ARTIFICIAL INTELLIGENCE AND ITS APPLICATIONS

HUMAN-COMPUTER INTERACTIONS AND INTERFACES

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INTRODUCTION TO HCI

Human-computer interaction (HCI) is *"...a discipline that is concerned with the design, evaluation, and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them..."*

HEWETT ET AL. ACM SIGCHI CURRICULA FOR HUMAN-COMPUTER INTERACTION. 2014.

HCI starting from the **understanding of behaviors, needs, and preferences of users** aims to **design interfaces and interactions that are intuitive, efficient, safe, and enjoyable** by **considering factors such as usability, accessibility, and user experience** with the goals of enhancing human capabilities.

AN HCI EXAMPLE

SIGNIFICANCE

HCI is always present in our everyday life in the modern world: from withdrawing cash using an ATM, to buying a snack using a food dispenser.

So, HCI is important because all devices should have easy-to-use and effective interfaces.

HCI is important to create products that are more successful, safe, functional, etc.

So, HCI should be involved at all stages of design/development of any product.

HCI is important to design/develop user-friendly products that anyone can use.

So, HCI integrates common sense and human/world understanding into products.

HCI is important to use familiar concepts to design easy-to-use products.

So, HCI uses metaphors related to user experiences (folders, books, typewriters, etc.).

TERMINOLOGY AND CONCEPTS

User Interaction: A user interaction is how the user acts on a device (and viceversa).

UI: A user interface (UI) is the space where interactions user-device occur.

UX: The user experience (UX) is how a user interacts with and experiences a product/service (including: utility, ease of use, efficiency, etc.).

HCI: A human-computer interface (HCI) is a UI that allows a human (user) to control a computer (device). In general, a machine is designed to apply some sort of mechanical force, whereas a computer is designed to process and store data; however, both require input from a human using the proper UI to perform the computer functions.

HMI: A human-machine interface (HMI) is a UI that allows a human (user) to control a machine (device). Depending on the application field, an HMI could include different software modules and physical controls, and its complexity could vary: from simple HMIs including levers and buttons, to complex HMIs providing voice/touch controls.

TERMINOLOGY AND CONCEPTS (2)

HCI Main Elements: HCI includes 3 main elements:

- The users (cognitive capabilities, experiences, etc.).
- The tools (computer, mobile phone, website, etc.).
- The context (environment, limitations, etc.).

HCI Principles: HCIis based on 7 principles:

- Use both knowledge in the world and knowledge in the hand.
- Simplify the structure of tasks.
- Make everything clearly visible.
- Make the mapping correct.
- Convert limitations into benefits.
- Design for errors.
- Standardize if everything else fails.

TERMINOLOGY AND CONCEPTS (3)

HCI Design Process:

The HCI design process includes 3 general phases:

1. **Research:** Before design/development starts, target audience and their needs (and related issues) must be studied. The results of this user investigation direct the HCI design process.

2. **Prototyping:** Providing answers to the needs/issues resulted in the previous stage. This phase includes both physical design (materials, colors, interactions) and conceptual design (how a device operates).

3. **Review:** After the finished product is ready, its design must undergo an evaluation involving experts and users to ensure that it complies with specifications and HCI design principles (this could lead to a re-design).

EVOLUTION

This is a brief history of human-computer interaction:

- 1941-44: early computing machines (**research-grade computers**).
- 1963-64: prototypes of point-and-click interfaces (sketchpad, mouse).

At this time, HCI was: function-centered, for specialists (not consumers), mainly mechanical.

- 1983-90: desktop computers and OS (**consumer-grade computers**).
- 1990: hypertexts (**Internet**, websites, webpages).

Before 2000, HCI was: function-centered, with few/no visuals, and with steep learning curve.

- 1999-2000: robot companions (social robotics).
- 2005-2006: **video game** consoles (widespread controllers, GUIs, etc.).
- 2007: mobile OS and **smartphones** (ubiquitous devices/interfaces).
- 2012: head-mounted displays (consumer-grade **VR-AR** interfaces).

