Software and Human Centricity

This paper presents the challenges identified by NESSI[1] for engineering human-centric software and digital services, and recommendations for research and innovation to address those challenges.

Motivation

Humans have very individual values, personalities and characteristics, and differ in age, gender, ethnicity, culture, language, education, socio-economic status and in many more ways. Moreover, human preferences are changing over time. It is not well understood how all these human factors and their interrelationship can be addressed in software and digital services.

Designing, developing, deploying and maintaining software-based systems is technically very challenging and many issues remain to be solved. The human-centric issues are often overlooked in the building of such systems. These issues include the critical human factors relating to different aspects of software engineering, such as personality, emotions, gender, age, disability, values and culture, and any other human factors involving customers, designers, developers, testers and end users.

The transformational impact that digitalisation has on humans and society needs to be better understood; the Internet is an ongoing social experiment. Digitalisation is rapidly taking place in Europe, with smart homes, smart transport systems, autonomous cars, industry 4.0/5.0, smart government and smart health care among the drivers. For example, developing the human-centric concept of Industry 5.0 requires a deeper understanding of all the direct and indirect positive and negative effects that the use of advanced digital technologies has on workers. Fundamental research is needed to provide these insights and to extend existing knowledge and models for human-centric software and digital services.

NESSI advocates that software engineering research should evaluate the impact of human-centric issues on software usage and acceptance, requirements engineering, design, testing, project management, and software maintenance and support. Specifically, software engineering will have to focus on capturing the complex end-user needs of next-generation solutions, considering diverse mental and physical capabilities, differing emotional reactions to technology, and diverse language, cultural and socioeconomic backgrounds. Software engineering must take account of the increasingly distributed and diverse nature of development teams, with differing personalities, work culture, engagement, commitment, gender and age. Other considerations include the increasingly complex nature of organisations deploying and maintaining digital solutions, and concerns over privacy and trust as well as trustworthiness of AI-driven solutions. Incorporating human-centric issues into software engineering for next-generation solutions is therefore critical for a productive and secure digitalization.

Finally, software engineering will have to ensure that next-generation software systems do not conflict with one or more of the European human values of inclusion, tolerance, justice, solidarity and non-discrimination[2], causing expectation mismatches and reducing usage, take-up and acceptance of software-driven solutions.

[1] NESSI (Networked European Software and Services Initiative), the European association promoting research, development and innovation in the field of software, data and digital services; http://www.nessi.eu/

[2] https://ec.europa.eu/component-library/eu/about/eu-values/

What is Human Centricity?

Digital technology acceptance is becoming important. It requires the evaluation of how people and society react to and adopt it in their everyday lives. This involves consideration of the psychological and sociological influences technology has on humans, and raises questions about the trustworthiness of digital technology and the fear and suspicion about it and especially about the motivations of the people and organisations that create and use it. In recent years we have seen an increasing emphasis on digital trust, and we can expect that issues around human centricity will become more pressing due to the increasing proliferation and pervasiveness of IoT and AI and developments such as the Metaverse.

Human centricity aims to achieve societal acceptance of software and digital services via two key objectives: that the asset in question is *ergonomic* ("relating to or designed for efficiency and comfort in the working environment"[3]) and *trustworthy* (worthy of trust: "firm belief in the reliability, truth, or ability of someone or something"[4]). The notion of trust is also related to risk via the trustor's belief in the reliability, truth, and the abilities of the trusted entity: if this belief is misplaced or betrayed, the trustor may be harmed or disadvantaged. Thus human centricity is also about ensuring that humans and human values play a central role in the implementation of software systems and digital services.

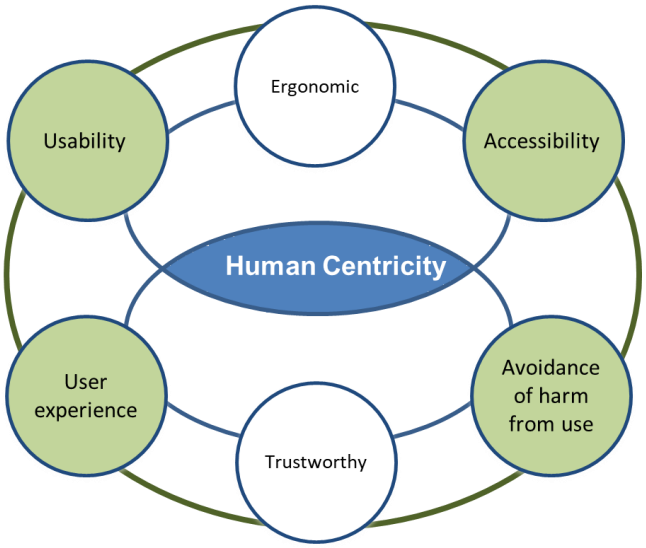

Figure 1 Human centricity: finding the optimal balance among closely interrelated attributes

