ANA BEDUSCHI
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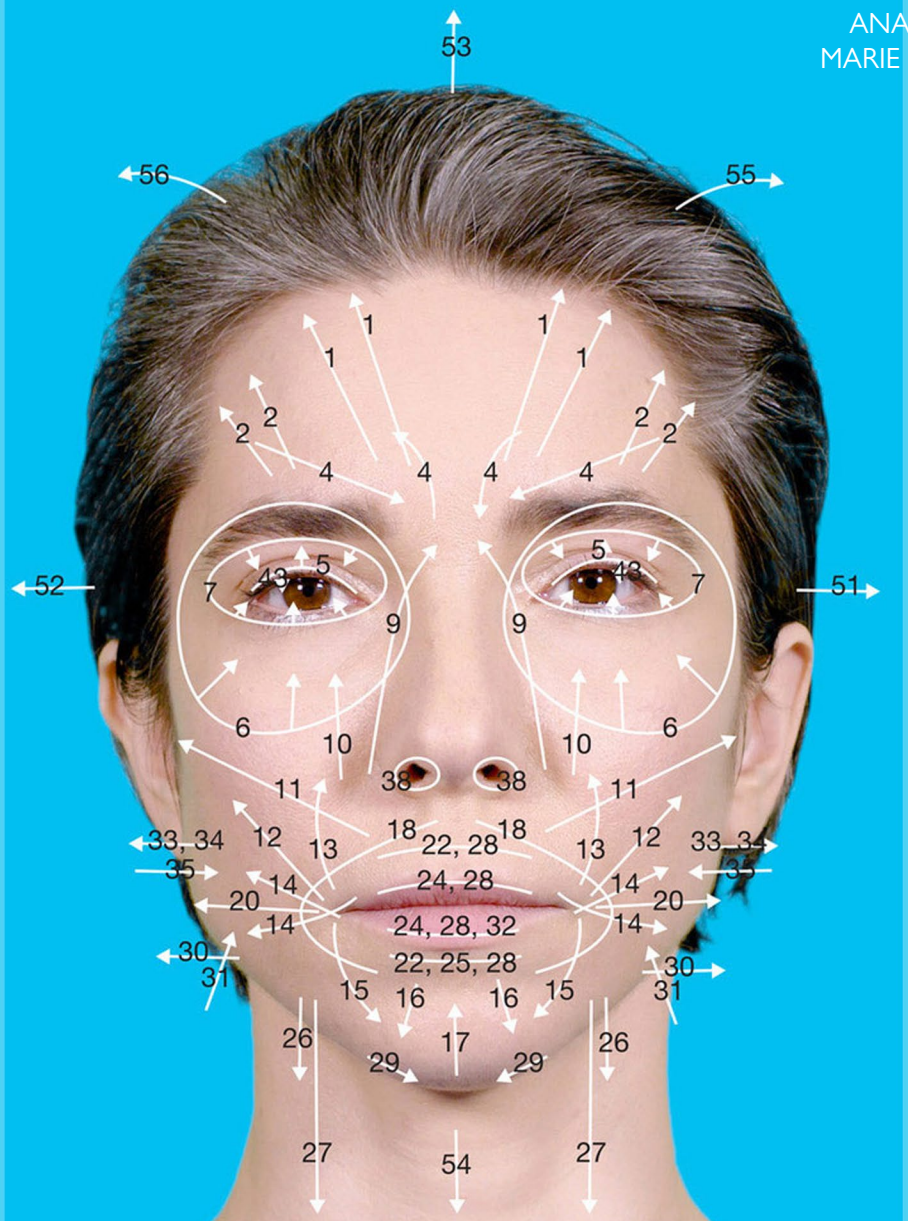

1	Inner Brow Raiser	16	Lower Lip Depressor	32	Bite
2	Outer Brow Raiser	17	Chin Raiser	33, 34	Blow & Puff
4	Brow Lowerer	18	Lip Pucker	35	Suck
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14	Dimpler	30	Jaw Sideways	61, 62	Eyes Left / Right
15	Lip Corner Depressor	31	Jaw Clencher	63, 64	Eyes Up / Down

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11 ARTIFICIAL INTELLIGENCE, MIGRATION AND MOBILITY: IMPLICATIONS FOR POLICY AND PRACTICE[1]

Introduction

Artificial intelligence (AI) technologies underpin everyday activities in more ways than many people imagine. Just as personalized newsfeeds utilize AI to service many millions of people worldwide, every Google search relies on AI algorithms to produce search results in mere milliseconds. AI-driven "smart" phones, "smart" appliances, "smart" houses and "smart" digital voice assistants (e.g. Alexa and Siri) are becoming increasingly commonplace in societies, enabling people to better manage their time, information and energy consumption. However, the development of AI capabilities has also triggered dire warnings from some futurists, including Stephen Hawking, Steve Wosniak and Elon Musk, who express concern over the long-term AI implications for humanity.[2] Perhaps the most significant aspect relates to AI weapons development, but the broader difficulties in aligning AI with human values underpin many concerns.[3]

Alongside growth in other sectors, AI has been increasingly used in the context of migration and mobility. The deployment of such technologies is not new, although there has been a recent surge in interest in AI utilization in migration as part of the broader raised profile of AI and related concerns about its development.[4] For many years, migration-related State authorities have used a variety of technologies, including AI systems, to support administrative processing and decision-making in matters related to migration. AI is increasingly used throughout the migration cycle, for example to facilitate pre-departure identity checks, support visa application lodgement and processing, enhance border procedures, produce data analytics on lodgement, applications and compliance with visa conditions (amongst other aspects), as well as to forecast migration trends. There can be benefits in applying AI technologies that are able to increase efficiency of systems and reduce processing times for clients, as well as better manage the increasing demand for migration-related services.

However, AI poses a variety of issues for policymakers, practitioners and migrants, including concerns about technology-enabled surveillance of individuals, the potential for systemic bias in AI decision-making in the areas of migration and mobility, the increased interactions between public and private sectors and their competing interests, and the negative impact of AI technologies on the protection of migrants' human rights.

Data-driven AI technologies also occupy a central role in the fight against COVID-19. Many governments around the world have implemented measures to monitor public health, such as mobile phone applications for contact tracing and digital health passports.[5] Such measures may disproportionately affect vulnerable groups, including migrant communities, thus impacting the protection of their human rights.

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1 Ana Beduschi, Associate Professor of Law, University of Exeter; Marie McAuliffe, Head, Migration Research and Publications Division, IOM.

2 Mack, 2015.

3 Wolchover, 2015.

4 Tegmark, 2016.

5 McAuliffe and Blower, 2021.

This chapter examines implications of AI for policy and practice in the context of migration and mobility through the prism of the existing international human rights framework of rules, standards and principles.[6] This is important because of the potential for human rights to be eroded – or bolstered – as a result of the design, development, implementation and expansion of AI technologies around the world.[7] The next section outlines key concepts and definitions, which is then followed by a brief precis of the current AI context. The use of AI across the migration cycle is then examined, with reflections on key strategic challenges and opportunities in this important area of new technology, including as it relates to the "future of work" and long-term migration trends.

Key concepts and definitions

There is no single, universally agreed definition of AI, although in a broad sense it can be thought of as "the programming of computers to do tasks that would normally require human intelligence".[8]

With its roots in computer science of the 1950s, AI was originally conceived to convey the aspirational development of a computer that would deliver the high-level or cognitive capability of humans to reason and to think – otherwise referred to as "general AI".[9] More than six decades later, however, high-level reasoning and thought remain elusive, and most of what is referred to as AI in non-technical discourse is a significant step down from this and is often more akin to a particular branch of AI called "machine learning".[10] This lower-order AI is referred to as "narrow AI", as it relates to the performance of narrow tasks, such as matching facial features in images or calculating the relevance of written material to specific search terms, rather than broader, more general "thinking".[11]

From its historical emergence in computer science, AI has developed over time to encapsulate different streams that utilize machine capabilities for such work as natural language processing, speech processing, machine learning, visual recognition, neural networks and robotics.[12] In reality, AI is not a single thing, but is a group of related technologies designed to match or replace human intelligence.[13] An overview of different definitions of AI offered by organizations and leading scholars can be found in Appendix A.

