# Design and Evaluation of High-Quality Symbiotic AI Systems through a Human-Centered Approach

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## ABSTRACT

Artificial Intelligence (AI) is significantly impacting foreseeing fields offering a better-automated decision making process and autonomous systems. Therefore, it is important to design high-quality AI systems that focus on the users' priorities and avoid potential unethical and undesired behaviours. In the current scenario, Human-Computer Interaction (HCI) and AI are not separate fields but they contaminate each other and, consequently, the symbiosis between humans and AI system is fostered. Ensuring that AI development benefits humans, while providing an high-level automation, remains a primary concern. For this reason, the human-centered design approach should be adopted to create systems that being trustworthy, safe, reliable, and governance compliant are able to enhance the user's cognitive abilities and protect they from potential risks. In this context, it is fundamental to identify guidelines to follow while designing high-quality Symbiotic AI (SAI) systems and metrics for their appropriate evaluation. Assessing the empirical validity of the proposed solution is of crucial importance and the planning and execution of a user study is one of the main aspects of this work.
The research project concerns the design of SAI systems, more specifically the definition of best practices and metrics to adopt while creating and evaluating these systems.
This contribution presents the preliminary results obtained during the initial part of the research. The main opportunities and challenges in this new research field are also discussed.

## CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in HCI**.

## KEYWORDS

Symbiotic Artificial Intelligence (SAI), Human-centered design, SAI metrics, empirical study

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## 1 INTRODUCTION

Over the years, AI has become a fundamental part of human daily life, so much so that it is now a predominant aspect in many fields, such as medicine, education, etc. However, it is important to guarantee the balance between the autonomy of the system and human control: on one side, a high degree of autonomy might be convenient; on the other side, in case the user is not allowed to intervene, e.g., dangers cannot be prevented. In this context, the Human-Centered AI (HCAI) discipline plays an important role in reaching the human-AI symbiosis. This has been defined by Ben Shneiderman as "a promising direction for designing AI systems that support human self-efficacy, promote creativity, clarify responsibility, and facilitate social participation" [13]. In this context, systems are designed and developed to empower humans rather than replace them. In fact, in the HCAI framework, it is stated that it is of crucial importance to design AI systems that are fully in human control while empowering people in ways that make systems reliable, safe, and trustworthy [13].
In the current scenario, the strict interdependence between the intervention of human and AI performances is ensured by SAI, which aims to boost human-machine collaboration. According to SAI philosophy, "the human understands and intuitively reacts to the machine, and the machine understands and intuitively reacts to the human" [6]. Therefore, it is possible to enhance the human-AI interaction by focusing on recognising humans' responses and emotions [6]. Thus, the human is put at the center of the process, giving relevance not only to their need but also to their behaviours. We are facing a new scenario in which two fields, in the past considered completely separated, i.e. AI and Human-Computer Interaction (HCI), are strictly correlated and contaminate each other. Therefore, this research focuses on defining guidelines and metrics developers can employ to design and evaluate SAI systems: the user and AI performances are considered and evaluated. In this regard, to have empirical evidence of the implemented solutions, it is important to plan and perform user studies during which direct feedback is gathered.
This paper presents and discusses the main challenges and opportunities that come from this new scenario and that characterize the PhD project. Currently, I am a first-year PhD student; therefore, to have an overall overview of this domain, I am studying the literature and gathering preliminary results. Preliminary results and the planning of future activities are described in the next sections.