The Horizon Europe 2021-2022 work programme on digital industry and space[5] advocates multidisciplinary teams from social sciences and humanities (SSH) to achieve human centricity:

> "SSH should provide a variety of human-centric approaches to develop smooth collaboration in the human-machine teams; to improve user experience; and increase awareness comfort, trust, skill and safety (physical and social) of workers in highly automated industrial environments by incorporating a greater understanding of linguistic, historic, and cultural concerns of end-users and workers, while taking into consideration a gender and intersectional perspective;"

[3] https://www.lexico.com/definition/ergonomic
[4] https://www.lexico.com/definition/trust
[5] https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/horizon/wp-call/2021-2022/wp-7-digital-industry-and-space_horizon-2021-2022_en.pdf

ISO 9241-220[6] standards cover the ergonomics of human system interaction and define basic aspects of a human-centred design. Both the statement in the Horizon Europe programme and the ISO standard serve NESSI as a starting point for considerations about human-centred software and digital services - in a wider perspective, not limited to industrial environments.

NESSI's interpretation of human centricity is finding the optimal balance among closely interrelated attributes to achieve acceptance of a software or digital service asset. Given the foci above, in simple terms, to be human centric the asset in question must be widely usable and accessible, safe to people, and should provide a positive user experience.

Usability

ISO 9241 defines usability as "the extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use".

This is about the user interface and what type of interactions – e.g. keyboard, voice, gesture and so on – the interface supports, and it includes a broader range of issues about the fitness for purpose and how reliable, robust, performant, and resilient the software is, in order to be used in an effective, efficient and satisfying way. Moreover, it addresses not only end-user facing software but also for example APIs that need to be usable by software developers and admin interfaces for system operators.

Accessibility

According to ISO 9241, accessibility is the extent to which products, systems, services, environments and facilities can be used by people from a population with the widest range of user needs, characteristics and capabilities to achieve identified goals in identified contexts of use. The aim in designing for accessibility is to widen the target population, thus making products, systems, services, environments and facilities more accessible to more people in more diverse context of use.

That means that software systems and digital services need to have human-centric design and features that make them more usable by everyone: to people with different cultural background, with disabilities and changing abilities due to aging, having access to specific devices or only to a slow internet connection, when driving a car or being in an emergency, etc. Accessibility may also refer to features that help to avoid vendor lock-ins (e.g. supporting data portability) or overload with irrelevant information.

User experience

The user experience "is a person's perceptions and responses that result from the use and/or anticipated use of a system, product or service. User experience focuses on the user's preferences, attitudes, emotions and physical and psychological responses that occur before, during and after use. A positive user experience, especially in terms of how easy or pleasing an interactive system is to use, can provide value to the user and/or to the organization that provides the interactive system".

User experience and usability are overlapping concepts, and therefore the terms are often used interchangeably. Following the ISO 9241 definition, usability is about getting a job done, while user experience is about the feelings resulting from the using the software. Thus good usability is not sufficient for a positive user experience. For example, the lack of personalization of an app or concerns about data sharing and privacy might impact the user experience in a negative way. Also, user experience is individual and may differ between people, and it can also change over time.

[6] ISO 9241-220:2019: Ergonomics of human-system interaction — Part 220: Processes for enabling, executing and assessing human-centred design within organizations. https://www.iso.org/standard/63462.html

Avoidance of harm from use

"Harm from use is the negative consequences for health, safety, finances or the environment that can result from use of the system, product or service. Human-centred design can help reduce the risk of harm from use arising from inadequate usability, accessibility or user experience."

In case of IoT systems it is obvious that defects in usability, accessibility, and user experience can have negative consequences including serious damage to the environment or to people. However, software systems and digital services in general can cause harm. For example, unsecure e-commerce applications can lead to financial loss; software of bad quality and with frequent failures can negatively impact the reputation of the company using this software. Emphasising active protection and following ethical principles in the design and operation of software can provide a competitive advantage to a company and can help to attract the best employees.

What does Human Centricity mean for software, digital services and data?

Human centricity of software, digital services and data technologies aims to make these technologies and the solutions based on them acceptable to humans. Ergonomic design makes software and services widely usable and accessible, and helps people to trust the software because when using it they have a positive experience, and they feel safe and respected.