Nowadays, HCI is: user-centered, mostly graphics-based, and easy-to-use.

EVOLUTION (2)

HCI emerged in the early 1980s, with the advent of personal computers, as a subfield of computer science initially focused on improving the usability of desktop computers.

With the invention of computer networks and smartphones, HCI shifted its focus from desktop environment to mobile environment; and over time it has expanded to incorporate other disciplines: computer science, cognitive science, and human-factors engineering.

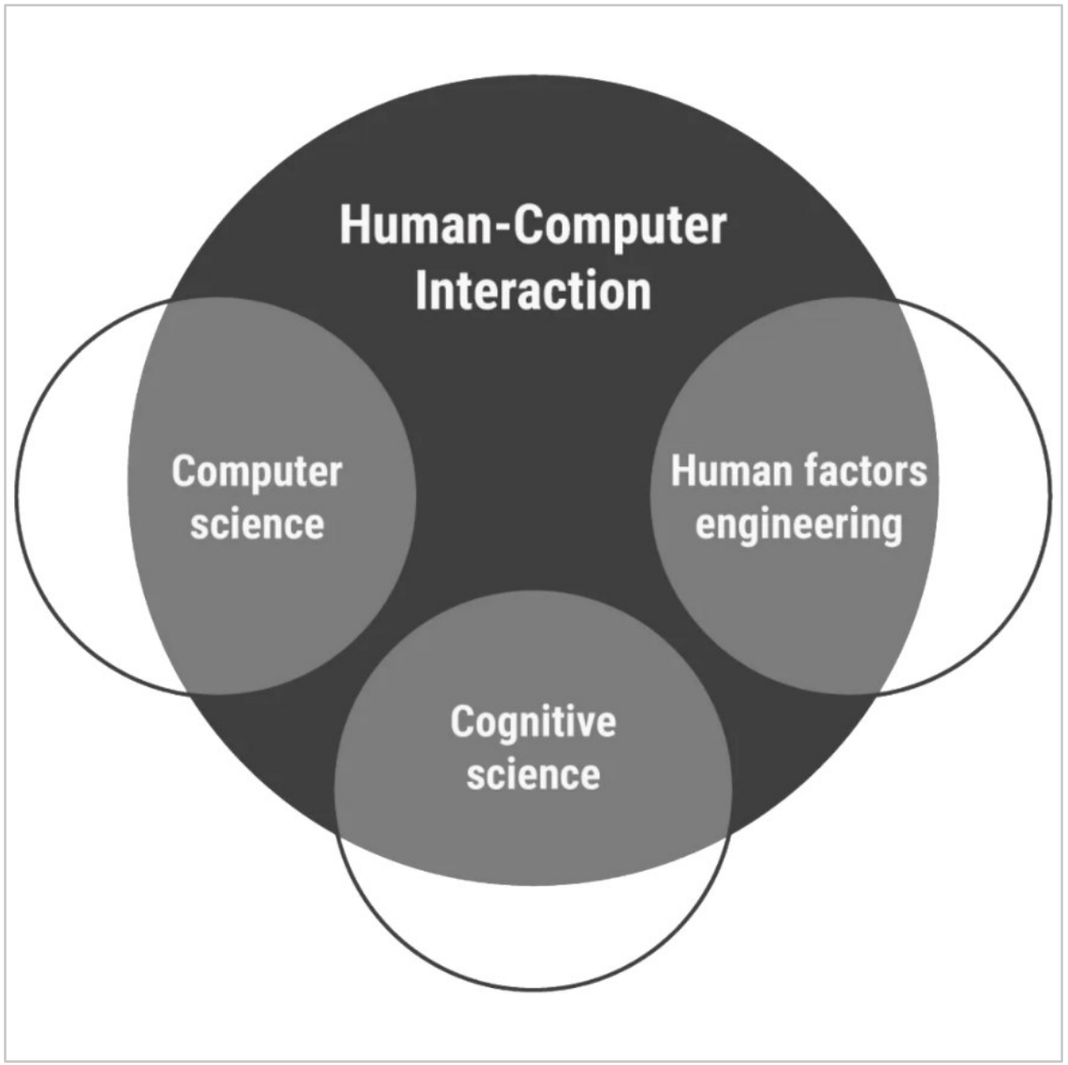
"...it no longer makes sense to regard HCI as a specialty of computer science... HCI expanded from its initial focus on individual and generic user behavior to include social and organizational computing, accessibility for the elderly, the cognitively and physically impaired, and for all people... It expanded from desktop office applications to include games, learning and education, commerce, health and medical applications, emergency planning and response... It expanded from early graphical user interfaces to include myriad interaction techniques and devices, multi-modal interactions, tool support for model-based user interface specification, and a host of emerging ubiquitous, handheld and context-aware interactions."

