HCI Research and Education in the Netherlands

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Executive Summary

The CHI NL Research and Education Overview. This document provides an overview of the Human-Computer Interaction research and education activities currently performed in the Netherlands. The overview aims to raise awareness of the importance of HCI research and education in the Netherlands. It is addressed to researchers, policymakers, and practitioners interested in HCI research and education to design a digital society that prioritizes the well-being of its people and fosters a more sustainable, equitable, and inclusive world.

To this end, this document serves several purposes:

1. Describe the role and importance of HCI research and education (Section 1).
2. Provide an overview of the Dutch HCI research landscape and the scientific research challenges (Section 2).
3. Provide an overview of the Dutch HCI education landscape (Section 3).

The Dutch CHI Community. This overview has been created as part of the Dutch ACM SIGCHI Chapter (CHI NL) Lobby activities. The Netherlands has a strong HCI community performing world-class HCI research and featuring a broad HCI educational offer. CHI NL is a foundation that connects, supports and represents this community. Historically, CHI NL has played a large role in promoting Human-Computer Interaction research and its application in the Netherlands. Most visibly, this was achieved through organizing conferences such as CHI Sparks and The Web and Beyond, smaller themed meetings, and the Gerrit van der Veer prize for student theses. After a prolonged period of lessened activity, CHI NL was reinstated as an official ACM SIGCHI Chapter in 2022. The mission of CHI NL is to 1) connect professionals in HCI within and (particularly) across academia and industry, 2) support professionals in HCI in academia and industry, and 3) to represent HCI professionals in relevant circles.

Why an overview? Despite its long tradition, the HCI community in the Netherlands misses a clear and concise delineation of the ongoing research and education activities and a coherent outlook on the important areas of interest for the near future. Therefore, the CHI NL chapter initiated a coordinated, collaborative effort to create this overview of the HCI Research and Education in the Netherlands.

The writing process. The overview collects inputs from dozens of scientists and educators in the Netherlands. It is edited[1] by Professors Regina Bernhaupt (Eindhoven University of Technology), Alessandro Bozzon (Delft University of Technology), Pablo Cesar (CWI and Delft University of Technology), Judith Good (University of Amsterdam), Judith Masthoff (Utrecht University), and Nava Tintarev (Maastricht University and Delft University of Technology). The journey of the document started with a retreat of the "Lobby" Task Force of CHI NL (Alessandro and Pablo) in the summer of 2022 at CWI, followed by a public event in October 2022 at TU Delft's "Design for AI Symposium," to introduce it and solicit contributions. A draft document was presented to the community in April 2023 during the ICT Open; feedback has been gathered and incorporated into this version.

1 Editors and contributors are listed in alphabetical order

1. Introduction

Future society: an ecosystem of people and digital technologies. As we envision the future of our society, it becomes increasingly evident that it will be an ecosystem where people and digital technologies are deeply intertwined. This development presents tremendous economic opportunities and a significant responsibility. In the rapidly changing digital landscape, it is essential to recognize that a digital society should be tailored around people, not technology. While technology evolves at an unprecedented pace, human nature has remained relatively constant. It is, therefore, not surprising to continuously encounter examples where technology still needs to deliver on its promise of improving people's well-being. Digitally enhanced ecosystems must be understood, designed, and engineered comprehensively and holistically, highlighting the need for an integrative human- and society-centric approach to digital innovation.

With the Netherlands as a key player, Europe has taken a leading role in addressing these challenges. The globally adopted 17 Sustainable Development Goals[1] (SDGs) call for technical innovations tightly connected to social innovations. More broadly, Europe has embraced these goals[2] and is strongly committed to creating a more sustainable, inclusive, and prosperous future for all. Horizon Europe[3], the European Union's research and innovation program, has identified "A human-centered ethical development of digital and industrial technologies" as one of its key destinations. This focus highlights the importance of integrating ethical considerations and human values into developing cutting-edge technologies. The Dutch government has formulated a mission-driven innovation policy concentrating on four societal missions: Energy transition and sustainability; Agriculture, water & food; Health & Care; and Security. These missions emphasize the need for societally situated technical innovations that address complex global challenges while placing people at the center of the digital revolution. By adopting human- and society-centered approaches, Europe and the Netherlands are poised to create a future where digital technologies and human values coexist harmoniously.

HCI's pivotal role in ICT research and education. In this context, Human-Computer Interaction (HCI) research plays a vital role in shaping the future of our digital society. At its core, HCI is concerned with *"the design, evaluation, and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them."*[4] As the first interdisciplinary field of Information and Communication Technology (ICT), HCI integrates knowledge and practices from diverse domains, such as computer science, design, psychology, sociology, ergonomics, communication science, law, linguistics, neuroscience, and urbanism.
HCI research advances state of the art in various topics, including (but not limited to) interaction with digital technology (theories, techniques, systems); understanding and modeling of systems and people in context; user experience and usability; digital accessibility; design tools, processes, methods, and principles; and visualization. While these topics are not unique to HCI research, they are distinctively approached through key enabling research and design methodologies that facilitate a principled understanding, design, and engineering of digitally enhanced socio-technical ecosystems.