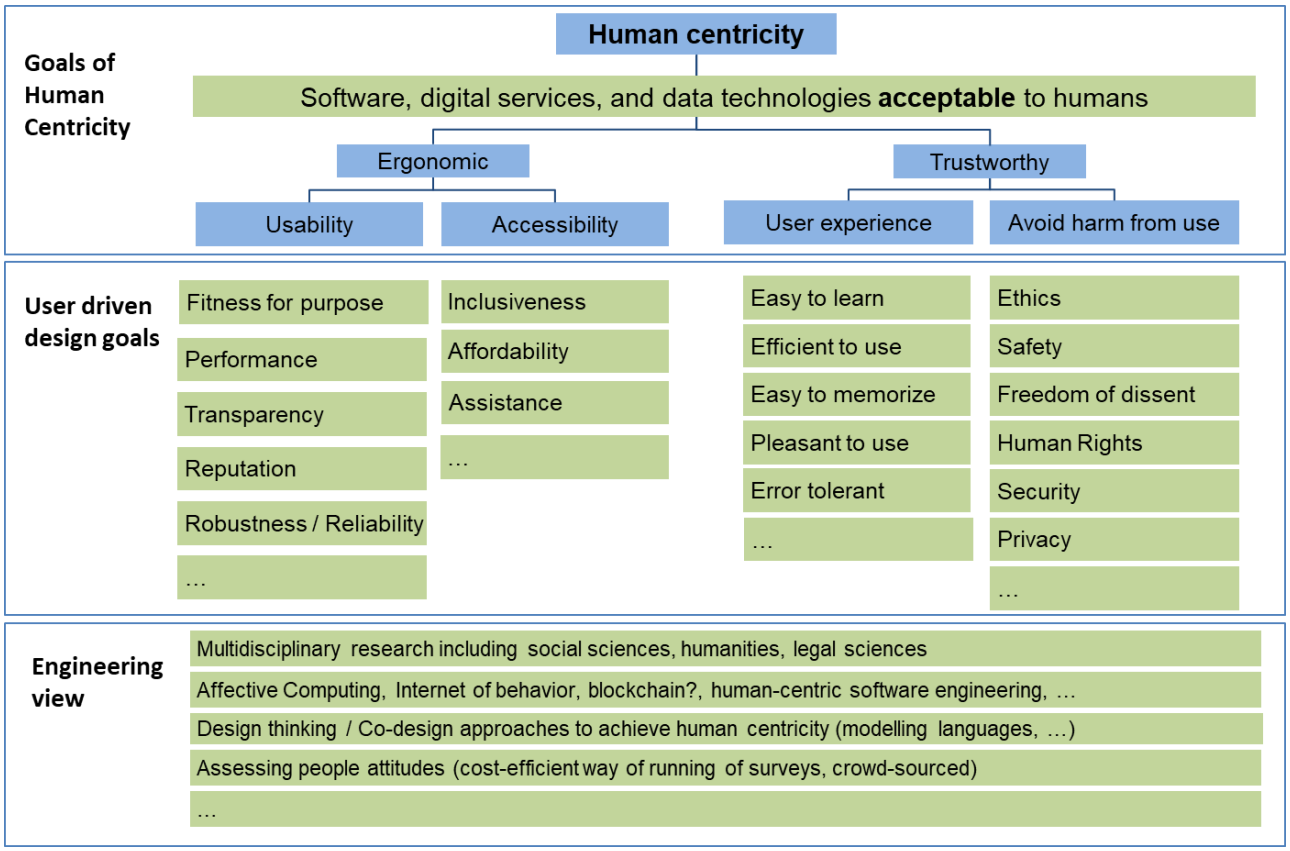

Figure 2 Human centricity and design goals

The lists of human centric aspects and related design goals are extremely long and challenging[7]. Gender, ethnicity, age, culture, personality, values, physical and mental abilities are among the key aspects of the human perspective and should be among the drivers for the design goals of software and digital services. Some of these aspects may conflict with each other, and need to be adapted to concrete use cases and individuals. Finding the right balance among all the different aspects will be at the centre of an approach to human centricity.

Major challenges to addressed include the following.

