Stakeholders - Requirements - Planning and Resouces allocation	Physical dimension: - presentation - size - interaction type - context of use
Sensor Screen: - phone - tablet - general screen	Interface design: - physical - digital graphic design - digital UX, UI	Design and Interaction: - Form - Interface - Presentation	Input and Output: - direct - loop - contextual
Mechanical: - joystick/ gamepad/controller - Virtual Mouse and Keyboard - Mechanical Mouse and Keyboard	2D and 3D graphics programs: - modeling - rigging - animation - industrial	Technology and Design: - Analytics - Development - Materials - Electronics - Aesthetics	UX: - Objective/Goal - Functionality - Interaction - Information - Sensory
Sensors and trackers: - detection and recognition - motion	Embedded and hardware development software: - firmware - application	Manufacturing and Production: - Packaging - Supply and Delivery	UI: - Layout - Navigation - Menu - Screen Elements
Misc. Input&Output devices: - digital - analog	Testing and Evaluation: - UX - product and market - software	User and Behavior: - Goals and desires - Information Architecture - Psychology and behaviors - social and group interaction	Special: - notifications - sound - music - 3D effects - spatial effects - misc.

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Human-computer interaction is a three-phase process, as presented in Figure 1.

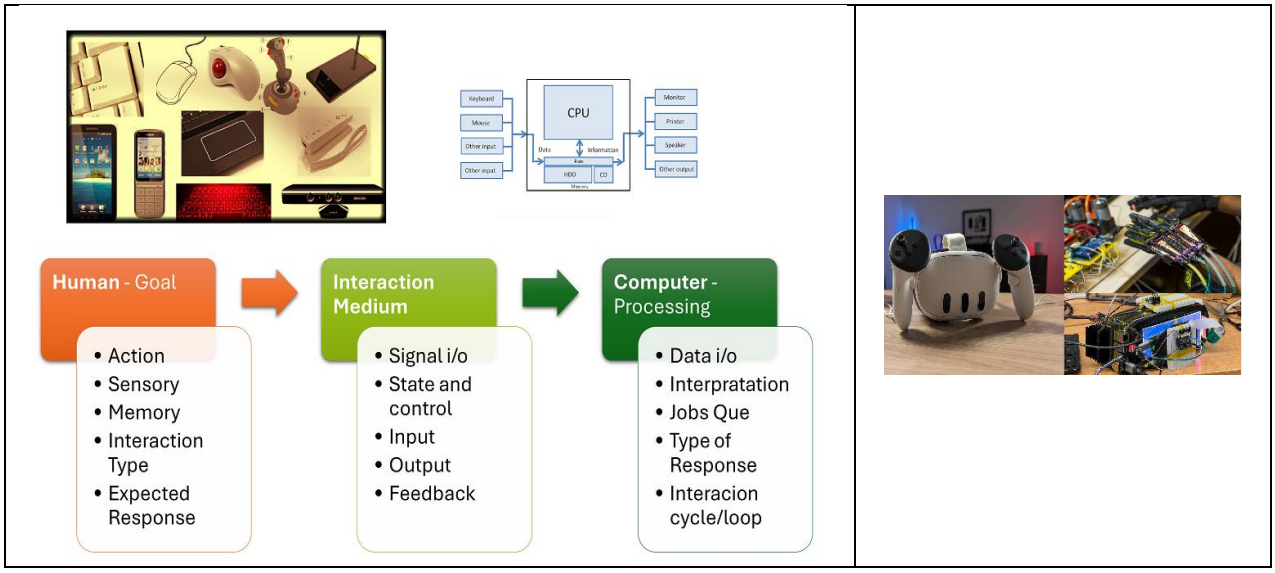

Figure 1 – General Human-Computer Interaction Components [6-9]

The essential first step is the user (human) defined goal that he/she needs to accomplish with the help (usage) of digital/analog/mechanical/misc. type of interactive device. User input is processed depending on the interaction medium and input type by the software system (computer, microcomputer, etc.). A list of underlying components, actions, and conceptual functions is presented in the bottom section of Figure 1 under the respective Interaction phase.