1 https://sdgs.un.org/goals
2 https://ec.europa.eu/eurostat/web/products-eurostat-news/-/wdn-20210615-1
3 https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe_en
4 https://dl.acm.org/doi/book/10.1145/2594128 - from the ACM SIGCHI Curricula for Human-Computer Interaction

Societal Impact of HCI Research and Education. HCI research has a long tradition and a track record in supporting the achievement of desirable economic, industrial societal, and planetary goals. A recent citation analysis[1] over 20 years (from the 1980s through 2018) of patents from the *United States Patent and Trademark Office* (USPTO) shows that HCI research greatly impacts innovation. HCI research is recognized for its ability to foresee opportunities and issues with emerging technologies, painting a compelling vision of possible futures while driving technological and societal innovation[2]. This has been partly acknowledged in the recent *Design Engineering Sciences sector portrait*[3] and the *Sectorplan Techniek II*.

Many challenges at the core of Dutch and European agendas **cannot be addressed without HCI research and education advances**. HCI research is key to understanding the evolving relationship between people, technology, and society. Through the methodological richness and decades of experience in interdisciplinary and transdisciplinary research, HCI research contributes human- and society-centered approaches to all sectors of economy and society, but especially in key application domains such as health and well-being, the future of work, learning, and education; mobility; urban and built environments; and governance. HCI is also essential for achieving sustainable goals through changes in people's and societal perspectives on their relationship with digital technology.

The Netherlands has a unique opportunity to bolster HCI research and education and to consolidate its role as a major international player in this critical field. Through world-class HCI research and education, the Netherlands will generate significant economic growth within and beyond the ICT sector. Moreover, HCI research and education will contribute significantly to creating a future that effectively balances the needs and desires of people with the opportunities and challenges presented by rapidly advancing digital technologies.

2. The Dutch HCI Research Landscape

Human-Computer Interaction (HCI) is an interdisciplinary research field concerned with studying, designing, evaluating, and implementing digital technology used by individuals, groups, or communities to achieve a specific goal. While initially concerned with computers, HCI has since expanded to cover almost all forms of digital technology and, more recently, biotechnology and emerging materials. HCI research focuses on the *interactive* and *experiential* relations between people and technology; it seeks to understand and improve such relations to enhance user experience, usability, accessibility, and overall satisfaction.

The relationship between HCI research and other disciplines. HCI research is fundamental for successfully implementing and adopting computer technology that interacts with humans. It is, therefore, natural for HCI research to engage with state-of-the-art computer technology such as Artificial Intelligence (e.g., Machine Learning, Computer Vision, Natural Language Processing, Recommender Systems, Generative AI), Data Science (e.g., database systems, search engines, user modeling, and personalization), Robotics, VR/AR/XT, Data Visualisation, Sensing, etc. However, HCI research distinguishes itself from its neighboring computer science research through its solid theoretical foundations rooted in cognitive sciences (e.g., psychology, sociology, linguistics), the humanities (e.g., arts, philosophy, anthropology), health sciences, and biology; and through its

1 https://arxiv.org/abs/2301.13431

2 20.1% of papers from premium SIGCHI-sponsored venues are patent-cited; the proportion of cited scientific paper is 1.5%. "HCI research diffuses into the industry at a similar rate as Computer Vision (25%) and at a higher rate than NLP (11%), both areasof substantial industry funding and interest.". Source https://arxiv.org/abs/2301.13431

3 https://d2k0ddhflgrk1i.cloudfront.net/Calendar/2021/06%20June/Sector%20Portrait%20-%20Design%20Engineering%20Sciences%20%28English%29.pdf

emphasis on qualitative and quantitative research and design methodologies. This broader view on computational technology allows for principled understanding, design, and engineering of digitally enhanced socio-technical ecosystems.

Similarly to the rest of computer science research, HCI research aims at designing computational systems that are *trustworthy* (i.e., explainable, contestable, and transparent), *safe* (i.e., robust to technical malfunctions, privacy-aware, and ethically and value-aligned), and *just* (i.e., accessible to all, usable and personalizable, adaptable and empathic, fair and bias avoiding). In addition, current HCI research puts a strong emphasis on values, such as: *sustainability*, referring to the design and development of technology that promotes long-term environmental and social well-being, and *democratic*, emphasizing design and development approaches (e.g., inclusive co-design, co-development, co-evaluation) that can ensure equal access, participation, and representation for all users, regardless of their background, abilities, or resources.

