Creating a conceptual framework for the design and deployment of autonomous systems from an intersectional perspective

Identifying inequality in Maritime Autonomous Systems (MAS)

This project explores how intersectionality can be operationalised in the design and deployment of MAS. Intersectionality is a concept originating from Black feminism (Crenshaw, 1991). It emphasises that individual experience is dynamic and a combination of different identities; it is a way to spot and address inequality and oppression within systems (Collins, 2019).

Intersectionality research and praxis have exploded over the past ten years, but it is rarely used for socio-technical systems design. The main challenge is how to translate intersectionality into the context of engineering and technology, and make it fits with detailed processes and functions. Intersectionality as a critical social theory in making requires critiquing existing knowledge and providing a new perspective (Collins, 2019). These need to establish heuristic frameworks, then test and iterate them through practices.

We want to provide methods that can practically use intersectionality in the autonomous system area because autonomous technologies risk enhancing existing inequality and oppression as well as introduce new risks for marginalised people (Ciston, 2019; Joyce et al., 2021).

Methodology

The first phase of our research includes benchmarking and literature review. We started with a benchmarking study by looking at comparable industries. First, we decided 7 sectors that might involve autonomous technologies in the London Stock Exchange (aerospace and defense, automobiles and parts, chemicals, construction and materials, industrial engineering, industrial transportation, and oil, gas and coal). We sorted the company lists in each sector by the scale of value and selected 35 companies (the largest scale top 5 in each sector, this number was for practical reasons). We added a bus company that was recommended in a discussion. We read their websites and manually filtered out 12 companies due to no apparent relations with autonomous technologies. For the rest of them, we read through their websites and found that the Equality, Diversity & Inclusion (EDI) policies (1 of them did not publish an EDI policy, therefore, 22 in total) were the most relevant information for identifying policy and practices related to intersectionality issues. However, these policies were rarely involved in autonomous system design and deployment.

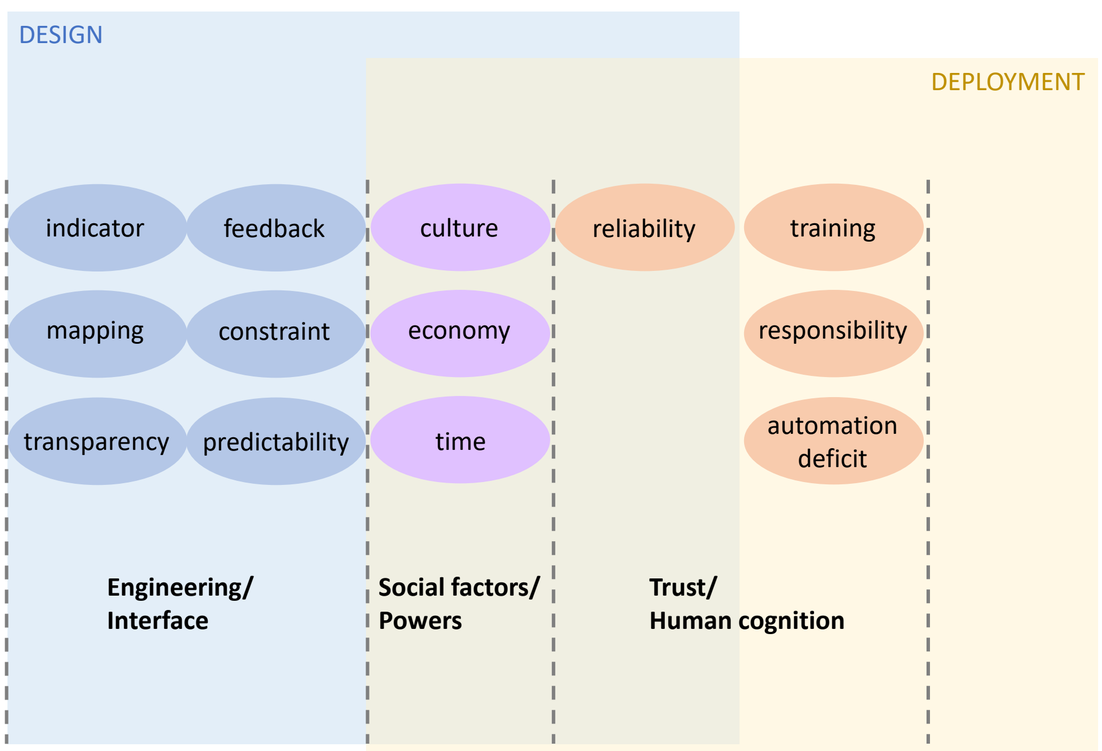
Second, we decided to use a keyword search on Google search, Google News, and Google Scholar to identify more companies that could be more directly involved in our focus. Keywords included: Autonomous ship, autonomous car, autonomous train, autonomous plane, autonomous drone, and autonomous medical robot. Companies that appeared on the first two pages of the search results were checked by reading their websites. After manually filtering, 20 companies were selected out of 349 (131 out of 349 were relevant, 21 out of 131 had business in the UK, and 1 out of 21 overlapped with companies selected in the first step). Moreover, we decided to add UK companies with good EDI reputations as a part of this benchmarking. Through keyword search (company with good EDI practices UK), we got "Inclusive Top 50 UK Employers 2021/22" and "Stonewall Top 100 Employers 2022" (Stonewall is an organisation that focuses on LGBTQ+ equality). For practical reasons, we selected the top 10 from each list. We got 40 companies in this step (66 in total).