AI-based systems can be purely software based, acting in the virtual world (e.g. voice assistants, image analysis software, search engines, and speech and face recognition systems) or AI can be embedded in hardware devices (e.g. advanced robots, autonomous cars, drones and Internet of Things applications).[14] It is also useful in the context of this chapter on migration and mobility to offer definitions of commonly used terms that relate to AI technologies, such as:

- **Algorithms**: These are sets of machine instructions used to process and solve problems. AI algorithms can analyse data, find patterns, make inferences and predict behaviour at a level and speed greatly surpassing human capabilities.[15]

6 E.g. UN, 1966; UNHRC, 2011; UNHRC, 2008.
7 UN SG, 2020; Pizzi et al., 2020.
8 Mehr, 2017.
9 Jordan, 2019; Tegmark, 2016.
10 Jordan, 2019.
11 Tegmark, 2016.
12 McLaughlin and Quan, 2019.
13 Duan et al., 2019; Walsh et al., 2019.
14 European Commission, 2018: para. 1; Accenture, 2018.
15 LeCun et al., 2015.

- **Machine learning**: Machine learning is one of the techniques by which machines are trained to perform tasks that are generally associated with human intelligence, such as natural language processing.[16] Machines learn from vast amounts of data, including big data sets, using algorithms.

- **Deep learning**: A subset of machine learning, deep learning imitates the functioning of the human brain and is increasingly being relied upon for image and face recognition.[17] Deep learning applications structure algorithms into layers to create an artificial neural network, enabling machines to learn and make decisions on their own.[18] This makes it difficult or even impossible to explain how the machines reach specific decisions.[19]

- **Big data**: Big data can be defined as the "large volumes of high velocity, complex and variable data that require advanced techniques and technologies to enable the capture, storage, distribution, management, and analysis of the information."[20]

- **Digital identity**: A digital identity refers to a set of attributes available in digital format and relating to a person or entity.[21] These attributes include biometric data (e.g. fingerprint, eye scan, 3D face map), and demographic data (e.g. date and place of birth). They can also be combined with evidence of government-issued ID (e.g. passport, driver's licence) and digital activities on social media, including search history online and geotagging data. Existing digital identity platforms use AI as well as blockchain-related technologies to verify the identity of individuals by enabling "digital identity wallets" to run via online platforms and mobile phone devices.[22]

- **Chatbot**: A computer programme designed to converse with humans, especially over the Internet.[23]

How are digitalization and AI related?

AI technologies rely on underlying data capture and digital capabilities in order to be applied. "Digitalization" of aspects of migration systems is, therefore, a necessary condition for the application of AI technologies. However, digitalization does not necessarily result in AI technologies being developed and implemented. Compared with digitalization, AI in migration and mobility is currently much more limited.

AI is routinely used in a variety of sectors, including agriculture, finance and banking, education and health care, as summarized in Appendix B.

16 Flach, 2012; Nilsson, 1982; Ertel, 2017.

17 LeCun et al., 2015.

18 Ibid.

19 Rudin, 2019; Angelov and Soares, 2020; Watson and Floridi, 2020.

20 TechAmerica Foundation, 2012.

21 ISO, 2019.

22 E.g. Sovrin, available at https://sovrin.org and Digital Identity Alliance, available at https://id2020.org.

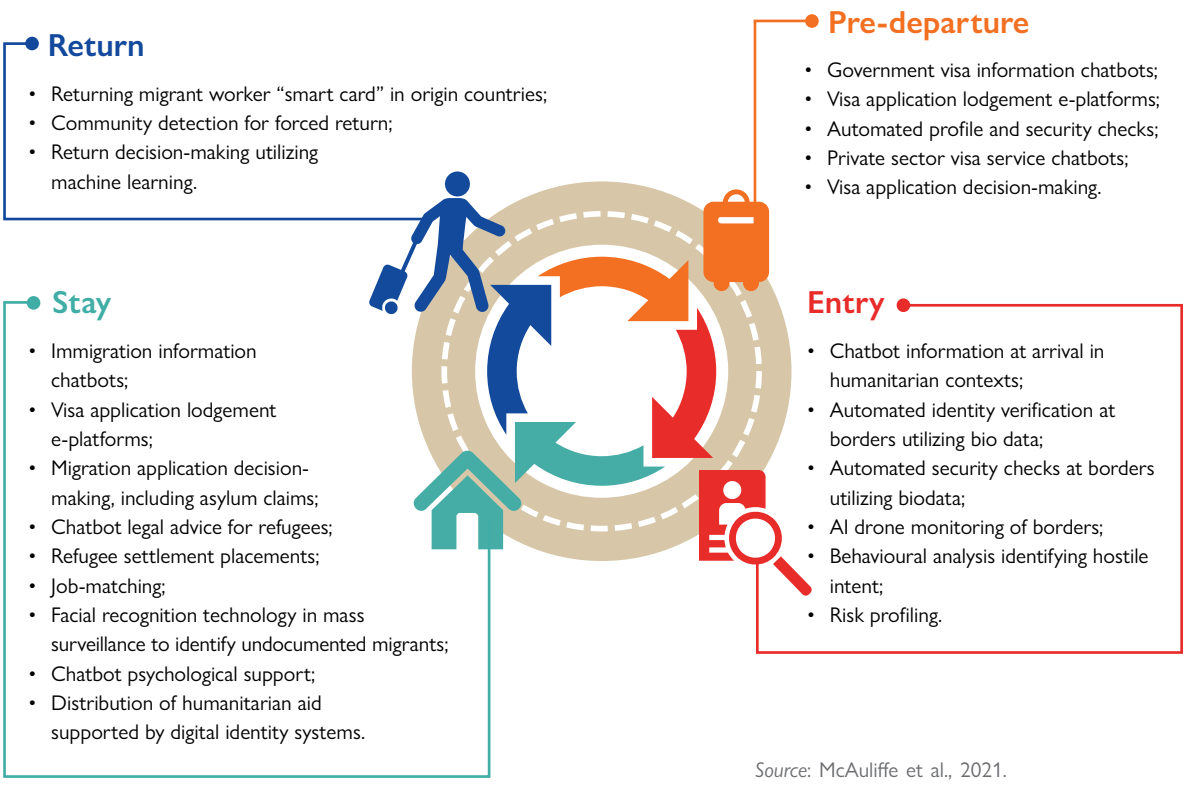
23 *Cambridge Dictionary* definition available at https://dictionary.cambridge.org/dictionary/english/chatbot (accessed 14 January 2021).

AI technologies throughout the migration cycle

Notwithstanding a recent surge in interest, AI technologies have actually been used in the fields of migration and mobility for many years.[24] For instance, AI and related technologies have been used in Australia, the United States of America, Japan, many European countries and the European Union to manage increasing numbers of cross-border movements.[25]

This section situates the analysis within the historical context of uses of AI technologies in migration and mobility. It describes the key uses of AI throughout the migration cycle,[26] providing examples of AI capability and deployment at the different stages: pre-departure, entry, stay, and return, noting that more examples can be found in relation to entry and stay. This section also describes the application of AI technologies in migration forecasting, through for example the use of predictive analytics. A summary of AI technologies throughout the migration cycle is provided in Figure 1. The next section then provides an analysis of the key issues and challenges, as well as the main benefits, that result from the increasing use of AI technologies in migration and mobility processes, especially in the context of human rights.