Results. At the center of applications, software, and systems interaction is human – the user. The reason the interaction process is initiated and instanced is due to the user having a single or several goals that they wish to accomplish. The interaction systems in the process are just a tool used by the used to achieve the desired goal. Figure 2 highlights the user-centered interaction loop with a focus on the interaction processing feedback loop. The interaction activity consists of the user interface, input, and output processing functions, that send appropriate commands towards the main System Processor unit.

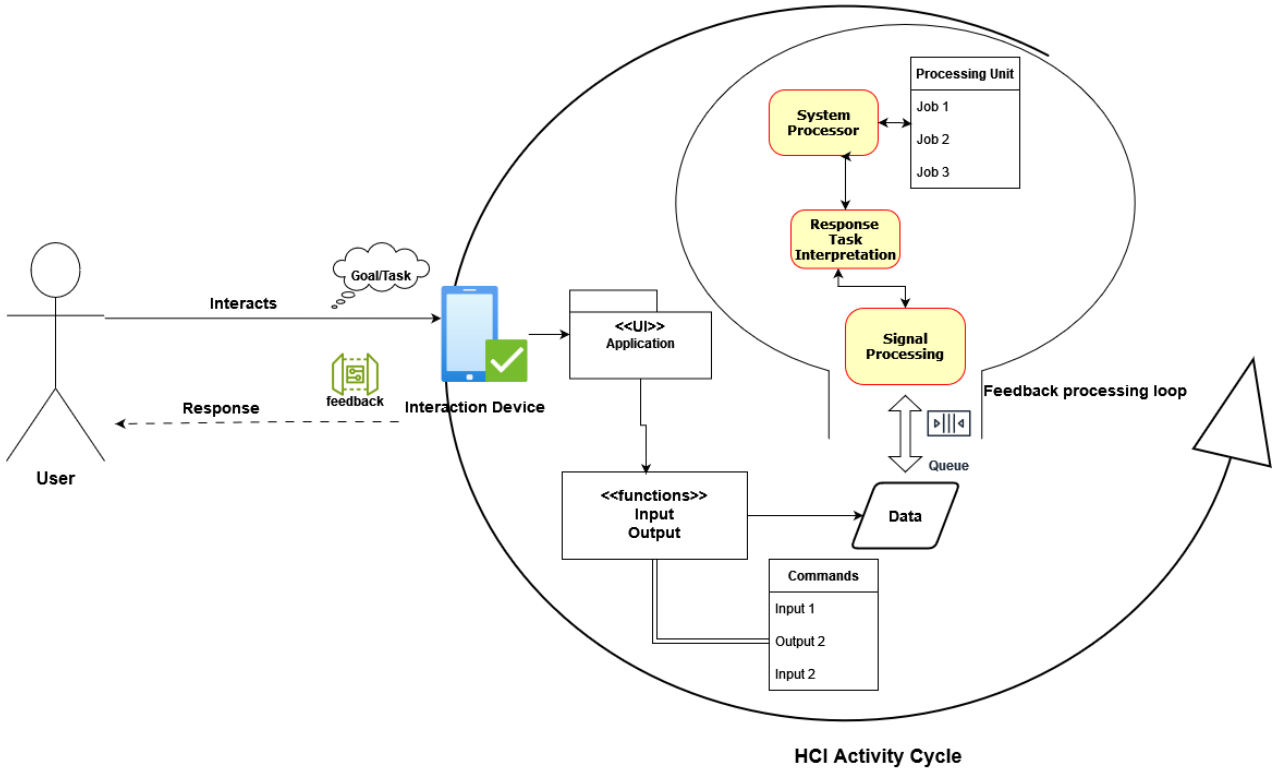

Figure 2 – Feedback loop in UI and Digital Engineering Design Systems

Figure 3 illustrates the Human-Computer Interaction Process with a focus on major users, functions, and underlying systems. The process is divided into three layers – conceptual programming functions, applications modules and components, main systems, and data processing units. There are several types of users who directly or indirectly affect the interaction cycle, user or player directly influences and interacts with the systems, while the rest of the stakeholder's team is responsible for the production and maintenance of the deployed application/system. Systems' internal communication and processing logic can be broken down into two parts – user-centered services and system internal processing services modules.