Characterizing the Dutch CHI NL Research Landscape. The Netherlands has a strong HCI community performing world-class HCI research and offering broad HCI education. When writing this document, the CHI NL community features 20 research units from 8 universities, two research institutes, and three universities of applied sciences. The list of organizations officially part of CHI NL is available at *https://chinederland.nl/hci-in-nl/.*

Dutch CHI researchers mostly operate within Computer Science, Information Science, and Design faculties. Traditional venues for HCI research are SIGCHI (SIGCHI - Special Interest Group on Computer-Human Interaction) Conferences[1] (e.g., CHI, UBICOMP, CSCW, DIS, HRI, IUI, UIST, IMX) and journals[2] (e.g., ACM TOCHI, ACM Interactions, Computers in Human Behavior); however, HCI-related conferences and journals are also featured in other international interest groups such as SIGACCESS (Accessible Computing), SIGCSE (Computer Science Education), SIGIR (Information Retrieval), SIGMM (Multimedia), SIGMOBILE (Mobility of Systems, Users, Data & Comp), and SIGWEB (Hypertext, Hypermedia, and Web), the Design Research Society, and others.

To facilitate a coherent overview of the areas of HCI research where there is critical mass in The Netherlands, we organize current research challenges around three objects of study for HCI research: *interactions* (Section 2.1), *tools* and *methodologies* for the *design* of HCI systems (Section 2.2), and *tools* and *methods* for the evaluation of HCI systems (Section 2.3).

2.1 Interaction Modes

Interaction in HCI is a polysemous word that can assume different meanings based on different theoretical and empirical mindsets[3]. *Interaction* represents more than the simple interplay between a human and a computer system, although this traditional notion can still be used. More broadly, *interaction* concerns two entities that influence each other's behavior over time. Based on this characterization, we organize the current research challenges around different types of entities: *humans* (in all their different roles as actors in digitally enhanced socio-technical systems), robotics technology (Section 2.1.1), data technology (Section 2.1.2), AI technology (Section 2.1.3), computer-supported communication technology (Section 2.1.4), multimedia technology (Section 2.1.5), and creative technology (Section 2.1.6).

1 https://sigchi.org/conferences/past-sigchi-conferences/
2 https://sigchi.org/publications/
3 In their 2017 CHI Paper (http://www.kasperhornbaek.dk/papers/CHI2017_Interaction.pdf), Hornbæk and Oulasvirta define interaction as "simply … the core of HCI". They identify seven concepts of interaction: Dialogue, Transmission, Tool Use, Optimal Behaviour, Embodiment, Experience, and Control. In the same paper, the authors advocate for an improvement in the scope and specificity of the term.

2.1.1 Human-Robot Interaction

Human-Robot Interaction (HRI) is a multidisciplinary field (incl. robotics, artificial intelligence, engineering, cognitive science, psychology, philosophy, and design) that studies the interaction between people and robotic systems. Studying human-robot interactions frequently involves physically embodied robots, which sets it apart from other computing technologies. Embodied interaction has the potential to shift away from user interfaces traditionally developed for human-computer interaction, such as control panels or screen-based interfaces, and move toward more natural modes of interaction. These modes of interaction are based on how people connect and include verbal and non-verbal forms. Robotic systems often appear autonomous, interactive, and adaptive, prompting people to perceive these systems as social actors. Consequently, users mentally reason about these systems and may attempt to interact with them as if they were human, pushing the boundaries for humanlike interaction.

The field of HRI focuses on developing robots that can interact with people intuitively within various everyday environments, which opens technical, social, and design challenges. Technical challenges result from the complex dynamics of human social spaces, while design challenges relate to the system's appearance, behavior, and sensing capabilities to inspire and guide the interaction. Social challenges involve human affect, social cognition, and behavior during human-robot interactions. More specially, identified issues include designing effective and appropriate robot appearances, interventions, and behaviors. This means leveraging robot learning capabilities while implementing strategies to prevent unintended consequences. These strategies should enable properly calibrated or appropriate trust from humans towards the robot. Appropriate trust also relies on anticipating societal impact and steering towards not only "accurate", but also morally (personal and normative) and ethically (community- or society-prescribed) acceptable application scenarios. A final challenge is the effective and fair allocation of tasks between humans and automation.

2.1.2 Human-Data Interaction

Human-Data Interaction (HDI) is an umbrella term that describes a broad research area focusing on understanding, designing, and evaluating how humans create, process, visualize, and make sense of data, information, and knowledge. HDI encompasses several disciplines, including computer science, data science, information science, artificial intelligence, data visualization, information visualization, psychology, and design. HDI concerns how people interface with data from physical, cognitive, perceptual, interactional, and social perspectives. HDI aims to develop tools, techniques, and methodologies to enable people to engage with data, communicate, make informed decisions, and achieve their goals efficiently and effectively.