Figure 1. Artificial Intelligence and the migration cycle



Source: McAuliffe et al., 2021.

24 ANAO, 2008.
25 ANAO, 2012.
26 Gmlech, 1983; McAuliffe and Koser, 2017.

AI technologies have been developed and deployed over many years to support pre-departure aspects of migration and mobility management. Several government authorities have for example harnessed emerging technologies in the areas of visa application lodgement e-platforms and pre-departure checking, including the use of biometric data.[27] In anticipation of the 2000 Olympics in Sydney, the Australian Government introduced a system of pre-departure checking of bio-data linked to passenger boarding, so that airlines could not board passengers and crew onto an aircraft unless they had been cleared to do so.[28] Referred to as advanced passenger processing, this system was designed to draw on new technology and enhanced connectivity supporting real-time checking through border security systems. The more generic versions of these types of systems, known as advanced passenger information (API) systems, have subsequently been regulated by international guidelines covering their development and use globally.[29] API systems are seen as a way to overcome a range of problems in managing the movements of people internationally, most especially related to the significant growth in global travel and projected further growth, but also in relation to security threats, including terrorism and drug smuggling; significant carrier penalty regimes; and efficiency gains for border agencies through greater automation.[30] API requires automation of cross-checking processes involving multiple systems by utilizing AI capability to conduct searches and match biodata and other variables stored in different domains.

Alongside the growing use of AI technologies in border systems, online visa application platforms and the development of "e-visas", processing systems have also allowed automated systems utilizing the analytical capability of machine learning to process routine visa applications and refer more complex applications to case officers.[31] Again, one of the first automated systems was developed by Australia in 1996 in anticipation of the surge of visitors attending the Olympics, which then led to further developments over subsequent years and reductions in staffing levels overseas previously needed to process routine visa applications.[32] One of the early online visa application systems resulted in between 15 and 20 basic application checks being automated, thereby significantly reducing processing time and staffing costs.[33] In the first online system, human visa officers were still required to make the final decision on the application. However, these online platforms have been further developed over time so that they can provide automated decisions for low-risk applications, including the use of profiling techniques that do not require a human visa officer to be involved.[34] More complex cases or applications that do not "fit" the processing algorithms are then referred to visa officers for assessment and final determination.

More recently, there have been increased efforts to develop chatbots for information service functions provided by government authorities, as well as for private sector service providers such as commercial migration agents or visa application centres, to assist potential clients exploring opportunities to migrate for work or family reasons, study overseas or work temporarily in other countries.[35] Chatbots have also been developed by migrants who themselves had struggled to navigate the vast amount of information (and misinformation) on visa and immigration regulations.[36]

27 ANAO, 2008; DIAC, 2008; Shelfer and Verner, 2003.
28 DIAC, 2008; Franzi, n.d.; WCO, IATA and ICAO, 2010.
29 WCO, IATA and ICAO, 2010.
30 Ibid.
31 Aggarwal, 2018; PwC, 2011; Molnar, 2018.
32 PwC, 2011.
33 Rizvi, 2004.
34 Ibid.
35 E.g. https://hellotars.com/chatbot-templates/travel/H1mUrB/immigration-services-chatbot.
36 Hemmadi, 2017.

Entry

In a similar vein to changes in pre-departure processes, the management of entry-related processes, especially those directly focused on borders, has seen automation and enhanced analytical capability being increasingly utilized to improve efficiency and manage increasing passenger numbers. Automated border gates using biometric and biographical data for identity and security-related checking require substantial investments in data collection, IT systems and AI capabilities such as machine learning.[37] As a result, many countries are unable to roll out such sophisticated systems, leaving them to rely on manual systems and traditional border guard assessment protocols to detect potential integrity issues.[38] In addition, there can be challenges in initial implementation and questions regarding sustainability. In South Africa, for example, the introduction of biometric technology (fingerprint and facial recognition technology) as part of the government's modernization programme, initially at O.R. Tambo International Airport, caused delays due to the time required to collect passenger biometrics.[39] As a result, only non-nationals' details were collected, which goes to the broader issue of digital capabilities underlying the implementation of AI functionality. The broader issue of asymmetrical power between States in relation to AI migration technologies is discussed in the text box below.

Other areas that have seen a rapid rise in AI technologies have been in border detection systems, such as AI-backed drone technology,[40] as well as behavioural analysis in public locations, including airports and other mass transit facilities.[41] This AI-driven behavioural analysis utilizes machine learning to read biometric data such as facial (micro)expressions, gait and other physical movements to identify those intent on causing potential harm to others, although such approaches have been highly contested for reasons related to (in)accuracy, intrusiveness and privacy.[42] Other highly contested initiatives include the so-called "virtual border wall" between the United States and Mexico, currently being developed by United States Customs and Border Protection (CBP) in partnership with leading tech firms as part of CBP's innovation programme.[43] If this goes ahead, the "virtual border wall" will involve mass surveillance via drones and towers deploying capabilities similar to Google's Vision AI product, which can rapidly detect and categorize people and objects in an image or video file.[44]

Deepening asymmetries between States

The deployment of AI technologies can deepen such asymmetries in two main ways. First, it can amplify the so-called digital divide between States with more advanced technological capabilities and those lacking such technologies.[a] AI enthusiasts' main claim is that it can be used to cut costs and increase efficiency.[b] AI technologies would, therefore, be advantageous for migration and asylum procedures, which are normally lengthy, primarily manual, and largely based on migrants' and asylum-seekers' claims.

Accordingly, AI technologies could cement the leading position of those AI-capable States, which would be placed at the forefront of the global efforts to manage migration in the years to come. Such a situation would create an AI divide. In this new paradigm, States with less advanced technological means could be

37 Thales Group, n.d.; WCO, 2019.

38 Heath, 2019; IOM, 2016.

39 Darch et al., 2020.

40 Campbell, 2019; Koslowski, 2005.

41 Al Hamar et al., 2018; Rawlings, 2019.

42 Al Hamar et al., 2018; Huszti-Orbán and Ní Aoláin, 2020; Jupe and Keatley, 2019.

43 Fang and Biddle, 2020.

44 Ibid.; Google Cloud, 2020.

further isolated. … Besides, the AI divide could either reinforce or, conversely, represent a shift from the North–South paradigm.[c] If those AI capabilities concentrate in the global North, the AI divide would rather reinforce the existing North–South paradigm. However, if States in the global South take the opportunity to develop their AI capabilities, this could give them an additional means to exert influence in matters related to migration management as fully fledged AI-capable States. … Accordingly, the AI divide could simultaneously contribute to deepening the already asymmetrical relationships between North–South States, while shifting the focus slightly towards what could come to be the "AI-capable States and the others" split in international migration management.

Source: Abridged extract from Beduschi, 2020a.

a Norris, 2001.
b Chui et al., 2018.
c Chetail, 2008.