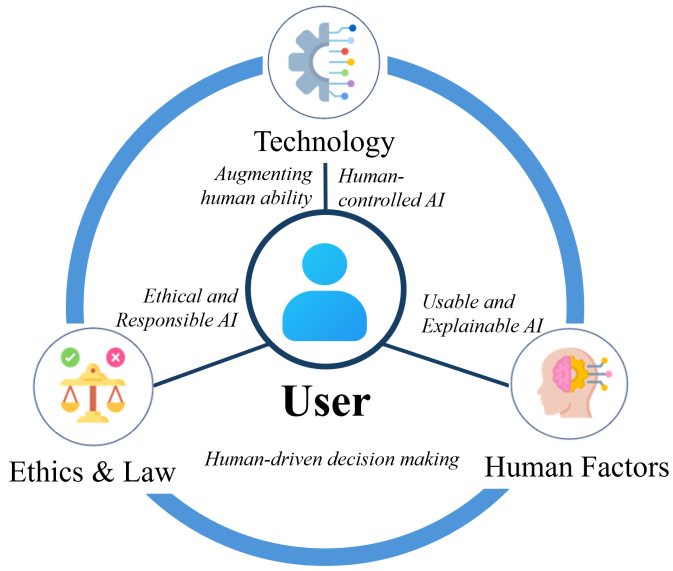


**Figure 1: Design goals across three main dimensions: Technology, Ethics & Law, and Human Factors (Adapted from [15])**

The contribution is structured as follows: Section 2 describes the objectives of the research project; Section 3 describes the detailed research motivations; Section 4 presents the research questions and the possible approaches to adopt to find answers; Section 5 describes the work plan that will be followed during the three years; Section 6 provides an overview about the related work; Section 7 presents brief conclusions.

## 2 OBJECTIVES

The research project focuses primarily on enhancing the human-AI interaction by envisioning and suggesting solutions for designing Symbiotic AI (SAI) systems and defining a methodology to evaluate their scientific validity. Additionally, due to the novelty of the field, not much research and related literature is available regarding the definition of new AI models and techniques that poses the attention on reliability, safety, and trustworthiness. For this reason, this is one of the crucial aspects of the project.
More specifically, the objectives of the project are the following:

- Creating innovative measurement criteria that revolve around the desired properties that the final model should have (e.g., reliability, safety, and trustworthiness).
- Guaranteeing transparency allows the user to easily comprehend the motivations behind the decisions taken from the system, even if they are not AI experts.
- Defining new interfaces and interaction mechanisms to be compliant with these new needs.

## 3 RESEARCH MOTIVATIONS

In this context of study, researchers have to face many challenges. The main objective is to create SAI systems that, at the same time, can foster human-AI interaction and that can prevent undesired behaviors. In particular, the main challenges can be low-level explainability, data biases, data privacy, and ethical issues. Since they can represent a potential risk for the users, it is crucial to understand how to address the ethical and moral challenges associated with AI [1]. Therefore, because during the learning phase, AI systems can adapt their behaviour to the users' needs, it is necessary to reduce as much biased data as possible, which may lead to wrong decisions. In this way, fairness and non-discrimination against the users can be guaranteed. To reach these objectives, it is necessary to consider regulations e.g., the General Data Protection Regulation (GDPR) and the AI Act (AIA), during the design and development process of SAI systems [3, 5]. An important aspect of the GDPR lies in the clauses about automated decision-making which provide the right of explanation for all individuals to obtain "meaningful explanations of the logic involved when automated decision making takes place" [5]. Currently, the EU is moving towards a more privacy-preserving approach regulating in the field of bio metrics technologies, which are used to identify, verify, or confirm a person's identity based on their physiological (external appearance) or behavioural (how they act) characteristics. In 2021 the first ever attempt to enact a horizontal regulation for AI was presented: the European Commission proposed the AIA, an EU regulatory framework on AI, which focuses on the specific usage of AI systems and the associated level of risks (i.e. minimal, limited, high and unacceptable risk); the classification ranges from some AI systems presenting unacceptable risks that would be prohibited to those AI systems presenting only limited risks that would be subject to very light transparency obligations [3].
Another challenge lies in the black-box nature of AI models; the difficulty lies in understanding their outputs. Since users are not able to comprehend which are the reasons behind the system's output. Therefore, to involve humans in the decision process and to foster symbiosis with this technology, the focus is shifted to explainable models that allow end users to "understand, appropriately trust, and effectively manage the emerging generation of AI systems" [7]. In this way, the system can be perceived as trustworthy, safe and reliable.
Additionally, it is important to find a way to measure the explanation's effectiveness and, in particular, the quality of the symbiotic relationship; this should be assessed according to how it is helpful for the users. To reach this goal, human-centred design approaches and techniques are needed: a multidisciplinary scenario is presented in which AI and Human-Computer Interaction (HCI) researchers collaborate.