JOHN M. CARROLL. THE ENCYCLOPEDIA OF HUMAN-COMPUTER INTERACTION (2ND ED.) 2019.

EVOLUTION (3)

HCI involves a multidisciplinary approach, drawing from computer science, cognitive science, and human factors engineering.

Additionally, HCI overlaps with many other fields of study: user-centered design, user-interface (UI) design, user experience (UX) design, and others (*e.g.*, ubiquitous computing, in-vehicle systems, ambient intelligence, etc.).



HCI IN INDUSTRY

Today, we use devices that are more and more complex, and the cognitive load of human-computer interactions has constantly increased together with the operating error rate.

For these reasons, HCI is more critical than ever, and it has provided benefits to several industrial fields. These are just few examples:

- **Healthcare:** HCI has been used rigorously to design medical interfaces focusing on accurate visualization and simple operation for medical instruments.
- **Education**: HCI has been used to improve educational applications as well as to develop alternative methods for e-learning.
- **Entertainment:** HCI has been used to provide users with immersive and engaging experiences in museums, exhibits, live-events, etc.

SUPPORTING TECHNOLOGY

Modern HCI involves a multitude of technologies:

- **Internet of Things (IoT):** Devices that can communicate with each other and with users by combining digital systems with sensors, actuators, and other devices.
- **Motion Tracking:** Technologies that can track in real-time the user/device motion. The outputs can be used to implement novel interactions and interfaces.
- **Speech Recognition:** Technology that can recognize human speech and that can be used to implement voice-based interfaces designed for natural language.
- **VR-AR:** Technologies that allow unconstrained immersive virtual environment and use specialized interface devices useful to design novel HDI.
- **Spatial Computing:** Technologies that use user actions (motions, speech) and physical environment as inputs for interactive systems that use the perceived surrounding environment as the "canvas" for multimedia outputs (video, audio, haptic).

HMI-HCI EXAMPLES

This section shows different interfaces for the same function: **text typing**. In particular:

- A **traditional typewriter** as an example of a function-centered HMI.
- A **modern keyboard** as an example of an HCI still using the typewriter metaphor.
- An **ergonomic keyboard** as an example of an HCI more user-centered.
- Innovative keyboard interfaces considering: different user needs, innovative technologies, different contexts.
    - A **one-handed gaming keyboard**.
    - A **laser projection mobile keyboard**.
    - An **AI-enabled mobile phone keypad**.
    - A **virtual keyboard** for VR-AR.

A TYPEWRITER HMI

The Underwood Model 5 (right), commercialized in 1899, became the most successful office machine of the time, and set the modern standard of how a typewriter worked and looked like.

This HMI (the typewriter) is: function-centered (designed considering mechanical limitations and language properties), with minimal visuals, and definitely not easy-to-use.

A KEYBOARD HCI

In the early 1970s, computer keyboards started to look like what we use today.