Each phase of the data lifecycle propagates different technical and ethical challenges, from data collection and curation to data visualization and interaction. In HDI research, data *collection* is typically performed through *sensing* devices - i.e., physical, visual, and aural acquisition -- and *wearables* -- i.e., technology incorporated into clothing or accessories -- that sense and transmit data about the people's physical state, activities, and environment. Sensing devices and wearables are essential for developing interactive systems that can adapt to the user's needs, preferences, and context and provide real-time feedback and interventions when necessary. Common challenges for data collection systems include issues of acquisition (e.g., quality, ecological validity); integration (e.g., multi-modal fusion); user experience (e.g., comfort, usability, aesthetic); social and cultural acceptability; privacy, security, ownership, and contestability; and scalability and robustness.

Data quality is a long-standing and enduring problem that has received re-newed attention due to the popularisation of data analytics, machine learning, and decision-support applications, and the acknowledged relationship between (lack of) data quality and biased and harmful outcomes. Data *curation* includes activities -- such as annotation, cleaning, and transformation -- that are primarily performed by people (crowd workers, annotators, data scientists) whose social/cultural/educational background and working practices directly affect data quality. Common challenges in data curation include provenance and transparency of curation processes, quality metrics, and evaluation benchmarks; lack of guidelines and standardized practices; lack of support tools for personalized, scalable, privacy-by-design, domain-specific, and explainable data curation.

Data interaction technology leverages human senses (vision, hearing, touch) to support reasoning over complex data. The design space of data interaction ranges from standard static charts to novel interactive representations of tabular, network/graph, time, or text datasets or algorithms and often incorporates computational methods, such as techniques for high-dimensional data and machine learning. Visualization and interaction can be performed in various settings, including desktop, mobile, wearables, AR/VR, and physical. Traditional data interaction challenges relate to humans' physical, perceptual, and cognitive limitations and display and computational limitations. Additional pressing challenges in the digital society include interaction techniques as tools for policymaking, policy communication, decision-making, and explainability of AI systems. HDI research is strongly empirical and includes both quantitative and qualitative evaluation methods. Both domain-specific and societal settings impose additional evaluation challenges due to the tacit knowledge of domain experts, the inherent complexity of data and tasks, and issues of diversity and inclusivity of vulnerable or marginalized populations.

2.1.3 Human-AI Interaction

Human-AI interaction is an umbrella term that describes a broad research area focusing on the interaction between humans and artificial intelligence systems, such as research on conversational systems, virtual humans, Human-in-the-Loop systems, and personalized systems. Conversational AI systems (e.g. chatbots, virtual assistants, voice assistants) use dialogue to interact with humans, based on natural language processing technology. Virtual humans simulate human appearance and behavior, typically in virtual, augmented, and mixed-reality settings. Human-in-the-loop systems use human supervision or intervention to ensure the quality and reliability of AI output. Personalized systems automatically adapt to individual users' characteristics (e.g., knowledge, interests, personality, motivation) and context.

Main challenges for human-AI interaction systems include ensuring: (1) human awareness of the system's limitations (especially for more human-like interaction); (2) system transparency and trustworthiness; (3) intuitive and effective interaction; and (4) integration into system design of human values (societal values such as fairness, non-discrimination, democracy, and personal values such as friendship, independence, comfort). Additional challenges for conversational AI systems include (1) ensuring user engagement; (2) enabling the detection of and recovery from ambiguities, misunderstandings, and conversational breakdowns; and (3) personalization of conversations, including the drawing on previous interactions. For virtual humans, additional challenges are: (1) realism of appearance, facial expressions, and body movements; (2) social and emotional intelligence, appropriately dealing with social situations, portraying emotions, and reacting to human emotions; (3) cultural awareness (e.g., regarding facial expressions, gestures, personal space, social norms); (4) the ethical and diverse representation to avoid potential biases or discrimination; and (5) accessibility for people with special needs. Additional challenges for human-in-the-loop systems include (1) prevention of cognitive overload of human operators; (2) provision of human operator awareness of the complex/dynamic situation and the system's state; (3) clear and effective ways for humans and AI to collaborate; (4) prevention of human cognitive biases and errors. Additional challenges for personalized systems include (1) providing users with transparency and control regarding the usage of personal data and personalization; (2) interaction and interface design to support fairness, serendipity, and diversity and prevent bias and filter bubbles; and (3) ethical considerations on what systems are allowed to do.

2.1.4 Computer-Supported Communication and Interaction

Computer-Supported Communication and Interaction focuses on the design and use of technologies that affect groups, organizations, communities, and networks[1]; enabling new ways of living and working together. As a result of globalization and deployment of interactive systems, the way we work and live has significantly changed, where groups of people are often spread across the globe. They also break up and are refactored more frequently than ever before. This has significant consequences in terms of cohesion, serendipitous information exchange, and collaboration opportunities. This area of research is already covered in other sections like Human-Data Interaction (e.g., Web and social media) and Human-Media Interaction (e.g., media-based interaction).