The diagram represented in Figure 1 summarizes the research motivations that lie behind the project: the *User* is at the centre of the SAI systems' design and development while considering *Human Factors*, *Technology* and *Ethics and Law*. The figure also highlight that there is a strict interdependence not only between the user and the three dimensions but also among them. Specifically, *Technology* ensures that users are kept at the center of AI systems through a human-machine symbiotic relationship that enhances human capabilities; *Human Factors* guarantee that users can control AI systems that are perceived as usable thanks to the effective interaction design and explainable since they provide understandable

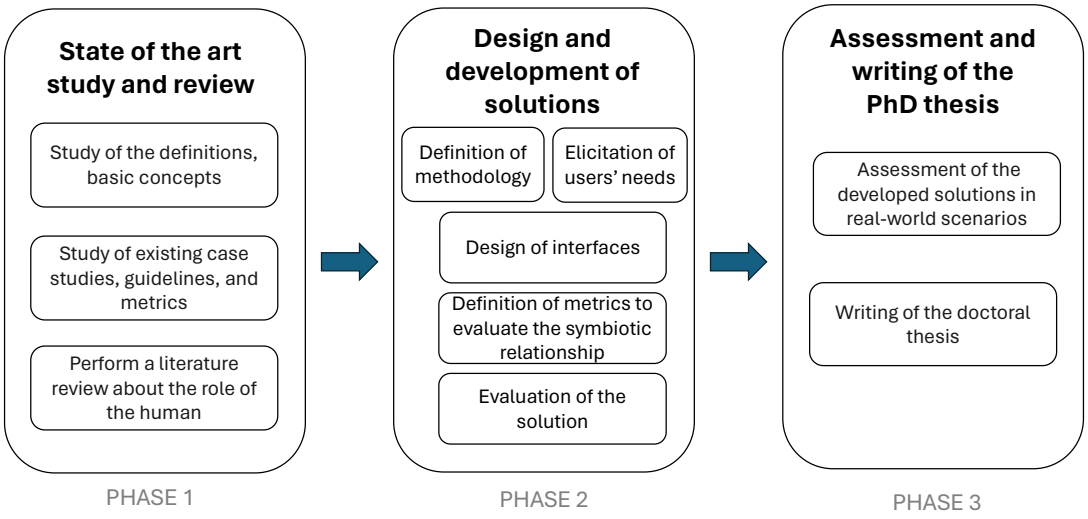


**Figure 2: Planning of the PhD project during the three years. The three main phases with the correspondent activities are represented.**

outputs; *Ethics and Law* aims to address ethical issues in AI systems to develop ethical and responsible artefacts that guarantee human-driven decision-making [15].

## 4 RESEARCH QUESTIONS

The research questions that power the research project are the following:

*(RQ 1) What are the current gaps within the intersection of HCI and AI? How can they be strategically addressed?* The primary objective of this study is to understand the basic and well-established concepts and methodologies necessary to define instruments (e.g., guidelines, design patterns) to design high-quality SAI systems. A thorough analysis of the current scenario will be conducted by performing a systematic literature review; this is a starting point for the definition of new principles and metrics to apply to the design and evaluation of SAI systems.

*(RQ 2) What are the current gaps in traditional metrics for evaluating SAI systems?* It is necessary to further analyse the existing literature to have an overall understanding about how the well-known UX and AI metrics can separately evaluate AI and human performance. The gathered information can be useful to understand how these aspects can be merged and to establish a starting point for the definition of new metrics that can be employed to evaluate the trustworthiness, safety and reliability of SAI systems. Additionally, it is also important to understand how these three dimensions can be theoretically and mathematically defined and how are related among them.

*(RQ 3) How this new SAI interaction paradigm, in which the human and the AI systems are involved, can be evaluated?* It is necessary to define metrics to use for the proper evaluation of the SAI relationship.

In the end, to define and validate the proposed metrics and principles both qualitatively (e.g. focus group and interviews) and quantitative (e.g. surveys, longitudinal studies and controlled experiments) empirical methods will be employed.

## 5 WORK PLAN

The established work plan referring to the entire duration of the research project (i.e. 3 years) is presented. In particular, the problem approach is presented, the empirical study design is illustrated, and the most important metrics and the threats to their validity are discussed. Finally, the data collection and analysis approaches, and the summary, which covers both the current state of the research and the expected results are reported.