In the late 1970s, personal computers started being commercialized including their own keyboards (one of the first was the IBM PC and its Model F keyboard, below).

This HCI (the keyboard) is: using the typewriter metaphor (same layout of keys), is still function-centered (key layout not considering user-hand workspace), is still using minimal visuals, but is now easy-to-use (because of the typewriter metaphor).

AN ERGONOMIC KEYBOARD HCI

The limitations of function-centered keyboards lead alternative solutions.

Starting in 1926, ergonomics keyboards were proposed to solve the issues of standard keyboards. One of the first commercially-successful ergonomic keyboards was the Natural Keyboard by Microsoft (below the 2019 Microsoft Surface Ergonomic Keyboard 4000).

This HCI (the keyboard) is: using only in part the typewriter metaphor (same keys layout, but no grid layout), and is now more user-centered (considering hands orientation).

INNOVATIVE KEYBOARD INTERFACES

An example of an innovative user-centered HCI: a one-handed gaming keyboard designed for video gamers, allowing at the same time the typing with the left hand and the pointing-and-clicking with the right hand.

INNOVATIVE KEYBOARD INTERFACES (2)

An example of an innovative user-centered HCI: a laser projection mobile keyboard designed for mobile phone users, facilitating typing by increasing the size of the keyboard surface relying on laser projection and infrared finger tracking.

INNOVATIVE KEYBOARD INTERFACES (3)

An example of an innovative user-centered HCI: an AI-enabled mobile phone keypad, the Nokia 7110 was the first mobile phone to integrate the T9 predictive text method to facilitate the composition of SMS text messages using a 9-keys keyboard.

INNOVATIVE KEYBOARD INTERFACES (4)

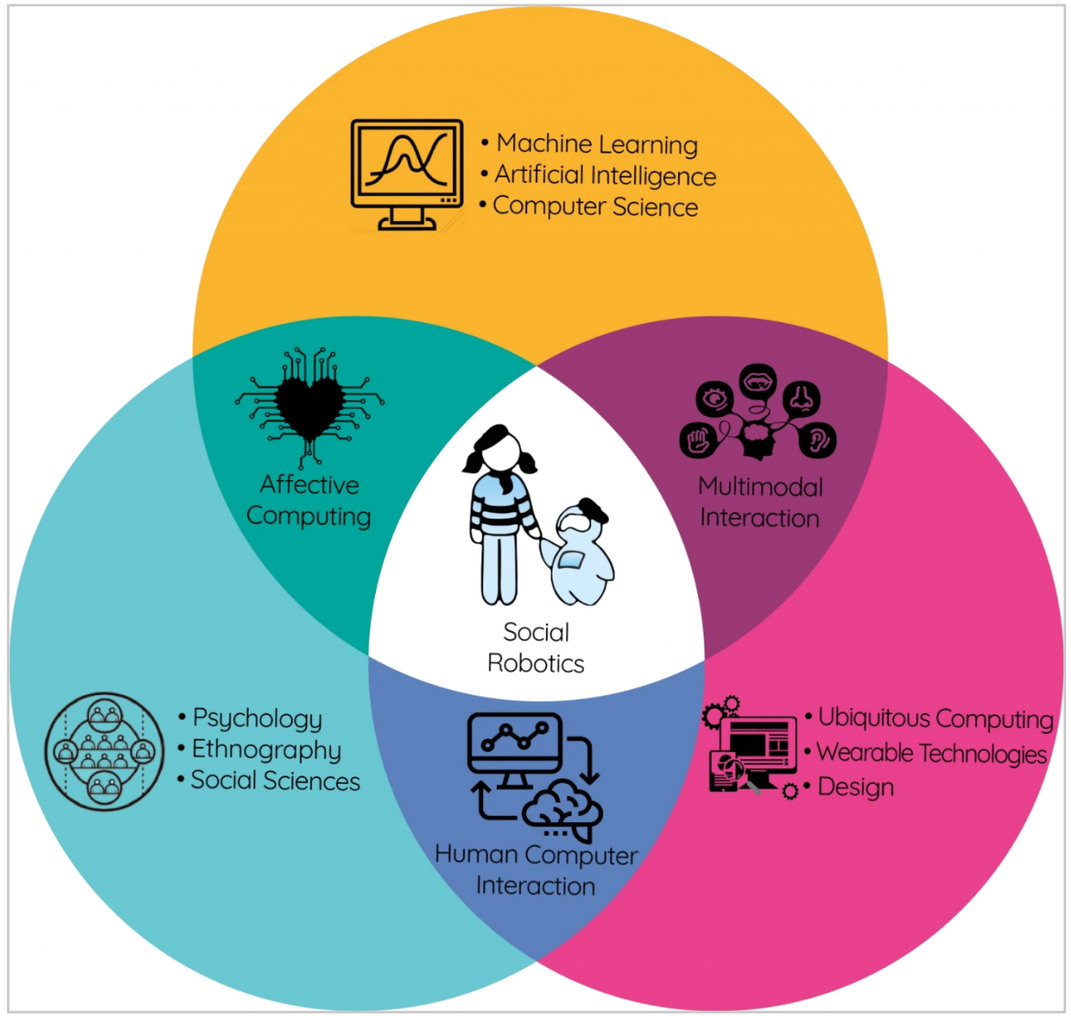
An example of an innovative user-centered HCI: a virtual keyboard for VR-AR, allowing text typing by using controllers and replacing the lack of haptic feedback with visuals and sounds.