Stay

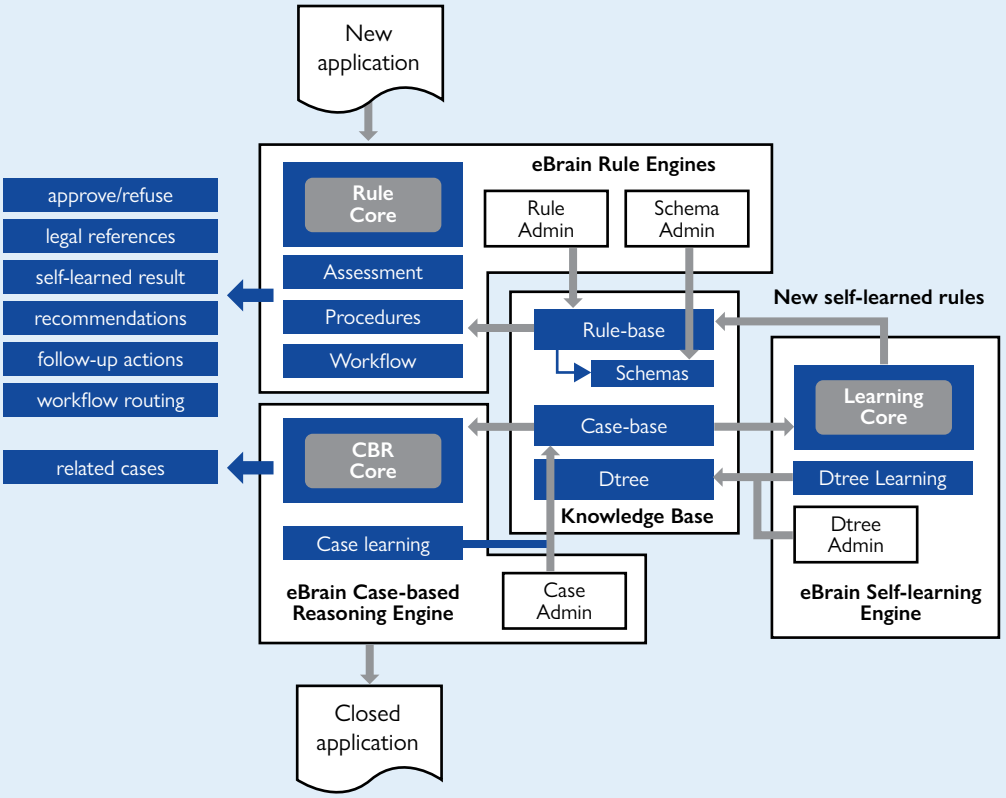
Chatbots are increasingly featuring in the provision of information and advisory services to migrants in destination countries, and have been developed by government authorities, such as Finland's immigration robot assistant, called Kamu,[45] as well as by civil society organizations supporting migrants. For example, a chatbot called Mona, designed to provide refugees with basic legal advice, has been developed by the United States-based startup Marhub in an effort to provide accurate information in real time.[46] We have also seen the development of chatbots that provide psychological support to refugees and internally displaced persons, who are often extremely vulnerable and unable to access mental health services. One such initiative by United States-based tech company X2AI involved partnering with a non-governmental organization in Lebanon to provide Arabic-language support via a chatbot called Karim, which delivers personalized text messages to Syrian refugees, using natural language processing and cognitive behavioural therapy capabilities.[47] Karim is an offshoot of an initial mental health chatbot called Tess, which delivers services to more than 19 million people worldwide.[48]

Application e-platforms and visa-related decision-making are similar to the pre-departure processes discussed above; however, after people have entered a country they may have ongoing interactions with immigration authorities, such as to renew visas, apply for a new visa type, or demonstrate compliance with visa conditions through staged processing. The use of AI has been found to reduce the need for manual processing and in-person appointments, such as has been achieved in Hong Kong SAR, China, where the immigration department's eBrain system reduced processing times and community costs, as described in the text box below.[49]

45 Miessner, 2019.
46 Peters, 2019.
47 Solon, 2016; Sengupta, 2019.
48 See www.x2ai.com.
49 Wong and Chun, 2006.

Hong Kong SAR, China immigration department's eBrain system

In early 2006, the Hong Kong SAR, China immigration department introduced a new eBrain system using AI capability to improve case processing. A visual representation of eBrain's overall AI architecture demonstrates the complexity of the overall scheme and the way in which machine-learning aspects feature within its architecture.



In addition to e-lodgement of applications, the eBrain system is used for case management and decision-making. After lodgement, the eBrain schema-based reasoning engine generates a set of suggested actions, such as requesting additional documentation, to get the application to a state that can be assessed. Machine learning is used to build procedural knowledge of typical steps taken for different kinds of cases.

Source: Wong and Chun, 2006.

Machine learning incorporating algorithmic data analysis has also been tested and used to support better refugee resettlement placement in Switzerland, which had previously been performed by human case officers, resulting in improved outcomes for refugee integration.[50] Other similar initiatives – such as the global Matching and Outcome Optimization for Refugee Empowerment (MOORE) initiative – utilize machine learning, integer optimization and

50 Bansak et al., 2018.

matching theory to determine the best matches between refugees and local communities.[51] Refugee resettlement optimization applications using AI technologies are fairly limited and specialized, although it is not clear whether similar systems are already in place for other migration programmes in destination countries, such as those for skilled workers.

One deployment of AI technologies that existed well before COVID-19, but which came under the spotlight during the pandemic, was related to the use of AI surveillance technology to track and monitor groups of interest, including migrants.[52] In the United States, for example, AI facial recognition technology has been used by immigration authorities to conduct mass monitoring of people in traffic flows to detect undocumented migrants.[53] Similar capabilities relying on facial recognition software have been implemented in many other countries, as outlined in the text box below.

Global expansion of AI surveillance

AI surveillance technology is spreading at a faster rate to a wider range of countries than experts have commonly understood. At least 75 out of 176 countries globally are actively using AI technologies for surveillance purposes. This includes: smart city/safe city platforms (56 countries), facial recognition systems (64 countries), and smart policing (52 countries).

Liberal democracies are major users of AI surveillance. The index shows that 51 percent of advanced democracies deploy AI surveillance systems. In contrast, 37 percent of closed autocratic states, 41 percent of electoral autocratic/competitive autocratic states, and 41 percent of electoral democracies/illiberal democracies deploy AI surveillance technology. Governments in full democracies are deploying a range of surveillance technology, from safe city platforms to facial recognition cameras.

Governments in autocratic and semi-autocratic countries are more prone to abuse AI surveillance than governments in liberal democracies. Some autocratic governments are exploiting AI technology for mass surveillance purposes. Other governments with dismal human rights records are exploiting AI surveillance in more limited ways to reinforce repression. Yet all political contexts run the risk of unlawfully exploiting AI surveillance technology to obtain certain political objectives.

Source: Abridged extract from Feldstein, 2019.

Return

In the context of return migration, there appears to be much less utilization of AI technologies. Insofar as return relates to programme integrity, such as the return of failed asylum seekers, visa overstayers or unlawful non-citizens, AI technology does appear to be utilized to facilitate return processes; however, its implementation appears to be more related to mass population surveillance initiatives to detect potential undocumented migrants for forced return.[54] There are also indications in court documents from the United States showing that private sector data

51 Trapp et al., 2018.

52 IOM, 2020.

53 Matyus, 2020.

54 Majidi et al., 2021.

brokers, which use AI algorithms to pull together a wide range of data on individuals to create "data dossiers", are being utilized to identify potential deportees.[55] In this sense, both physical surveillance and virtual surveillance techniques that utilize AI technologies are being drawn upon to identify potential returnees.

The consequences of relying on AI technologies in forced return can be very significant, especially if there is overreliance on such systems without other forms of human assessment or verification. In 2016, the United Kingdom revoked the visas of around 34,000 international students on the basis of a contracted language services company's AI human voice recognition analysis indicating that the students had used proxies in English language tests needed to secure visas. However, subsequent human analysis found that around 7,000 (or 20%) of these students had been falsely accused of cheating, with the United Kingdom immigration appeals tribunal finding that the evidence used by the Home Office to deport the students had "multiple frailties and shortcomings".[56]

The use of AI technologies in the return of migrant workers back to their origin countries has had some traction, but appears to suffer sustainability and implementation obstacles. In Bangladesh, for example, the introduction of "smart cards" in 2010 to support smoother departure processes of migrant workers has been useful for border processing and data collection purposes, but calls to utilize these cards also for returning migration workers have not eventuated.[57] Multipurpose smart cards would assist in further movement away from a paper-based migration management system to a digital system, enabling better data collection and related analysis for policy and programming purposes.[58]

AI as a tool to predict movements, while also shaping long-term trends

Forecasting migration and mobility has been undertaken for many years and has typically relied on statistical modelling, as well as expert insights. With the expansion of data sets, especially in humanitarian displacement contexts (such as IOM's Displacement Tracking Matrix), there is an increasing focus on the use of AI technologies to leverage these data.[59] Unsurprisingly, predictive analytics is increasingly being used in the context of humanitarian settings; recent research has highlighted the growth in AI technologies to predict humanitarian crises, including displacement impacts due to conflict and violence, food insecurity, disease outbreaks and disaster.[60] Of 49 initiatives utilizing AI technologies, such as machine learning, big data and statistical modelling, the researchers found that the focus was on where humanitarian crises will occur (71% of initiatives) and who will be affected (40%).[61] Less emphasis was placed on what such predicted crises will involve and when crises are likely to occur.