### 5.1 Problem Approach

In this section, the approaches which is intended to be adopted to reach the defined objectives, are presented. To create SAI systems that are reliable, safe, and trustworthy, it is important to underline that the end user must be included in all the phases of the system design. The first approach to be explored is to involve users in the creation process, allowing the modification of the element to be considered during the training phase of the AI model. More specifically, it is necessary to define novel metrics that revolve around the desired properties that the final model should have regarding reliability, safety, and trustworthiness and that can be used during the training phase. To achieve this goal, it is crucial to investigate if human-centered design approach to the customization of the models is being conducted.

For this reason, a starting point of the research project is a systematic literature review to understand whether and how the AIA appropriately considers the human-side, it has been planned because the AIA is coming into force in the European Union and will

change the future of AI. This activity is being conducted and it can be considered as a starting point for the definition of new principles and methodologies to adopt in this new context.
Analyzing the current research scenario three lacking design dimensions are highlighted that, if investigated, can provide building blocks for the creation of SAI systems: i.e. clarification, negotiation and reconfiguration. More specifically, the clarification "means explaining directly the reason for the behaviour/decision of the AI system"; the negotiation "means reaching the system outcome through a sequence of iterative negotiation steps driven by the interaction between the user and the AI system"; the reconfiguration "means the possibility to trigger simply (within the reach of non-expert users) the retraining of the AI model(s) on new examples [4]".
Another approach that will be considered is to design models that are fitted considering the mental model of the final users. User studies will be performed to gather information about the mental model of the users and potentially obtain design requirements or guidelines for the creation of AI-based systems.
The approaches previously discussed can be summarised by referring to the activities that characterize the various phases of this work, as shown in Figure 2. Specifically:
*(Phase 1) State-of-the-art analysis.* In this phase, the following activities will be performed: analysis of the definitions, basic concepts and application of HCAI to reach the Human-AI symbiosis; identification of existing case studies, guidelines, and metrics in the field of SAI; execution of a literature review about the role of the human in the current scenario.
*(Phase 2) Design and development of SAI solutions.* In this phase, the following activities will be performed: elicitation of users' needs and definition of the technical methodology to follow; design of interfaces for interacting with SAI systems to foster the symbiosis between the human and the computer; definition of metrics to evaluate the symbiotic relationship; preliminary evaluations of the designed solution through user studies and defined metrics.
*(Phase 3) Assessment of SAI solutions and writing of the PhD thesis.* In the final phase, a further assessment of SAI solutions in the real-world scenario will be performed. In the end, the Doctoral thesis will be written.

## 5.2 Empirical study design

The design of the empirical study represents an important role in the development of scientific knowledge and practical guidance for design. It creates the foundation for improving design processes, methods, and tools. To evaluate the human-AI symbiotic relationship, as shown in Figure 3, it is important to consider on one side stakeholder's needs and characteristics, and on the other side to evaluate trustworthiness, safety and reliability it is possible to consider as a starting point the existing User Experience (UX) and AI metrics; after, novel metrics that can be employed to evaluate the symbiosis will be defined.
To assess the validity of the obtained results, they will be evaluated through appropriate evaluation techniques. In particular,

- Novel metrics that can be employed for training SAI systems, will be assessed through the conduction of user studies.
- User interfaces of the SAI systems will be evaluated performing user testing. To assess their usability, the System Usability Score (SUS) scale [2] and Net Promoter Score (NPS) [10] will be employed.
- A critical evaluation and field studies will be performed to test the work in a real-world context and to evaluate the best practices for the development of SAI systems.

The user studies that will be executed are characterized by the following phases: planning, preparation, execution and analysis of results. During the first phase the entire process of evaluation is planned, in particular it is established which aspects of the system will be evaluated (e.g. usability, trustworthiness, etc.), through which resources will be realized and how the analysis of the obtained results will be performed. In the second phase, the tasks to perform, the number of participants and their profile are defined; then, the measures to gather are identified and, referring to these, logistics aspects and the necessary resources to perform the test are prepared. In the third phase the test is performed and at the end questionnaires are administered and/or interviews are performed. After which, the obtained material is analysed and conclusion are drawn [9].
To comprehend the validity of ideas a pilot test was conducted with three researchers in the field carrying out unstructured interviews. After, the first and second phases of the user studies were partially conducted in which it was established that a first test, conducted to examine the new interaction paradigm, can be performed considering maximum 5 participants (the gender is not important) that have different level of expertise with technology; the latest aspect is important to create a solution that can be used also without the help on an IT expert. It is worth to highlight that the number of testers was established according to the Nielsen rule: generally, the range between 3 and 5 users is sufficient to detect more than the 75% of problems [9].