AI AND HCI

Nowadays, the cognitive load of human-computer interactions constantly increases together with the operating error rate.

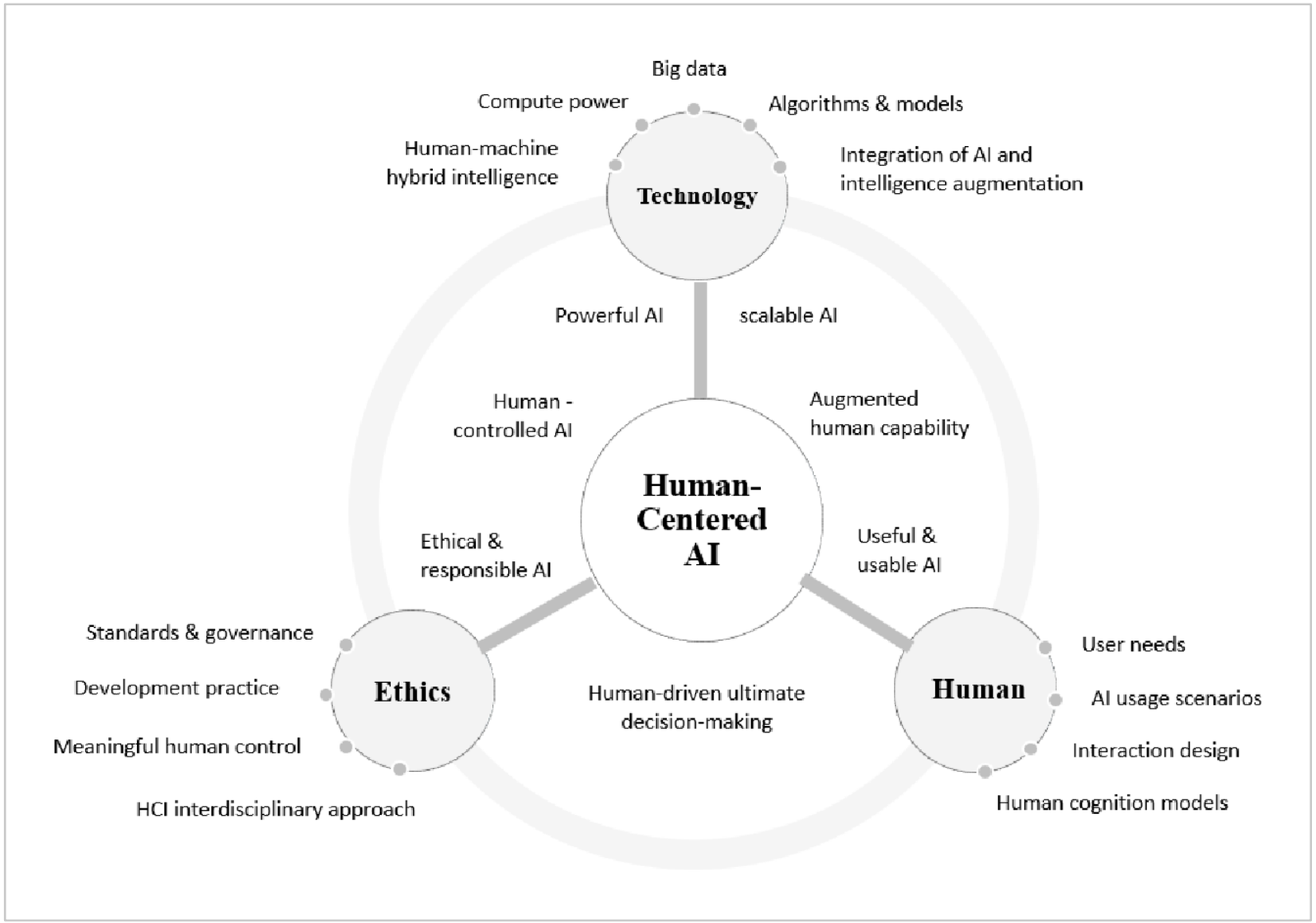
This has promoted the integration of AI techniques into HCI interfaces, opening new possibilities for humans and computers to interact.