Interaction processes happen not in the vacuum space, but rather in a real-world environment. This is especially true for industrial, medical, and mobile applications. Figure 4 visualizes the context of use and design impacting factors. Each of the interactive systems should consider usage environment, time and location, where the device and application can be and will be used. Certain tasks and interaction activities influence how a user will interact with the given system, which might add additional constraints and limitations. Differentiating user type and purpose of the system usage is vital in early system design stages, as certain industries and professional environments place a large

weight on the end-user goal and step-by-step user-system interaction flow. All of these factors and more are highlighted in Figures 3 and 4.

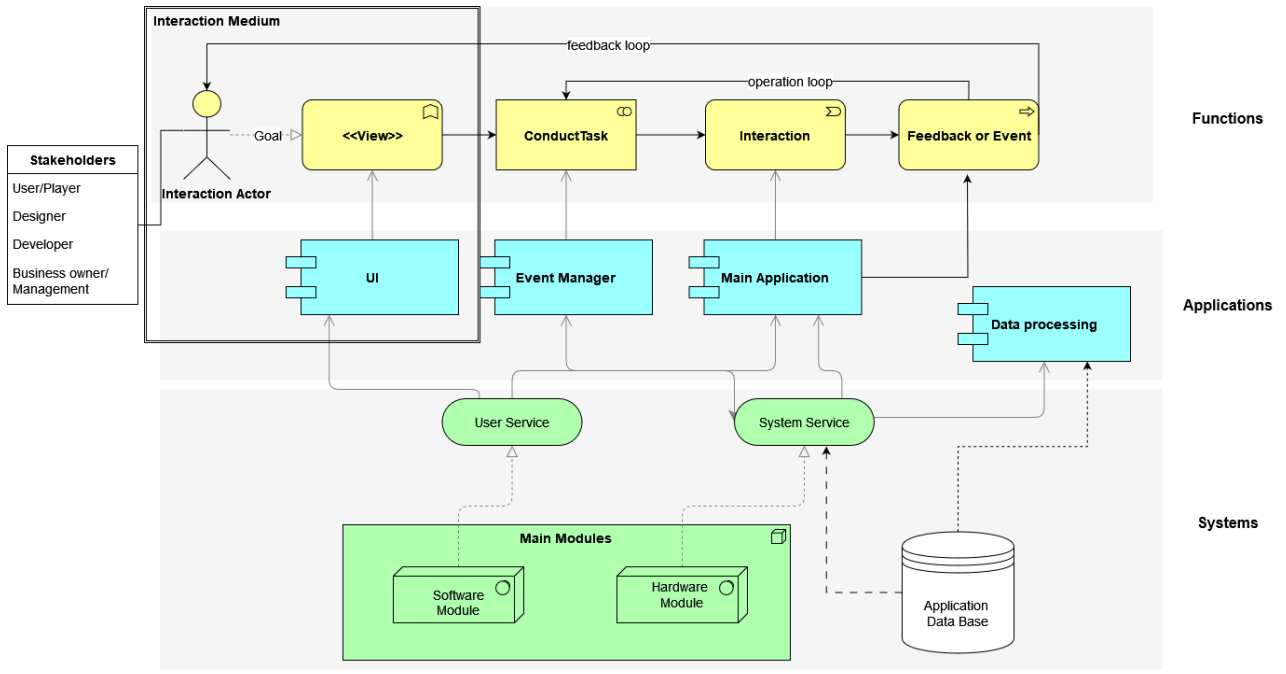

Figure 3 – Human-Computer Interaction Process – Users, Functions and Systems

Interaction processes happen not in the vacuum space, but rather in a real-world environment. This is especially true for industrial, medical, and mobile applications. Figure 4 visualizes the context of use and design impacting factors. Each of the interactive systems should consider usage environment, time and location, where the device and application can be and will be used. Certain tasks and interaction activities influence how a user will interact with the given system, which might add additional constraints and limitations. Differentiating user type and purpose of the system usage is vital in early system design stages, as certain industries and professional environments place a large weight on the end-user goal and step-by-step user-system interaction flow. All of these factors and more are highlighted in Figures 3 and 4.