While we see a trend relating to the scaling-up of predictive analytics technologies and forecasting applications, the analysis of how AI technologies are likely to impact international migration patterns over time is of more significance in strategic terms. This is because more and more occupations are being automated or otherwise replaced by computers, which in turn has the potential to affect migration dynamics worldwide. AI and the future of work is a strategic topic of keen interest to many, with some arguing that it is the traditional white-collar jobs that are most at risk.[62] This highly topical issue is summarized in the text box below.

55 Currier, 2019; Molnar 2019; Rivlin-Nadler, 2019.
56 Baynes, 2019.
57 Bhuyan, 2018; Rashid and Ashraf, 2018.
58 Rashid and Ashraf, 2018.
59 Bither and Ziebarth, 2020.
60 Hernandez and Roberts, 2020.
61 Ibid.
62 Hanke, 2017.

How will AI impact long-term migration patterns?

While it is unclear exactly how migration patterns will be affected, analysis points to significant shifts over time as countries seek to invest in AI in an increasingly diverse range of sectors, from health and social care, to agriculture, education and finance (see Appendix B). As part of the broader considerations of the future of work, automatization utilizing AI is expected to affect the economics that underpin migration, reducing the demand for migrant workers over the long term. These changes are likely to affect many labour markets globally, with significant destination regions for migrants workers not immune. In a report focusing on Bahrain, Egypt, Kuwait, Oman, Saudi Arabia and the United Arab Emirates, for example, researchers find that the automation of routine work is particularly relevant to migrant workers in these countries, as the majority are low skilled. In the United Arab Emirates, for example, more than 93 per cent of automation potential affects jobs held by migrant workers.

Sources: aus dem Moore et al., 2018; Ernst et al., 2018; Hanke, 2017; Hertog, 2019.

AI technologies in migration and mobility: key issues, challenges and opportunities

As AI systems become increasingly common throughout the migration cycle, they give rise to a variety of issues and pose significant challenges for the protection of migrants' human rights.

This section analyses these issues through the prism of the human rights law framework, identifying challenges, but also possible available opportunities. It elaborates on the descriptive analysis presented in the previous section by focusing on critical areas in which AI has a significant impact: visa and asylum processing and decision-making; border security and migration management; support to migration management; and migration and mobility in an interconnected world.

Visa and asylum processing and decision-making

AI technologies are frequently used for visa and asylum processing and decision-making. A key advantage of using AI systems is that they can speed up visa and asylum application processing while screening for security threats and reducing irregular migration. However, AI technologies make it possible to automate, often in untransparent ways, large-volume processing involving risk profiling, with limited transparency and often without the possibility of recourse.[63]

The lack of transparency and the presence of biases in AI algorithms is a widespread concern, extending well beyond migration. While humans also display biases in their decision-making independently of the use of AI, AI systems can amplify existing human biases, not just encode them. AI thus has the potential to institutionalize and systematize human bias. This can ultimately lead to discrimination and exclusion of people based on protected

63 McCarroll, 2020; Molnar and Gill, 2018.

characteristics, including race and ethnicity.[64] Bias is a common issue that permeates AI systems in a variety of sectors.[65]

Typology of biases in algorithms

1. **Historical bias** arises when there is a misalignment between the world as it is and the values or objectives to be encoded and propagated in a model. It is a normative concern with the state of the world, and exists even given perfect sampling and feature selection.
2. **Representation bias** arises while defining and sampling a development population. It occurs when the development population under-represents, and subsequently fails to generalise well, for some part of the use population.
3. **Measurement bias** arises when choosing and measuring features and labels to use; these are often proxies for the desired quantities. The chosen set of features and labels may leave out important factors or introduce group or input-dependent noise that leads to differential performance.
4. **Aggregation bias** arises during model construction, when distinct populations are inappropriately combined. In many applications, the population of interest is heterogeneous and a single model is unlikely to suit all subgroups.
5. **Evaluation bias** occurs during model iteration and evaluation. It can arise when the testing or external benchmark populations do not equally represent the various parts of the use population. Evaluation bias can also arise from the use of performance metrics that are not appropriate for the way in which the model will be used.
6. **Deployment bias** occurs after model deployment, when a system is used or interpreted in inappropriate ways.

Source: Abridged extract from Suresh and Guttag, 2020.

In the context of migration and mobility, the consequences of biased AI algorithms can be life-changing. For example, there is potential for visa applications to be rejected because the AI algorithms used for the initial triage do not correctly recognize darker skin complexions and misidentify applicants. Such a scenario is not far from reality. Facial recognition technologies are considerably less accurate when used to recognize darker-skinned female faces when compared with white male faces.[66] Commercially available facial recognition AI systems were also proven to be more prone to misidentifying black people's faces and matching them with faces of people who had previously been arrested by the police, in an investigation in the United States.[67]

64 Eubanks, 2018; Ferguson, 2017; Noble, 2018; Zuboff, 2019.

65 Creemers et al., 2015; Zou and Schiebinger, 2018.

66 Buolamwini and Gebru, 2018.

67 Snow, 2018.

These inaccuracies in identifying darker-skinned people's faces may be caused by a representation bias, due, for example, to a lack of diversity in the data sets used to train the AI algorithms. This effect may also be the result of a historical bias, reflecting decades of preconceptions and stereotypes in society. Technology is indeed shaped by long-standing cultural and context-based perceptions about race, ethnicity, gender and other inequalities prevalent in society.[68]

These illustrations are an important reminder that technology is not a neutral tool and that it can also make mistakes. Decision makers should be aware of this. They should also take into consideration the propensity of human beings to favour the suggestions presented by AI systems, even if there are indications that these are mistaken, a phenomenon known as automation bias.[69] Further, biometric matching involving algorithmic capabilities can be very difficult for humans to refute, especially where technology is able to extract information not able to be detected by the human eye (e.g. gait patterns, facial recognition and iris matching).[70] Therefore, procedures should be in place to allow individuals to obtain redress in case mistakes in the AI systems lead to erroneous decisions or even to violations of their human rights. Individuals should be able to challenge decisions made by or with the assistance of AI systems before an independent and impartial tribunal or authority, including through administrative procedures.[71] To enable procedural fairness, State authorities need to be transparent about how they use AI in visa and asylum processing and decision-making.

Despite recent progress, there are still many technical hurdles preventing AI systems from being fully explainable by humans, notably the more complex AI models, such as deep neural networks.[72] These are systems designed to learn by themselves through "thought processes" that are not fully explicable. Increasing reliance on AI technologies for visa and asylum processing, given this inherent unpredictability and opacity, risks compromising fairness and equity of processes.

Border security and migration management

As discussed above, AI systems are also present in the field of border security and migration management. They are used, for example, to automate identity verification at borders, to automate security checks and monitor hostile intention at borders, or even to monitor borders remotely using sensors and AI-powered drones.