AI algorithms have been developed to use user feedback with the goal of automating/facilitating a variety of HCI tasks: from UX design, to accessibility, and human-AI collaboration.



HUMAN-CENTERED AI

HAI: Human-centered AI (HAI) studies algorithms that are continuously improving because of human input while providing an effective human-computer experience.



HUMAN-CENTERED AI (2)

Implementing HAI should focus on these areas to ensure it is most beneficial to its users:

- **Understanding UX:** Research to understand UX, including: user surveys, focus groups, and customer interviews. Then use this data to design AI applications.
- **Design/Implement AI Applications:** Create AI apps to assist users in their tasks.
- **Evaluate Results:** Test the performance of a prototype of the AI app, monitoring user interactions, and evaluating their UX.

These are some of the areas included in Human-Centered AI (HAI):

- **The Internet of Behavior (IoB):** A system that uses sensors and other technologies to monitor, analyze and predict human behavior. It combines AI, big data, Iot, VR-AR, etc.
- **Affective Computing:** Systems that can detect, and simulate human emotions and moods. It combines computer science, psychology, and cognitive science.

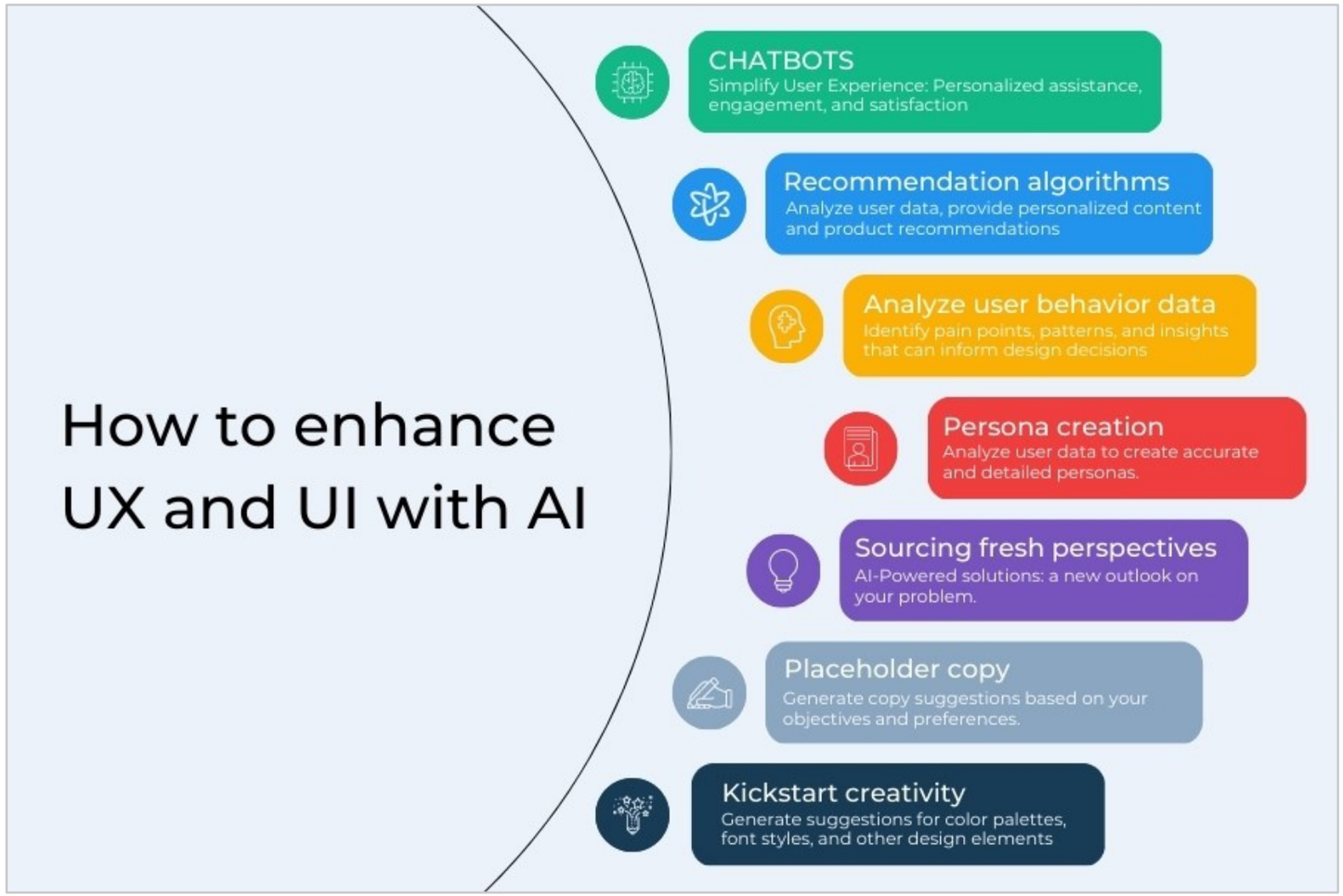
AI-SUPPORTED UX DESIGN

UX design has started integrating AI techniques to more efficient and successful products:

- By using AI technology UX designers can gain insights, recognize patterns effectively, and accurately predict user behavior.
- AI algorithms can analyze huge amounts of user data (browsing habits, preferences, and interactions) enabling the design of tailored user experiences.
- AI tools can be used to automate user testing. These tools conduct tests on prototypes and gather data that is used to create user-centric products.
- AI can help to enhance accessibility. UX designers can use AI tools to ensure that their products are inclusive and accessible to all users.