Third, 6 companies and organisations were recommended by our project partner the Maritime and Coastguard Agency (MCA). They all were operating MAS around the world. In addition, in our internal discussion, we added 10 companies and organisations to our list. They were identified by their inclusive practices in the press. Finally, we got 78 companies from 10 sectors (maritime, aviation/drone, transport, automobile, healthcare, industrial engineering, information technology, construction and materials, chemicals, and oil, gas and coal; 20 good EDI companies from too various sectors were not categorised).

Four, we analysed the EDI policies of these 78 companies. The first takeaway is the percentages of underrepresented groups that had been mentioned in the EDI policy of these companies (women 69%, ethnic minorities 36%, people with disability 36%, LGBTQ+ 24%). Another takeaway is only 6 out of 78 companies mentioned intersectionality. Policies for different underrepresented groups were mainly separated. Practical methods to use intersectionality were absent.

Followed by the literature review. First, Bentley et al.'s (2022) research provided an article pool with 4280 articles that were selected from the Scopus database by keyword search (intersectional and intersectionality). We conducted another keyword search in this pool to find the literature that might involve our topic. Keywords included: Transport, maritime, artificial intelligence, HCI, HMI, ship, marine, bus driver, shipping, autonomous, system, autonomous system, operator, machine operator, system operator, system interface, value sensitive design, engineering, interface. We obtained 70 results. Then we read through abstracts and identified 16 articles that were relevant to autonomous technologies. We read these 16 articles, they provided insight into identifying and addressing issues in interactions with autonomous systems that related to underrepresented and marginalised groups. However, there was no article about systems in the maritime sector and we could not find promising intersectional practices that we wanted to present in the first phase of our project.

Fig1. Factors and layers in the design and deployment of MAS



Second, we searched keywords on Google and Google Scholar (intersectional, intersectionality, maritime, autonomous system, information technology, IT, software, car, car design, autonomous car, drone, transport, etc.). After manually filtering, we got 6 promising intersectional practices in software engineering, drone engineering, car and autonomous car design, and public transport areas around the world. 5 of them explicitly used the concept of intersectionality in their practices while 1 did similar works but without using the term. Outputs of these practices included visualised framework, guidance, recommendations and sharing of experience, which provided promising insights and comparable examples for our research.

Third, we searched for literature on MAS design that involves human operators. After manually filtering, 4 MAS design research and 1 MAS accident case study were found. Critical analysis was conducted, we focused on identifying deeper factors and layers that were ignored by the previous research, especially those related to the perspective of identifying socially constructed inequalities.

The benchmarking study and literature review provided us with a view of how intersectional approaches have been used in comparable industries (or not). Intersectionality is a relatively new concept in the engineering area. In MAS, there are no established frameworks for intersectional design and deployment. Therefore, we needed to create our draft framework and test it in our research.

Draft intersectional design and deployment framework

We derived factors and layers in the design and deployment of MAS from the literature. We concentrate on two layers: Social factors (power-related) and trust (human cognition related) because factors in these layers are ignored or marginalised both in the design (the system itself) and deployment (external environment e.g., installation, training).