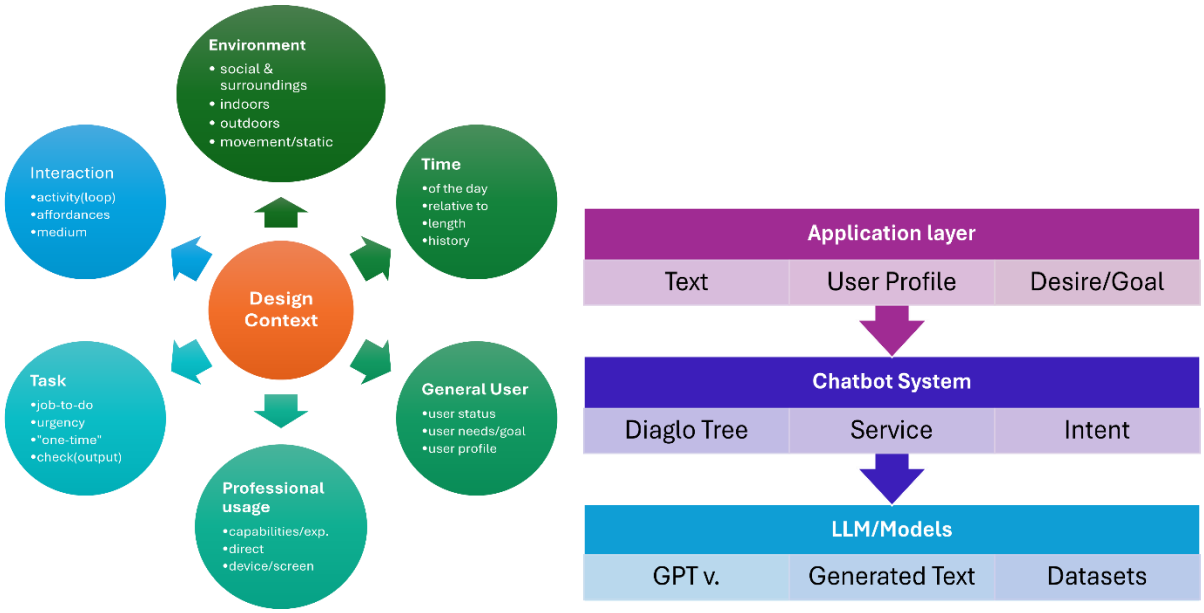

Figure 4 – Interaction Design – Context of Use

Table 3 presents six core interaction process phases (stages, steps). Each new interaction loop starts with the system boot (loading) and concludes with the system shutdown. After the system is loaded and operational, it loads the appropriate user interface (or similar input-output system) and enables a user-system interaction interface. The next phase is the user-system interaction loop and feedback loop, both of them are operating, and loading in parallel. Feedback and interaction can consist of "n" number steps, which are determined by the user or/and by the system. At each interaction cycle of the loop, the decision can be made to either move to the next step or get to the initial system step, or completely shut down the system. The interaction loop stops when the user decides to stop the interaction and the system saves its state and powers off. With this phase the interaction loop is complete, and system is disabled or is operating in the background listening to new input or internal event messages.

Table 3 – Interaction Process

№	Interaction phase	Systems	Components Actors	Result Feedback
1	**System boot**	Power controls Direct Interaction Authentication	Electricity Device User	Load the previous state Load new session Status indicator
2	**Load UI** **Enable Interaction**	GUI Input/Output functions Menu/Controls	Electronic device PC Hardware Application SDK/Libraries	Enable HCI process Controls -> On Interface -> Render Direct/Indirect Ctrls
3...n	**Interaction Loop**	Tasks General Functionality Enhanced Input	User Interface system UI Menu and Navigation	System Input Interpretation User Task(s) Execution
3...n	**Feedback Loop**	Enhanced Output Notification Event manager	System Event Manager UI Manager Data Manager	User Feedback System Task(s) Execution, Scheduling
n	**Decision making**	Action Evaluation System Planning	Application User Task Manager	Internal Application Data save/load Job Status Check
n+1	**Shutdown**	System save state Power Controls	Electricity Device User Data Manager System Event Manager	Save State Check Special Status Status Notification

The more detailed presentation of phase number 3 can be viewed in Figure 4 – Interaction and Feedback loops. Two actors interact with the systems during the loop – the user and the computational (general) system. In the center of the diagram denoted by the yellow rectangles are major system states. The interaction starts with the user action and the input information/task threads. Each new action is recorded and currently being processed by the event queue and Event Manager systems. While the user interacts and waits for the response, computational systems also engage in the interaction process by firing appropriate response and communications messages. The interaction process is part of larger server/client applications and database services (listed at the bottom section of Figure 4).