Computer-Supported Communication and Interaction brings several challenges related to groups of people collaborating: understanding, modeling, and interaction support. For example, there is a need to develop adequate theoretical frameworks for helping understanding group dynamics at the micro, meso, and macro level. Moreover, instrumentation of the environment (particularly in mixed ones) and data collection is hard due to basic restrictions. Finally, modeling the dynamic interactions based on the theoretical frameworks require a cross-disciplinarity approach, extensive datasets in ecologically valid settings, and multimodal machine perception of social and linguistic information. Such models should be able to dynamically support groups of people communicating and collaborating, providing the right digital processes and information during the interactions in an automatic manner. Core research topics include the development of automatic techniques to model the affective and cognitive processes associated with individuals and groups, when interacting. This includes computational approaches to understand, in real-time, group processes for collaboration and cooperation, hybrid intelligent support systems that allow the adaptation and optimization of the systems based on such understanding, and the provision of new metrics and assessment mechanisms, grounded in theoretical frameworks, to evaluate the interactions.

2.1.5 Human-Media Interaction

Human-Media interaction refers to the interface and interaction through which people share, process, and act upon information, engaging users interactively. The media can exist as (a combination of) images, video, light, sound, haptic, and olfactory elements and can include virtual, real, and mixed reality elements. This research area includes media-based experiences (from authoring to consumption) and media-based communication (embodiment of the loops of interaction). Human-media interaction is omnipresent in society and in all aspects of our lives, from entertainment to education to health and well-being. It is a multidisciplinary field, including a wide range of disciplines, including design, multimedia engineering, media studies, and media psychology and sociology.

Key challenges to be considered include media-based communication, new content forms and formats, creation production tools and workflows, media experience understanding and assessment. In the area of media-based communication, some relevant challenges include the design of cross-modal interactions combining various media to optimize mutual communication, experience and wellbeing; personalization of media interactions to support diversity, inclusivity, accessibility, health and wellbeing; the support of immersion, presence, engagement and coherence of the final integrated experience; understanding how to scale up media interactions from individual interaction to group interaction to mass interaction at society level; and the choreography to ensure the interactions are ethical, secure, safe, and resilient. New content forms and formats is a broad topic, including multi-sensory and immersive media, affective augmentation systems, and large-scale deployments like games and broadcasting. Core challenges include the understanding of human multi-sensory perception-action loops in natural dynamic multi-modal interfaces; the visualization and sharing of hidden physiological data using different modalities and using diverse media; characterisation of immersive (XR) experiences towards immersion, presence,

1 https://sigchi.org/conference_series/cscw/

engagement and coherence of the final integrated loop of interactions. Applications include development of gaming and sport research in order to ensure that they remain a positive pastime for users as a stress reliever, providing social connections, and can be applied in serious contexts and can consider complex societal issues. Finally, the production workflow and tools, together with the assessment of media experiences continue to be an active area of research, given the new formats and the reach of media-based experiences. Many challenges remain at the production, distribution, and user levels, including the use of AI-based tools and technologies for the creation of media; production workflows that incorporate the user (and audience); object-based production platforms for developing and deploying immersive and interactive multi-screen productions; Socially-aware multimedia authoring for empowering end-users to create and share media based on storytelling principles; and protocols and mechanisms (including physiological signal methods) for evaluating immersive and interactive experiences, including objective and subjective data acquisition, analysis methods, and objective modeling of experience.

2.1.6 Creatvie and Artful Interactions

By Creative and Artful Interaction, we refer to HCI research that impacts the creative industries and the Digital Humanities through the development of technological innovations. In the Netherlands, Creative Industries was designated one of the ten priority sectors for heavy government investment in 2011. Digital humanities focus on developing computational approaches to humanities questions and digitizing humanities archives and cultural heritage articles. DH in the Netherlands, notably under the umbrella of CLARIAH, remarkably contributed to analyzing textual, audio, and audio/oral archival material. Creative and Artful Interactions emphasize the creation of new technologies with usability and human-centered applications in mind. Current AI technologies are a prominent example of technologies that give little room for (user) testing and adaptation. With their black-box policies, recently commercialized AI systems brought with them interactional, ethical, and legal challenges unseen before. We exemplify opportunities and challenges with a representative technological advancement that significantly impacts creative industries and Digital Humanities alike: Generative AI.