There are advantages in using AI in the context of border security and migration management. AI systems can analyse vast amounts of data, including big data, to identify patterns and predict behaviour.[73] They do so at speeds vastly surpassing human capability. AI algorithms can thus increase efficiency by streamlining repetitive tasks that depend on the review of large amounts of data.[74] Depending on how they are designed, developed, and deployed, AI systems can fast-track identity verification at border crossing points. They can also contribute to better identification of individuals posing potential threats to national security, public safety and immigration programme integrity.

68 See UNGA, 2011; UNHRC, 2020a.

69 Huszti-Orbán and Ní Aoláin, 2020; Wickens et al., 2015.

70 Israel, 2020.

71 This is according to the International Covenant on Civil and Political Rights (ICCPR) (UN, 1966: art. 14) and UN HRCttee (2007).

72 Graves and Clancy, 2019; Pasquale, 2015; Watson and Floridi, 2020; Vilone and Longo, 2020.

73 Burrell, 2016.

74 Chui et al., 2018.

However, AI systems also bring many risks for the protection and respect of migrants' human rights in the context of border security and migration management. First, there are significant concerns about the respect for individuals' right to privacy. Under international human rights law, everyone has the right to respect for their private life and correspondence, which includes personal information in digital formats.[75] Measures restricting the right to privacy must only be taken to safeguard a legitimate interest, which includes national security and public safety. They must also satisfy the cumulative tests of legality, necessity and proportionality.[76] The legality test requires that measures adopted by States have a legal basis in domestic law and are compatible with the rule of law. They must be accessible and foreseeable and afford adequate legal protection against arbitrariness.[77] The necessity test demands that the measures adopted address a pressing social need.[78] The proportionality test requires that the measures taken by public authorities are proportionate to their legitimate aims and represent the least-restrictive viable solution.[79]

Second, there are concerns about the collection and use of sensitive personal information, such as biometric data. In particular, a central problem relates to the modalities of storage, processing and access to the data by different public authorities and services. These concerns are heightened by the establishment of interoperable information technology (IT) systems. Interoperability allows data to be available and easily shared between different IT systems, including those used for the management of border security and migration. In the European Union, a dedicated agency called eu-LISA oversees the implementation of interoperable IT systems concerning asylum, border management and migration.[80]

There is no doubt that, on the one hand, interoperability can improve AI systems, enhance security and provide for better identity management.[81] For example, if data sets lack interoperability because they are only available in incompatible or different proprietary software, AI systems that are heavily data-driven will not reach their full potential. However, on the other hand, interoperability may also allow for mistakes in one data base to be cascaded forward if they are not quickly identified and corrected. For example, a person could be erroneously identified as a security threat with this information being recorded in one data base. If this mistake is not promptly corrected, border authorities that might access information in that data base could refuse entry and unfairly place this person in detention. The person in this scenario may not even be aware of the mistake in the data base. The lack of transparency could make it more difficult to rectify the error and allow the individual to obtain redress for the violation of his or her right to liberty.[82] Accordingly, interoperable IT systems should be developed in line with the basic principles of data protection. These involve lawfulness, fairness and transparency, purpose limitation, data minimization, accuracy, storage limitation, integrity, confidentiality and accountability.[83]

Third, there is a growing risk that the technologization of borders, using AI technologies such as AI-powered drones and/or AI-driven behavioural analysis of biometric data, may lead to excessive technology-enabled surveillance of

75 Universal Declaration of Human Rights (UNGA, 1948: art. 12). See also ICCPR (UN, 1966: art. 17); European Convention on Human Rights (CoE, 1950: art. 8); American Convention on Human Rights (OAS, 1969: art. 11); UNGA, 2014; UN HRCttee, 1988.

76 UNGA, 2014: para. 23.

77 UNGA, 2014: para. 23; UN HRCttee, 1988; ECtHR, 2008: para. 95.

78 UNGA, 2014: para. 24; ECtHR, 2008: para. 101.

79 Ibid.

80 Available at www.eulisa.europa.eu.

81 European Commission, 2017.

82 ICCPR (UN, 1966: art. 9).

83 EU, 2016: art. 5.

individuals.[84] While surveillance may be necessary to meet national security and public safety interests, measures that disproportionately interfere with people's privacy are not tolerated in a democratic society.[85]

AI supporting migration management

AI systems are also used to facilitate access to services and the integration of migrants and refugees throughout the migration cycle. For example, chatbots can now provide legal advice and psychological support to migrants and refugees, AI-powered applications can assist with refugee settlement placements, and digital applications can be used to support migrant integration in the host country. Chatbots have also been developed by migrants as a result of their own experiences in navigating vast amount of (mis)information on visa regulations and processes, as highlighted in the text box below.

Botler: the A.I. chatbot developed by a migrant

Amir Moravej's body may have been in Tehran, but his mind was in Montreal. The engineer had spent a half decade in Canada, but an expiring work permit forced him to leave the country and return to his native Iran. Back home, Moravej scoured immigration forums and joined group chats where applicants shared advice and information about their cases. "It was impossible for me to read all of it," he recalls. "So I wrote a bot to go and read all the forum posts, and find the ones that were most relevant to my own case."

A little over a year ago, Moravej landed in Montreal once more, this time as a permanent resident. His creation has become Botler, an immigration tool powered by artificial intelligence…The first scheme Botler is being applied to: the Programme de l'expérience québécoise (PEQ), for foreign workers and students residing in Quebec. "Imagine you don't have any information about the [program] but you want to apply," instructs Moravej. "You can use this bot for the whole process, from the very beginning to the very end."

Users start by answering questions about their qualifications and circumstances, which allows Botler to determine if they're eligible for the program. Would-be applicants who meet the criteria then upload their documents, which the tool reviews. "If everything is fine, the bot will create an application package" that can be submitted to the immigration ministry, explains Moravej. Users who miss the mark get to see what gaps remain in their application, and what conditions they must meet to become eligible.

Botler's machine learning engine uses the guidelines published by Quebec's immigration department, and was trained on anonymized data from real cases. Lawyers at Montreal firm Campbell Cohen, which is partnering with the startup, conducted the product's quality assurance testing.

Source: Abridged extract from Hemmadi, 2017.

84 E.g. UNHRC, 2020b.

85 UNGA, 2014: para. 24; Molnar, 2020.

At the same time, this trend has also raised concerns about the limits of "techno-solutionism", or the attempt to use technology to fix all sorts of problems.[86] Migration is indeed a complex phenomenon that cannot be easily managed.[87] In this sense, it cannot be easily "fixed" by technology either.

Technology may indeed enable capabilities and function as an equalizer of societal disparity.[88] For example, digital identity initiatives may provide excluded individuals, such as migrants and refugees who cannot prove legal identity, with the means to open a bank account and access a variety of services in a host country.[89] AI technologies can also reduce processing times and eliminate or reduce the inconvenience and time required for in-person interviews with immigration case officers, which often need to be booked weeks in advance (see text box below). However, their implementation is not without risks, as discussed in the next section.

AI visa e-platforms and client service processing improvements

Paper-based manual visa application lodgement and processing systems require hard copies of application forms to be submitted by the applicant, together with copies of relevant documents. Case officers knowledgeable about the relevant laws, regulations and guidelines then review applications and often request additional supplementary documents from the applicant. When all the supporting documents have been submitted, and an interview (if needed) conducted, the case officer will then make an assessment, which may require endorsement by a more senior colleague. The entire process may require several visits by the applicant; total processing times can be from several days to several months, depending on the visa type and complexity of the case.