Algorithm step-by-step for feedback loop design (Figure 4):

1. The user has a goal – and needs to complete the action;
2. System loads and provides appropriate interaction interface;
3. A user interacts with the UI via micro-interactions, input action can be single or multiple;
4. Event Manager processes actions and makes a queue (in case of multiple user activities or based on system requirements/architecture);

5. System loads output – provides feedback based on User Action and Event Manger System via Communication interface system depends on software and hardware architecture, as well as specific application and embedded device software;

6. A user reviews feedback or receives notification from the list of output types, he chooses whether to continue the micro-interaction or stop (or a system event can force a user to stop or continue);

7. The system stops or moves into hibernation/standby modes.

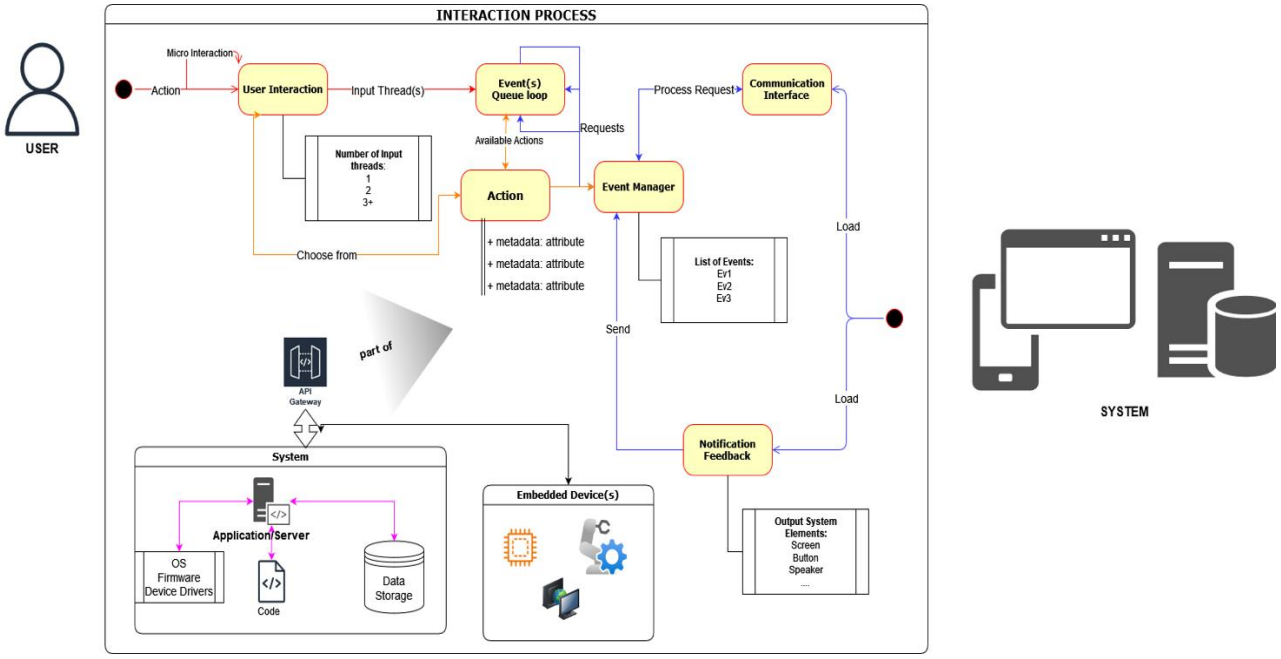

Figure 4 – User Interaction – Feedback Systems and States

Discussion. The modern user interface is a very multilayered and complex system. The user interaction process is no longer limited to simple keyboard types or single-button interactions. There are a great number of widely available interaction devices and output mediums, mobile phone screens, VR glasses, gamepads, and game controllers, but the input-output system is not limited to just the number of devices listed. The user interaction has many steps and stages to it the list of available interaction activities is also great in number. As discussed, the human-computer interaction goes in loops, feedback loops to be precise. The essence of the Human-Computer interaction process revolves around tasks and activities started by the user and processed by the system. The context of use plays an important role in the interaction cycle, as it provides experienced designers with awareness and knowledge of the user, when and how the system will be used. The interaction process itself is made of some steps, components, actors, and systems. Each application has its own interaction and feedback loop. However, implementation can be done based on the system abstraction and certain algorithms, such as feedback loop system and algorithm.