AI algorithms require a steep learning curve and heavy investment in computational resources. However, with the increasing availability of pre-trained models and cloud services, the level of expertise needed to use AI technology continues to decrease, creating “hybrid” experts who bridge the gap between technology and arts with much more ease. The latest Generative AI models greatly simplify the analysis of textual and visual materials. Likewise, with tools such as ChatGPT, Midjourney, Dall-E, or Stable Diffusion, it has become possible to create intricate 2D/3D visual materials, poetic texts, or enjoyable music via simple interfaces and descriptive sentences. Finally, these models simplify several downstream tasks, such as generating/populating thousands of web pages based on a few samples, or the automatic design and development of applications based on short descriptions. These opportunities also bring relevant challenges: maintaining human expertise in the loop, especially for the sake of adequately addressing user needs for the automatically created services, apps, and tools; the speed of adaptation and the resources needed to invest for such updates; copyright issues and sharing of copyrighted materials and private information with commercial enterprises.

2.2 Design Theories and Methodologies

Theories and methodologies are central to design practice. By defining the roles and agencies of those involved in the design process, they carry ideas about what design and designing could be, and therefore, what should be matters of concern in HCI (i.e., its purpose, the values to which we should uphold, the measures of rigor, and legitimate procedures). Various methods, tools, approaches, and design processes have been developed over time, shaping the HCI agenda and its priorities. In this context, we consider approaches that place emphasis on different units of analysis and (hence) units of design: (a) human-centered, based on needs and desires (Section 2.2.1),

(b) (behavioral) data-centered (Section 2.2.2), (c) material-driven (Section 2.2.3), and (d) more-than-human (human-nonhuman) (Section 2.2.4).
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2.2.1 Human-Centered Design

Human-centered design is an approach that prioritizes the needs, wants, and limitations of the people who will ultimately use the product, service, or system being designed. The goal is to create effective, intuitive, and enjoyable solutions but also create real value. As such, human-centered design is often seen as the counterpart of technology-driven innovation and used to mitigate technological push.

Grounding design on real needs requires gaining a deep understanding of potential users. This is achieved by conducting contextual and user research that, through interviews, surveys, observations, and other forms of data gathering, allows to surface needs, desires, values, habits, and pain points.

Contextual and user research insights are elaborated into several research artifacts, such as personas and journey maps, intended to inform the design process and keep it tight to human needs. Insights are ultimately used to define design requirements that reflect the needs and desires of the target audience but also provide specific, measurable, achievable, relevant, and time-bound actionable design directions. Given the focus on human needs and desires, human-centered design extensively leverages participatory practices to ensure a rich understanding of the target audience and assess the fit of the designed interventions.

Human-centered design is often challenging to practice because it is time-consuming and resource-intensive and may have to mitigate conflicting values and views, especially when working with diverse groups of people and entities. As effective collaboration and communication and design approaches tailored to each case are needed, human-centered design requires specific expertise. In addition to this general complexity, human-centered design is confronted with three major challenges: 1) fast-paced technological developments, 2) lack of inclusivity, and 3) lack of ecological view. Technological developments on the one hand come with a strong technological push that is diametrically opposed to the overarching scope of responding to human needs of human-centered design and, on the other hand, the complexity of technology makes it hard for people participating in design to express meaningful and informed opinions. Regarding inclusivity, there is now a growing awareness of the fact that, despite human-centered and participatory practices that aspire to make design inclusive, specific social groups tend to remain excluded and neglected, resulting in products, services, and systems that may be discriminatory for those groups. Last, due to the focus on primary users, human-centered design has been shown to be short-sighted and ends up neglecting how the needs and wants of people may conflict with the ones of the environment, resulting in processes incentivizing non-sustainable design interventions.

2.2.2 Data-centric Design

Data-centric Design is an approach for collaboratively generating design-relevant insights from behavioral data (e.g., from sensors, self-reports, or system logs), complementing the qualitative design and research methods. Data-centric Design lies at this intersection of Design and Data Science to strengthen Human-centered Design approaches while opening avenues for responsible and effective use of behavioral data. It is the critical bridge between Human-Centered Design and Data Science to support effective yet responsible use of data in HCI research.

On the one hand, the foundation of Human-Centered Design lies in democratic processes and a strong focus on user needs. Digitalization makes data a central part of this process, thus creating concerns, tensions, and friction between the design solution and the use of data. On the other hand, designers must recognize the power of behavioral data to inform, drive, and evaluate their design. This tension raises critical challenges to address to harness data effectively and responsibly in HCI research, revolving around three challenges: 1) there is an abundance of data and an access scarcity. There is data about everything, yet researchers and people whose behavior is captured in the data cannot meaningfully access it. 2) data is currently explored in isolation because of the silos it is captured from, the privacy -preserving processes it must comply with, and the complexity arising from data trails. This keeps the focus on 'thin' data while much HCI research benefits from 'thick' (e.g., qualitative for a small number of people) data. 3) means of leveraging data as a boundary object to connect and collaborate remains limited. This prevents tapping into the expertise of data participants, leveraging personal data with appropriately informed consent, and supporting meaningful and reciprocal exchange of values.