Through the use of AI technologies, visa application lodgement processes can become much faster and eliminate the need for visits to immigration offices. Straightforward, low-risk applications can be submitted online, paid for and processed within minutes, reducing the inconvenience of in-person visits and allowing much faster decisions. These capabilities also allow for the more complex and/or higher-risk cases to be handled by human immigration officers. Such systems, as highlighted above, have been in place in some countries for more than two decades; however, they require significant information and communication technology (ICT) investment and they can only work effectively where the ICT accessibility for clients is high. In some regions and countries, the lack of ICT risks undermining service delivery and can result in inability to access online e-platforms. For example, there exists a digital divide between developed and developing countries, with 81 per cent of individuals using the Internet in developed countries, compared with 40 per cent in developing countries and only 15.6 per cent in the least developed countries. Further, there is also a digital gender gap, with higher Internet access rates for men than for women in all regions of the world; globally, men's access rate is 51 per cent and women's is 44.9 per cent.

Sources: Aggarwal, 2018; IOM, 2016; ITU, 2019; Rizvi, 2004; Wong and Chun, 2006.

86 Latonero and Kift, 2018; Morozov, 2014.

87 Castles, 2004.

88 Haenssgen and Ariana, 2017; Beduschi, 2019.

89 See, for example, Digital Identity Alliance, available at https://id2020.org and The Rohingya Project, available at https://rohingyaproject.com.

Migration and mobility in an interconnected world

As the world becomes increasingly interconnected, technology gives people the means to access more and more sources of information. This profoundly influences and impacts people's strategies and decisions to move.[90] For example, mobile phone technology enables migrants to stay in touch with family, friends and humanitarian organizations, but it is also exploited by smugglers and a variety of criminal networks, including via social media applications.[91] GPS and geolocation technologies embedded in mobile phones allow people to find and compare routes while on the move. Search engines are frequently used to gather information about transit and destination countries. While using these technologies, people leave behind significant digital footprints that can be exploited and analysed. Data-driven AI systems build on such varieties of available data.

Two main sets of challenges are particularly relevant for data-driven AI systems used in migration and mobility.

First, the growing "datafication" of migration management, whereby different types of data including biometric, satellite and big data are increasingly collected, stored and used for migration management, can lead to critical issues.[92] Poor practices in the collection, including storage and analysis of data from vulnerable groups such as some migrants and refugees, can have significant consequences. Cybersecurity flaws and poor storage practices could expose sensitive information about migrants and refugees.[93] This can have dangerous consequences for their safety if the data fall into the hands of malicious actors or persecuting agents.

Further, mistakes in data sets used to train AI algorithms can be cascaded forward if they go undetected. If these are proprietary algorithms or "black boxes", they can be even more difficult to audit, making it harder to identify any errors.[94] Such mistakes can have devastating effects. For instance, people may be denied access to essential services if they are misidentified due to an error in the software used to collect biometric data or to recognize people's faces. If these are humanitarian services provided within the context of a situation of conflict, the consequences for the affected people can be even more ravaging.[95]

Second, such concerns about the "datafication" of migration and mobility are further exacerbated by the increasingly common interactions between the public and private sectors. The private sector plays a central role in designing and developing the technologies that will later be deployed by States and international organizations at all stages of the migration cycle.

Technology companies have been positioning themselves in the humanitarian and migration arena for many years.[96] Such public–private interactions raise concerns for data protection. For instance, data-sharing practices and access to sensitive data by private corporations should only occur when there are sufficient measures in place to safeguard the basic principles of data protection.[97]

90 McAuliffe and Goossens, 2018.

91 McAuliffe, 2016.

92 Broeders and Dijstelbloem, 2016:242–260; Beduschi, 2019.

93 Parker, 2020a; Parker, 2020b.

94 Pasquale, 2015.

95 See International Red Cross and Red Crescent Movement, *Humanitarian Crises Digital Dilemmas*, available at https://digital-dilemmas.com.

96 Molnar, 2019; Parker, 2019; Kinstler, 2019.

97 Kuner and Marelli, 2020.

More broadly, States, international organizations and the private sector are often motivated by potentially conflicting interests. For example, private companies may logically follow their commitment towards profit-making and the safeguarding of the interests of their shareholders; whereas States defend the public interest, while international organizations need to act within the limits of their mandate to protect the interests of their beneficiaries. These different motivations are subsequently reflected in the design and development of AI systems. Some argue that profit-making interests frequently prevail.[98]

Conversely, migrants' interests and the protection of their rights are often unaccounted for in the design, development and deployment of these technologies. For example, activists and experts have raised the alarm about private sector access and control over migrants' data, often without any meaningful consent.[99] There are also reservations about international organizations' practices in the field, which create additional bureaucracies and may hinder the protection of migrants and refugees.[100] Scholars have also pointed out the challenges concerning the monetization of the insights gathered from migrants' data and the incentives in maintaining a crisis narrative.[101]

A human rights-based approach is, therefore, needed to address these issues and rebalance the power structures at play. International human rights treaties and the United Nations Guiding Principles on Business and Human Rights offer a comprehensive framework for algorithmic accountability.[102] Similarly, States, international organizations and technology companies should adhere to the humanitarian "do no harm" imperative when designing, developing and deploying AI systems throughout the migration cycle.[103] This ensures that once deployed, such AI systems do not damage the populations they are intended to serve.

Moreover, States and international organizations can require that providers of AI technologies, including private sector suppliers, abide by human rights standards and basic principles of data protection. They can use public procurement processes for this purpose.[104] These can include specific clauses in public procurement notices requiring that suppliers implement technical and organizational measures to integrate data protection principles into AI systems by design and by default.[105] They can also request that AI technology providers assess the impact of their products against human rights standards before the deployment of these AI systems.[106] Such practices can increase algorithmic fairness and accountability and prevent situations in which these technologies are tested on vulnerable populations, such as some migrant groups, without the prior assessment of risks.

98 Madianou, 2019; Zuboff, 2019.

99 See, for example, Molnar, 2019 and Madianou, 2019. See also UNGA, 2019; UNHRC, 2020a, 2020b.

100 Duffield, 2016; Read et al., 2016; Latonero, 2019.

101 Taylor and Meissner, 2019.

102 McGregor et al., 2019.

103 Sandvik et al., 2017.

104 Martin-Ortega and O'Brien, 2019; Beduschi, 2020b.

105 Kuner and Marelli, 2020.

106 Danish Institute for Human Rights, 2020.

Conclusion

AI in migration and mobility is not a new phenomenon. However, the increase in computational power, advances in technologies and the availability of large amounts of data have provided fertile ground for the contemporary development and expansion of AI in this area.

This chapter framed the analysis of the uses of AI within each stage of the migration cycle, demonstrating that such technologies have already influenced pre-departure, entry, stay and return policies and practices. Additionally, it acknowledged how the expansion of AI in labour markets is expected to impact long-term migration patterns, as technologies and automation increasingly affect the future of work around the world.

AI certainly brings about a series of advantages for policy and practice. For example, AI systems can increase the efficiency of migration management by streamlining repetitive tasks that depend on the review of large amounts of data. Depending on how they are designed, developed and deployed, AI systems can fast-track identity verification at border crossing points. They can also contribute to better identification of individuals posing potential threats to security.

In this regard, good practices include machine-learning tools incorporating algorithmic data analysis to support refugee resettlement placement through chatbots providing information and advisory services to migrants in destination countries. There is also a growing focus on the use of AI to predict the likelihood of displacement events and populations at risk of displacement, ostensibly in order to support and avoid such events.

Such predictions could help authorities to prepare more efficiently for large influxes of people. This could contribute towards fulfilling their human rights obligations.[107] For example, State authorities could act swiftly and better prepare their reception facilities, based on migration and movement forecasts. However, these predictions could also be used to reinforce non-entrée policies, understood as measures aimed at obviating access by migrants and asylum seekers to a State's territory.[108] These include unlawful non-refoulement practices, as forbidden by Article 33 of the Refugee Convention and human rights treaties.[109] Therefore, it is important to acknowledge that AI systems also present many risks for the protection and respect of migrants' human rights in the context of migration and mobility.