## 5.3 Definition of most important metrics

Considering the Goal-Question-Metrics (GQM) approach, which is a valuable method for identifying meaningful metrics concerning the quality of the software [14], the probable metrics that will be employed to assess the validity of the project are presented. More specifically, *Goal* represents the main objective of the project and provide the context for the questions and metrics; *Question* outlines the defined goals with specific questions; *Metrics* represents the quantitative measure of the system's performance [14]. The possible goals, questions and metrics that can characterize this research work, even if it is at a preliminary stage, are the following:

- **Goal (G):** Design and develop high-quality SAI systems and define metrics to proper evaluate them.
- **Questions (Q):** (Q1) To what extent does SAI systems enhance the user trust? (Q2) How well does the system adapt to changing contexts and user needs? (Q3) How much SAI systems are able to enhance the users' cognitive abilities?
- **Metrics (M):** Metrics that can be employed for (Q1) are the *Trustworthiness*, which measures the level of user's trust level also in terms of prevention from the risk and system's efficiency, and the *Accuracy* which measures the correctness of the decision taken by the system. For (Q2) *Adaptability*

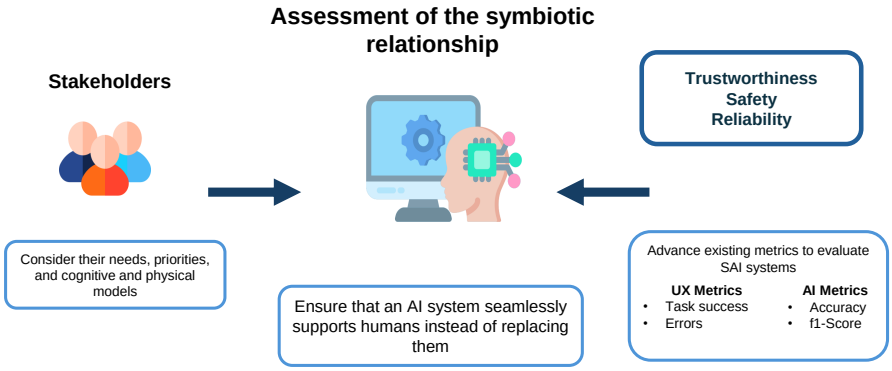


**Figure 3: Metrics' role in the assessment of the Human-AI symbiotic relationship.**

can be adopted; this evaluates how much the system adapts its behavior to new data. For (Q3) can be defined a metric called *Interaction Enhancement (IE)* which, considering the time and the effort employed by the user during the interaction process, evaluates if the human-AI collaboration brings benefits.

## 5.4 Data Collection and Analysis

Data will be collected and analysed in many ways depending on the purpose.
To have a first overview of the context of study, a literature review is being conducted and data will be collected by analysing the gathered results. Specifically, the collected papers will be classified and analysed using a mixed approach of data coding, i.e. a-priori coding and in-vivo coding: the first categorized paper in dimensions that were established before the classification activity; the second implies the definition of dimensions while papers are analysed [8].
Data that are needed for the design of the SAI systems' user interfaces will be collected through gathering requirements techniques, such as interviews and/or questionnaires [9]. Finally, data obtained from the user studies will be employed to assess the validity of the proposed solution, i.e. metrics, guidelines and user interfaces.

## 5.5 Validity Threats

In the current section, some of the threats that can take place and possible mitigation approaches are presented.
In the context of SAI, where the focus is shift on the strict collaboration between the human and the AI system, the threats can impact the effectiveness, reliability, and ethical aspects of such systems. Some of these are the following:

- **Human-AI Trust.** Lack of trust in AI systems can hinder the human-AI collaboration. This threat can be faced communicating AI limitation and building trust through positive interaction experiences.
- **Data Bias and Fairness.** Biases can be present in data used for the training of the model; this can lead to discriminatory behaviors of the system. A possible mitigation technique can be, for example, consider various data sources and retrain AI models to reduce as much as possible bias.
- **Complexity of Human-AI Interaction.** The new interaction paradigm can lead to misunderstandings or unexpected consequences that can make the user feel stressed and frustrated. A possible mitigation can be design usable and intuitive interfaces that provide a clear explanation of the decision taken by the AI system.
- **Data Privacy.** Since AI systems can be vulnerable to cyberattack it is important to avoid to share personal information of the users with these. A possible mitigation can be to anonymize data being compliant with regulations (e.g. GDPR).
- **Ethical Challenges.** SAI systems may violate ethical norms and/or rights of the users. Therefore, it is important to establish ethical guidelines to follow while designing and developing these systems.