We found research involving social factors and trust in MAS design could go back to 2004, which Chipman and Kieras's (2004) research on building a cognitive model to understand human operators. Recently, human-related MAS design research was more under the concept of human-centred design (Costa et al., 2017; Gernez, 2019; Grech & Lutzhoft, 2016). Through three recent human-centred design research in MAS, we found Gernez's (2019) design framework that has a relatively complete mapping of the design process and was tested in a real working environment. Gernez's framework became a starting point for us to investigate ship design processes. However, this human-centred design framework does not explicitly include the organisational environment that the system is located in and the power dynamics within it that could cause inequalities. These could include white supremacy, heteropatriarchy, capitalism, and settler colonialism (Costanza-Chock, 2018). Intersectionality focuses on centring underrepresented voices by including marginalised groups and changing the power relations that underlie social inequalities (Collins, 2019). Our intersectional approach tends to be more holistic than human-centred design, therefore the organisational environment is crucial to consider. Three parts of our intersectional design and deployment framework are field study, co-design, and resourcing.

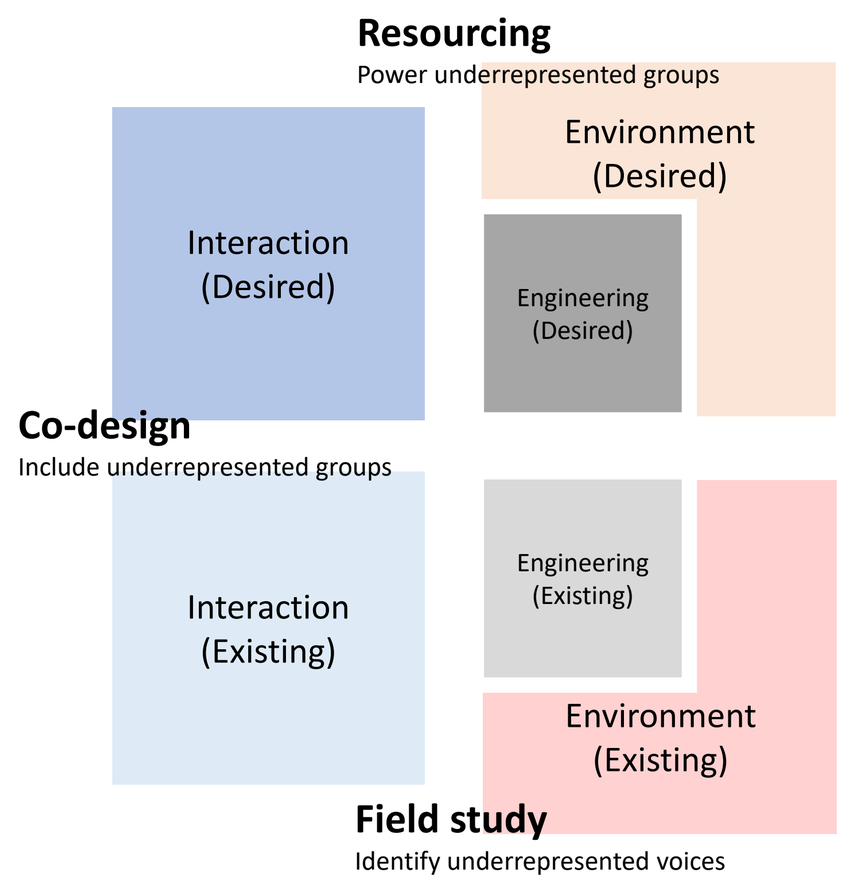
Field study: Not only study the existing engineering part but also the human-machine interaction part and the external environment. Methods could be shadowing, walk-through, thinking aloud, and interviews.

Co-design: It is a process to understand the desired human-machine interaction and understand the difference between desired and existing interaction. MAS co-design can involve task analysis, scenario mapping, and design concept materialising.

Resourcing: Providing supportive deployment for a new system design, which includes investment (system installation, facilities, and training), personnel, and regulations.

Based on this framework, we are generating intersectional guidance for the design and deployment of MAS.

Fig2. Draft intersectional design and deployment framework



What is next?

The next step of this project will be interviews with seafarers from underrepresented groups to understand their experiences. Followed by ship system design serious game workshops with ship system designers and seafarers from underrepresented groups to test and improve the guidance. Our intersectional framework and guidance will be iterated until they can be practically used in the design and deployment of MAS.

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