See: UX Planet - *"AI in User Experience (UX) Design: A Fresh Approach"*

AI-SUPPORTED UX DESIGN (2)



See: Usability Hub - *"AI and UX Design"*

AI FOR SPEECH AND TEXT

These are some of the examples of AI applications to text- and speech-related tasks:

- **AI-Powered Writing Assistants:** Systems supporting correct writing also considering the stylistic elements using AI technology.
- **AI-Based Text-to-Speech Generators:** Technology able to convert text to speech by using generative AI to create realistic voice overs for digital content.
- **AI-Enabled Speech-to-Text Transcribers:** AI tools capable of understanding and converting user conversations into text transcripts.
- **AI Multimodal Translators:** AI systems able to translate from speech or text into speech or text, supporting multiple languages.
- **AI Service Chatbot:** AI software designed to simulate a realistic conversation with a human user for customer service or other supporting systems.

HUMAN-AI COLLABORATION

Today, AI is mainly used to automate processes. However, some of the most outstanding performances are achieved when AI systems and humans work together. This human-AI collaboration allows humans and AI to complement each other's strengths:

- **Human Strenghts:** Leadership, teamwork, creativity, social skills, etc.
- **AI Strenghts:** Speed, scalability, quantitative outputs, etc.

Humans Assisting AI: Humans can assist AI by: (1) traininig AI to perform certain tasks, (2) explaining the AI outcomes (of the tasks performed by AI), and (3) sustaining the responsible use of AI.

AI Assisting Humans: AI systems can assist humans by: (1) amplifying humans cognitive capabilities, (2) automating low-level tasks, and (3) extending humans physical capabilities.

See: HBR - *"Collaborative Intelligence: Humans and AI Are Joining Forces"*

AI FOR DECISION-SUPPORT SYSTEMS

Today it is easy to gather data, and then analyse it; however, the decision-making process can be challenging, even after finishing a complete data analysis.

A Decision-Support System (DSS) bridges the gap between data analytics and decisions.

A DSS can be completely managed by AI, or humans, or a mix of both.

An Intelligent Decision Support System (IDSS) is a DSS powered by AI.

These are some real-world applications for IDSSs:

- Robo-advisors can **help novice investors** in the stock market.
- Online streaming services can **recommend TV shows** to viewers.
- Medical doctors can use an IDSS to facilitate **detection in medical imaging**.
- Marketing staff can use an IDSS to **model buyer personas**.

See: *Sisu - "What is a Decision Support System in Artificial Intelligence?"*

AI-HCI CHALLENGES

AI-HCI integration raises some concerns:

- The level of autonomy of the AI system (the degree to which humans are involved in the AI system), and its transparency and explainability.
- The ethical and social implications of their use (accounting for cultural, social, and ethical values and norms of the users and the contexts).
- The privacy, security, and consent of the users and their data.
- The complexity, uncertainty, and diversity of users and environments (the variability, ambiguity, and unpredictability of human behavior, language, and emotions).

Finding the proper balance between technological advancement and preserving human values (the trade-off between efficiency, accuracy, and fairness) is critical for ensuring that AI provides maximum benefits.

AI-HCI OPPORTUNITIES

AI-HCI integration also offer some opportunities:

- Enabling new forms of AI-driven interactions enriching user experiences.
- Inventing new modes of expression in creative domains by using generative AI.
- Leveraging collective intelligence by drawing wisdom from users and communities.
- Empowering users to create/personalize/control their own systems and experiences.

In the future: devices will not wait for user commands but will understand and anticipate user needs, user-device conversations/interactions will be as fluid and natural as those between humans, and AI will tailor unique user experiences designed ad-hoc for each different user.

AI-HCI FUTURISTIC EXAMPLES

These are some example of futuristic applications of HCI:

- **Touchless 3D Modeling:** Designing a product in 3D using VR-AR technology.
- **Smartphones:** Novel materials/technologies will accomodate new interfaces.
- **Seamless Data Editing:** Modifying files seamlessly between apps and devices.
- **Work Meeting:** Controlling virtual/in-person meeting using novel interfaces.
- **Smart Appliances:** IoT home devices with innovative user interfaces.

In the future, HCI will be: faster and more precise, integrating multiple technologies in a single device, with a faster learning curve, and with a high degree of mobility.

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