## 5.6 Current State of the Work and Expected Results

The current state of the research project, referring to the obtained preliminary achievements, and expected results are presented.
First, one of the most important aspect to investigate is about the extent to which the human is considered while designing and developing SAI systems; specifically, it is important to understand how to consider the mental model of the human since from the training phase of the AI model. For this reason, an initial contribution of the research project is a systematic literature review that aims to analyse the current scenario that concerns this aspect. This activity is still work in progress, but from a first analysis of an initial set of papers, emerged that the aspects concerning the human are not almost considered respect to the others, such as privacy, explainability, fairness, etc. Additionally, I am also planning another systematic literature review to understand how trustworthiness, safety and reliability are considered in literature to define solutions that allows to address the gaps between HCI and AI. The final result will be metrics that can be used to evaluate the symbiotic

relationship between the human and the AI system referring to the three dimensions, i.e. trustworthiness, reliability and safety.
At the end, user studies, qualitative and qualitative analysis will be performed with the aim to gather information about the mental model of the users and potentially obtaining "design requirements" or "guidelines" for the creation of AI-based systems in specific domains. In conclusion, in line with the previously defined objectives, the expected results will be:

- the definition of novel metrics that revolve around the desired properties that the final model should have (i.e., reliability, safety, and trustworthiness).
- the design of new interaction mechanisms that are able to foster the symbiosis between the human and SAI systems.

## 6 RELATED WORK

Since a new perspective in which HCI and AI are strictly correlated and contaminate each other is proposed, a new discipline was born: HCAI. This perspective allows individuals to think and act in extraordinary ways, by combining user experiences with embedded AI methods to support services they want. This is ensured by SAI, that aims to boost human-machine collaboration by enhancing human cognitive abilities and the interaction process.
Referring to SAI philosophy, AI systems should be designed according to a human-centered approach to foster human-AI symbiosis. In this regard, in the early 2000s the Defense Advanced Research Projects Agency (DARPA)'s Augmented Cognition (AugCog) program focused on achieving a complete human-machine symbiosis, "where the human understands and intuitively reacts to the machine and the machine understands and 'intuitively' reacts to the human" [6]; recognizing human responses and emotion this level of interaction is fostered [6].
In this context, with the objective to renew design methodologies for products and services, Ben Shneiderman presents a framework which proposes three ideas: (1) designing and developing systems which are able to guarantee human control while having high levels of automation; (2) shifting the focus on empowering humans rather than replacing them; (3) following a three-level governance structure (team, organization and industry level) to develop more reliable systems, emphasize safety culture and promote trustworthy SAI systems [12].
The need for introducing human needs in SAI design and development has been addressed in numerous works which provide design guidelines for researchers and practitioners. To reach the human-AI symbiosis, it is necessary to allow the user to comprehend why the system takes a decision. In this regard, eXplainable AI (XAI) systems can be introduced; they were defined by the DARPA as "AI systems that can explain their rationale to a human user, characterize their strengths and weaknesses, and convey an understanding of how they will behave in the future" [7]. These explainable models can enable end users to "understand, appropriately trust, and effectively manage the emerging generation of AI systems" [7]. This objective can be reached by iteratively involving the users in the development process through requirements gathering techniques (e.g., interviews and questionnaires) [11].

## 7 CONCLUSION

This paper presents the main challenges and opportunities of the research project. Currently, I am at the the beginning of this work and I am focusing on exploring the current scenario. The objective lies in envision innovative solutions that can be employed to face the existing challenges.
However, based on the results obtained from the preliminary analysis, it is possible to state that the human is not widely considered when concerning AI aspects. Therefore, focus is put on understanding how to fully consider the human during the entire life-cycle of SAI systems, starting from the definition of requirements to their evaluation.

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