- Societal attitudes change over time. Multidisciplinary studies of social attitudes and changes – including longitudinal studies into technology acceptance – are needed to get the basic understanding and the feedback required for the human centric design and update of software and digital services.
- Software and digital services are tools which may be used for good or ill. Understanding who is misusing these and how they are being misused requires research into mechanisms to identify and research into countermeasures to address harms from misuse of software, services and platforms (e.g. propagation of misinformation and hate using social media).
- Companies use of citizens' data is often not transparent and can lead to mistrust. Alternative business models and easy to use mechanisms that provide transparency, data sovereignty, and privacy protection to users need to be investigated.
- To be able to develop human-centric software we need to research and develop software engineering methodologies that explicitly involve multiple disciplines (especially the relationships between social sciences and humanities, economics, law and ICT), taking the different perspectives into account over the whole of the software lifecycle, from design and development through evolution and update to decommissioning. A better understanding of the various facets of human centricity still needs to be developed; human centricity is about transparency, trust, openness (including e.g. data portability), privacy, ease of use, inclusiveness, technology acceptance and many more. There is need for interdisciplinary teams and transdisciplinary research that blends the socio with the technical. Specific research questions include: how to integrate co-creation approaches in a more systematic and cost-efficient way across the entire software development lifecycle; how can that work for continuous integration / continuous deployment (CI/CD) pipelines; will that mean automated and continuous monitoring of the user behaviour and how that could be aligned with privacy requirements?
- How to make people accountable for their actions online? In the real world you have *one* identity (legal person); in the online world you have many identities and perhaps some AI-based agents might even take decisions on behalf of you, so misbehaviour is not so 'accountable'. Research is needed to understand how real identities can be linked to online identities and intelligent agents, to encourage acceptable behaviour and to make people more interested in their online identities and the consequences of misbehaviour.
- How to ensure any attempt at accountability and audit of users does not violate their right to privacy? Online accountability for both providers and users needs to be balanced against fears and threats of surveillance or invasions of privacy, and appropriate trade-offs will need to be explored.
- There is a need to investigate commercial drivers for human-centric software and digital services, covering the following questions. How to motivate people to use and to pay extra for human-centric software? What are the business models and drivers for human-centric software and digital services?

[7] Human-centric software engineering for next generation cloud and edge based smart living applications, John Grundy, 2020 20th IEEE/ACM International Symposium on Cluster, Cloud and Internet Computing

How can people assess that the software is really human centric? Would certification and a quality label for human centricity be seen as attractive, and how would its values be clearly communicated to the general public so they see value in it? If this is to be pursued, identification of criteria for certification is needed. Motivations for service providers in providing human-centric software and digital services, and how human centricity impacts reputation and trustworthiness of a company, should be investigated. Can human centricity be a competitive advantage?

- Investigations are needed into public acceptance of software and digital services that conform to the themes of human centricity as described in this document. This involves communicating the themes of human centricity in lay language, so that the benefits of a human-centric software or digital service can be comprehended.

Recommendations

Meeting the challenges identified above will require support for research and innovation in multiple disciplines. Investment in software-related research is needed in Horizon Europe to support the following.

- Inter- and transdisciplinary research including social sciences and humanities is required to develop these insights and to apply them through the entire lifecycle of human-centric software and digital services. It needs to be combined with knowledge about the domain and the context in which the software will be applied.
- The end user of human-centric software and services, and the roles of designers, developers, testers, and operators – meaning all stakeholders involved in the software lifecycle – need to be taken into consideration. Developing appropriate skills and raising awareness about the importance and opportunities of human-centric software will be key.
- Special focus should be placed on socio-economic aspects including cost-efficient approaches for designing, developing, and operating human-centric software, and measures and metrics that show the value and support the adoption of human-centric software. Mandating human-centricity in EC-funded research projects might be a way forward and could lead to a quality label for human-centric software.
- The central aspect of trustworthiness requires interdisciplinary research into technologies and engineering methodologies for the design and evolution of software systems and services which are transparent, trusted and protect privacy. The right balance and trade-offs between transparency and privacy protection need to be explored to provide data sovereignty and to prevent and control misbehaviour of users and service providers.
- The increasing use of AI and ML in software systems calls for research dedicated to the human-AI interaction. Novel approaches are needed for human stakeholders to understand, influence, and trust what AI is doing in critical tasks, requiring the connection with research on explainable AI, AI ethics, etc.
- Specific software research areas to be supported include approaches for co-design and co-creation, domain-specific languages for requirement engineering, modelling languages covering human-centric aspects, affective computing (software to recognize, interpret, process and simulate human affects and feelings), the Internet of Behaviour (extending the IoT by combining technology, data analytics and behavioural science), and testing of human-centric software.
- Extensive trials as well as education and training programs for all stakeholders will be needed to put human-centric concepts into practice.