2.2.3 Material-Driven Design

The drive for embedded material interactions, exemplified by the emergence of ubiquitous and physical computing, has seen a reimagining of what we consider computational materials in HCI in recent years. Prominent in these lines of research is a material-driven design approach that sees efforts to understand machines and materials as having agency in the design process. Material tinkering and making is a means to logically think, learn, and understand materials to unlock their design potential. Bringing together knowledge and expertise from materials science, engineering, textiles, biology, advanced manufacturing, and interaction design, such work unveils how material qualities are tuned for desired functions and experiences that make interactive artifacts remain more relevant in our daily lives. The outcome is often new material compositions, supporting a move away from strong boundaries between physical, digital, and biological, broadening HCI design space with materials as diverse as smart/animated textiles, 3D-4D printed metamaterials, bacteria, and fungi.

The temporal capacity of both smart/computational and living materials from microorganisms to assume multiple aesthetic expressions and functions that unfold only over time (and in context) poses diverse technical and methodological challenges. Furthermore, designing with novel materials leads to societal challenges concerning user-acceptability (e.g., would people accept wearing and engaging with a living interactive garment made with fungi?) and ethical challenges when designing with living materials. Furthermore, the newness of such materials and processes might give designers the impression that a mere transformation of a new material to any application has value. This view can hinder a deeper investigation of its impacts on society and the planet. Hence, the implementation of sustainability in HCI materials remains a challenge.

2.2.4 More-than-human Design

More-than-human design is an approach that shifts the focal point of design concerns from exclusively human to include the diversity of living organisms and systems (e.g., microorganisms, fungi, plants, animals, rivers, mountains, etc.) and technological systems (e.g., conversational agents, internet of things, artificial intelligence, architecture, infrastructures, etc.). Designers and researchers, like all human beings, are part of extensive ecosystems within which it is not exclusively humans that act and produce effects; microorganisms, plants, and animals do so, too. More-than-human design engages the world of living things as a place where humans are considered alongside other living entities. Alongside living non-humans, the increasing presence of AI technologies creates an urgency for design research to expand the community's understanding of what to expect from technologies and rethink relations from the notion of tools towards collaborating agents.

Through this approach and views, the values and aims of the human are de-centeralized, and design is directed towards more complex understandings of future cohabitation with other forms of life, matter, and intelligence that blur the boundaries between humans, non-humans, and technology. The challenge is also to move away from the narrow focus on final artifacts and build new theoretical and methodological frameworks for how the community can understand the process of material making and, in turn, advance HCI's impact on culture, sustainability, materiality, design, and making practices.

2.3 Evaluation Tools and Methodologies

HCI evaluation tools and methodologies provide insights into improving designs and systems (so-called formative evaluations) and measuring how good a design or system is (so-called summative evaluations). Evaluation includes, for example 1) *Usability and user experience evaluation*: Research in this area aims to develop and evaluate tools and methodologies for measuring and improving usability and user experience. This includes expert-based evaluations (e.g., heuristic evaluations, consistency inspections, predictive human error analysis, and cognitive walkthroughs), usability testing, user surveys, diary studies, interviews, focus groups, and observations. 2) *Accessibility evaluation*: This focuses on ensuring that digital products and services are accessible to everyone, including those with special needs. Research in this area has focused on developing and evaluating tools and methodologies for accessibility testing, including automated testing tools, manual testing techniques, and user testing with people with special needs. 3) *Data visualization evaluation*: With the increasing use of data visualization in various fields, research in this area aims to evaluate the effectiveness of data visualization tools and techniques. This includes evaluating the accuracy and usefulness of visual representations of data and the usability of the tools used to create and manipulate visualizations. 4) *Personalized systems evaluation*: Research in this area aims to develop and evaluate tools and methodologies for measuring and improving the effectiveness of systems that automatically adapt to users. An example is the layered evaluation method and the use of simulated users. 5) *Emerging technology evaluation*: With the rapid pace of technological innovation, research in this area aims to develop and evaluate tools and methodologies for evaluating emerging technologies such as virtual, augmented, and extended reality, wearables, and smart devices. 6) *Collaborative evaluation* involves working with users and other stakeholders in the design and evaluation process. Research in this area aims to develop and evaluate collaborative evaluation methods, such as co-design, participatory design, and participatory evaluation. There is also research in specific application domains (for example, on evaluating digital behavior change interventions or interactive education systems).