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СИСТЕМИ КОРИСТУВАЛЬНИЦЬКОЇ ВЗАЄМОДІЇ ТА ЗВОРОТНОГО ЗВ'ЯЗКУ В ІНТЕРФЕЙСІ КОРИСТУВАЧА ПРИ ПРОЕКТУВАННІ ЦИФРОВИХ СИСТЕМ

Анотація. *Область «Взаємодія людини і комп'ютера» відповідає за дослідження нових способів і вдосконалення існуючих механік «користувач-комп'ютер» (користувач-пристрої). Процес взаємодії користувача з комп'ютером відбувається циклічно, і для кожної дії користувача або серії дій системи забезпечують відповідний зворотний зв'язок. Є багато видатних дослідників та дослідницьких робіт у галузі HCI, досліджень UI та інженерії взаємодії. Найбільш поширені роботи в області HCI, інтерфейсу користувача і взаємодії циклів зворотного зв'язку. Незважаючи на те, що область досліджень HCI та взаємодії не є новою, існує багато систем та можливостей, які залишилися невивченими або не отримали достатньої уваги. Серед них сфера цифрового дизайну, яка зосереджена на комплексному проектуванні системи, що включає багаторазове одночасне використання, взаємодію, складні взаємодії та зворотний зв'язок з кількома пристроями. Стаття присвячена розгляду актуальних питань щодо спосіб взаємодії людини- користувача з комп'ютерними цифровими системами. У центрі взаємодії додатків, програмного забезпечення і систем знаходиться людина – користувач. Причина, по якій ініціюється і інсталюється процес взаємодії, полягає в тому, що користувач має одну або кілька цілей, яких він хоче досягти. Така взаємодія відбувається, як правило, через відповідний інтерфейс, який може бути: механічним, цифровим, аналоговим, з сенсорним екраном тощо. Існує кілька типів користувачів, які прямо чи опосередковано впливають на цикл взаємодії, користувач або гравець безпосередньо впливає на системи та взаємодіє з ними, тоді як решта команди зацікавлених сторін відповідає за виробництво та підтримку розгорнутого додатку/системи. Певні завдання та активність взаємодії впливають на те, як користувач буде взаємодіяти з даною системою, можуть додавати додаткові обмеження та обмеження. Диференціація типу користувача та мети використання системи є життєво важливою на ранніх етапах проектування системи, оскільки певні галузі та професійні середовища надають*

великого значення меті кінцевого користувача та поетапному потоку взаємодії користувача з системою. Внутрішню комунікацію та логіку обробки систем можна розбити на дві частини – сервіси, орієнтовані на користувача, та модулі внутрішніх служб обробки системи. Для кінцевого користувача відповідного додатку або системи важливим є те, як саме буде реалізований цей процес взаємодії. Тобто, які будуть доступні органи керування, дії для взаємодії та механізми зворотного зв'язку від системи до користувача. Методи дослідження базуються на головних методологіях дизайну та аналізу цифрових продуктів з акцентом на користувальницькому досвіді, дослідженні вимог користувачів, контексту використання застосунку та представлення меню взаємодії з цифровим сервісом. У статті представлено результати детального опису та моделювання головного процесу взаємодії користувача із системою зворотного зв'язку (циклічний процес). Враховано контекст використання застосунку, головні бажання та цілі користувача при взаємодії, а також типи доступних варіантів взаємодії з інтерактивною системою. Представлений у роботі семи-кроковий процес користувальницької взаємодії включає в себе функції, дані, програмні системи та модулі, відповідну архітектуру програмного та апаратного забезпечення та методи внутрішньої комунікації між функціями циклу. Розроблено процес інтерактивної взаємодії, який описує повний цикл від початку до завершення роботи користувача з будь-яким цифровим, аналоговим, обчислювальним пристроєм, додатком, сервісом. Такий процес можна використовувати дизайнерам, розробникам програмного забезпечення, технічних засобів на етапі планування нової інтерактивної системи або удосконалення існуючої.

***Ключові слова**: HCI, інтерфейс користувача, комп'ютерна інженерія, проектування, дизайн.*