Key challenges in this research area are: 1) the balance between scientific rigor and practical relevance: evaluating any technology system or interactive system is complex and a multidisciplinary task that requires a balance between scientific rigor and practical relevance. 2) Addressing diverse user groups needs tailored methods and tailored tools, considering their different perspectives and experiences. 3) Evaluation methods cannot stand alone: They need integration into the design and development processes to ensure that the design meets the user needs and that evaluation measurements are feasible during the design process to inform design iterations. 4) Ethical concerns: While there is a detailed debate about the ethics of novel technology, evaluation systems must be able to represent, address, and respect these ethical guidelines (e.g., to what degree and detail to gather data, to enable users to opt out of any automatic behavior tracing, etc.). 5) Interactive systems are dynamic per definition; thus, evaluation is challenging as it must represent dynamic behavior and changes over (large periods). This is particularly the case for personalized systems that automatically adapt to users. 6) Evaluation of each aspect, not just the complete system, is needed. To gain deep insights into how to improve systems and what works and what does not, each system aspect (whether it is a system feature or a process as in the layered evaluation of adaptive systems) needs to be evaluated as far as possible in isolation, in addition to evaluating the system. 7) Ensuring the scalability of evaluation methods: Evaluation methods and tools must be scalable to evaluate large-scale interactive systems, such as those used in e-commerce or social media. Researchers must ensure that their evaluation methods and tools can be applied to large and complex systems while still providing meaningful and relevant results.

3. HCI Education in the Netherlands

The Netherlands offers HCI education at universities, universities of applied sciences (HBO) and many professional colleges (MBO). This section provides an overview of the programs and courses and identifies several opportunities.

Landscape: In terms of master's programs, the universities in the Netherlands offer the following:

- Design for Interaction[1] from Delft University of Technology
- Human-Computer Interaction[2] from Utrecht University
- Human-Technology Interaction[3] from Eindhoven University of Technology
- Industrial Design from Eindhoven[4] University of Technology
- Integrated Product Design[5] from Delft University of Technology
- Interaction Technology[6] from Twente University
- Media Technology[7] from Leiden University
- New Media Technology[8] from Tilburg University

And the universities of applied science, the following:

- Data Driven Design[9] from the University of Applied Sciences Utrecht
- Digital Design[10] from the Amsterdam University of Applied Sciences
- Game Technology[11] from Breda University of Applied Sciences

In addition to the existing master's programs, several bachelor programs in Dutch universities include HCI tracks, all of them offering specific courses at the bachelor's and master's levels.

Opportunities: HCI education has quite a strong footing in the Netherlands: it is taught at most research universities, all universities of applied sciences (HBO), and many professional colleges (MBO). This means that most professionals in the digital industries have been introduced to HCI-related topics. Still, there is room for improvement to ensure that HCI becomes a core topic for the next generation of professionals in the Netherlands. Most of the master's programs on HCI at Dutch universities focus on design and media technologies, apart from the ones at Twente University and Utrecht University. There is an opportunity for strengthening collaboration on HCI education across all educational levels (universities, HBOs, and MBOs), creating complementary programs at different faculties (including computer sciences), and forming a new generation of professionals on HCI.

1 https://www.tudelft.nl/en/education/programmes/masters/design-for-interaction/msc-design-for-interaction
2 https://www.uu.nl/en/masters/human-computer-interaction
3 https://www.tue.nl/studeren/graduate-school/master-human-technology-interaction
4 https://www.tue.nl/en/education/graduate-school/master-industrial-design
5 https://www.tudelft.nl/onderwijs/opleidingen/masters/msc-integrated-product-design/msc-integrated-product-design
6 https://www.utwente.nl/en/education/master/programmes/interaction-technology/
7 https://www.universiteitleiden.nl/en/education/study-programmes/master/media-technology
8 https://www.tilburguniversity.edu/education/masters-programmes/new-media-design
9 https://www.hu.nl/voltijd-opleidingen/master-data-driven-design
10 https://www.amsterdamuas.com/programmes/master-digital-design
11 https://www.buas.nl/en/programmes/master-game-technology

4. Outlook

This document is intended to raise awareness of the importance and extent of HCI research and education in the Netherlands. It provides an organized overview of research areas currently active in the country and several running education programs.

The overview highlights the presence of a critical mass of world-class HCI research and education activities backed by a growing community of scientists, educators, and practitioners. We believe the Netherlands should now capitalize on this rich ecosystem to consolidate its role as a major international player in this critical field by bolstering HCI research and education. In addition to better addressing human needs, this will generate significant economic growth within and beyond the ICT sector. The history of HCI has shown these mutual benefits consistently through the decades. CHI NL could be instrumental in this purpose by offering fertile ground for continuous cross- and trans-disciplinary dialogue.

Future activities include the drafting and distributing of a research and education agenda for HCI research in the Netherlands and further activities to improve synergy in education. In this direction, there is an opportunity for the creation of a National Research School on HCI, connecting researchers and PhD students, like the ones for Information and Knowledge Systems (SIKS), the Advanced School for Computing and Imaging (ASCI), Interuniversity Center for Educational Sciences (ICO), or the Research school for Media Studies (RMeS).

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