Three main implications for policy and practice can be drawn from this chapter:

- AI systems can amplify existing human biases, not just encode them. This can ultimately lead to discrimination and exclusion of people based on protected characteristics, including race and ethnicity. Bias is a common issue that permeates AI systems in a variety of sectors. Therefore, AI systems need to be developed in a way that deliberately and systematically seeks to remove or reduce bias throughout the process, from data collection and analysis to the reporting and assessment stages. Further, there is much greater awareness that overreliance on AI systems can result in incorrect and biased decisions, requiring policymakers and systems architects to ensure that regular monitoring and recalibration of systems, as well as human verification protocols, are in place.
- The increasing datafication of migration and mobility can create and magnify vulnerabilities. Datafication refers to the different types of data, including biometric, satellite and big data, which are increasingly collected, stored and used for migration management. Poor data storage practices and cybersecurity flaws can expose migrants'

107 UN HRCttee, 2004.

108 Hathaway, 2005; Gammeltoft-Hansen and Hathaway, 2014.

109 UN, 1951. See also ICCPR (UN, 1966: art. 7), as interpreted in UN HRCttee, 1992.

sensitive information. This can have dramatic consequences for migrants if the information falls into the hands of malicious actors. Such concerns are further exacerbated by the interactions between the public and private sectors. Technology companies have been positioning themselves in the humanitarian and migration arena for many years, raising concerns about data protection. Therefore, data-sharing practices and access to sensitive data by private corporations should only occur when there are sufficient measures in place to safeguard the basic principles of data protection.

- One of the key aspects currently underpinning analysis in this salient and strategic area of migration policy and practice is the extent to which a lack of transparency dominates. To some extent, this is likely to be fuelled by the risk of malicious acts of cybersecurity to undermine or control AI systems.[110] However, this in itself creates different risks, especially as they relate to the erosion of human rights.

Accordingly, a human rights-based approach is needed to address these issues and rebalance the power structures at play. For instance, human rights impact assessment tools could be used before the deployment of AI systems. This would increase algorithmic fairness and accountability and prevent situations in which AI technologies are tested on vulnerable populations, such as migrants and refugees, without prior assessment of the risks. Adherence to the "do no harm" imperative during the design, development and deployment of AI systems could help to mitigate some of the risks brought about by these technologies throughout the migration cycle.

110 Lohn, 2020.

Appendix A. Definitions of AI

There is no universal definition of artificial intelligence (AI), which is a generic term with wide applicability to many contexts. Some useful definitions that assist in explaining the term include:

Source	Definition
The Canadian Information and Communications Technology Council[111]	A multidisciplinary subject, involving methodologies and techniques from various fundamental disciplines such as mathematics, engineering, natural science, computer science and linguistics, to name a few. Over the last few decades, AI has evolved into a number of technological areas such as planning, natural language processing, speech processing, machine learning, vision recognition, neural networks and robotics, among others.
International Telecommunication Union (ITU) AI for Good Global Summit 2017[112]	A set of associated technologies and techniques that can be used to complement traditional approaches, human intelligence and analytics and/or other techniques.
High-Level Expert Group on Artificial Intelligence set up by the European Commission[113]	AI refers to systems that display intelligent behaviour by analysing their environment and taking actions – with some degree of autonomy – to achieve specific goals. AI-based systems can be purely software-based, acting in the virtual world (e.g. voice assistants, image analysis software, search engines, speech and face recognition systems) or AI can be embedded in hardware devices (e.g. advanced robots, autonomous cars, drones or Internet of Things applications).
World Intellectual Property Organization (WIPO)[114]	AI is generally considered to be a discipline of computer science that is aimed at developing machines and systems that can carry out tasks considered to require human intelligence. Machine learning and deep learning are two subsets of AI. In recent years, with the development of new neural network techniques and hardware, AI is usually perceived as a synonym for "deep supervised machine learning".
Organisation for Economic Co-operation and Development (OECD)[115]	An AI system is a machine-based system that can, for a given set of human-defined objectives, make predictions, recommendations, or decisions influencing real or virtual environments. AI systems are designed to operate with varying levels of autonomy.

111 McLaughlin and Quan, 2019.
112 ITU and XPrize, 2017.
113 European Commission, 2019.
114 WIPO, n.d.
115 OECD, 2019.

United Kingdom Government Digital Service and Office for Artificial Intelligence[116]	At its core, AI is a research field spanning philosophy, logic, statistics, computer science, mathematics, neuroscience, linguistics, cognitive psychology and economics. AI can be defined as the use of digital technology to create systems capable of performing tasks commonly thought to require intelligence. AI is constantly evolving, but generally it: • involves machines using statistics to find patterns in large amounts of data; • is the ability to perform repetitive tasks with data without the need for constant human guidance.
Nils J. Nilsson[117]	AI is that activity devoted to making machines intelligent, and intelligence is that quality that enables an entity to function appropriately and with foresight in its environment.
Hila Mehr[118]	AI is the programming of computers to do tasks that would normally require human intelligence. This includes the ability to understand and monitor visual/spatial and auditory information, reason and make predictions, interact with humans and machines, and continuously learn and improve.
John McCarthy[119]	It is the science and engineering of making intelligent machines, especially intelligent computer programmes. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable.
Dario Gil et al.[120]	AI is a field of computer science that studies how machines can be made to act intelligently. AI has many functions, including, but not limited to: learning, understanding, reasoning and interacting.
Ronald Ashri[121]	AI refers to the effort to create machines that are able to tackle any problem by applying their skills. Just like humans, they can examine a situation and make best use of the resources at hand to achieve their objectives.
Jerry Kaplan[122]	The essence of AI is the ability to make appropriate generalizations in a timely fashion based on limited data. The broader the domain of application, the quicker conclusions are drawn with minimal information, the more intelligent the behaviour.

116 United Kingdom Government Digital Service and Office for Artificial Intelligence, 2019.
117 Nilsson, 2010.
118 Mehr, 2017.
119 McCarthy, 2007.
120 Gil et al., 2020.
121 Ashri, 2020.
122 Kaplan, 2016.

Appendix B. AI usage in different sectors

Agriculture: AI is largely present in the farming and agriculture industry, especially with the increase in the use of intelligent tractors and plucking machines during harvest days. In addition, the agricultural sector relies on harvesting robots handling essential agricultural tasks such as planting seeds and monitoring crop and soil health. Flying and floating drones with AI capabilities are also being used to detect the quality of soil and water in order to improve the quality and quantity of crop yield.[123]

Business and finance: AI applications and usage have become essential for companies to save costs while improving outreach and quality of services. Computer algorithms and data-mining interfaces are allowing companies to improve the quality of their services by ensuring these better match customers' expectations and needs. For instance, Netflix and Amazon recommendation lists provide a more personalized experience by capturing their engagement patterns through data mining. Human agents are also being replaced by intelligent software robots such as chatbots that can provide customers with instant answers to their queries,[124] while reducing the cost of hiring human assistants.

Education: AI applications in education include adaptive learning technology,[125] which tailors content to students based on their abilities. AI is also used for plagiarism checking (e.g. Turnitin) and automated grading, as well as autocorrect and grammar checking (e.g. Grammarly).

Environment: AI has been integrated in ecological policy plans and has played a vital role in search and rescue missions in the responses to natural and human-made disasters. Examples include robots with AI capabilities that can sort recyclable material from waste, as well as using AI on satellite data to map and predict the progression of wildfires and find missing persons.[126]

Governance and security: Governments are using AI to improve security apparatuses. AI systems and autonomous flying machines such as drones are being used for surveillance to help automate the detection of, and response to, threats and patterns of criminal behaviour.[127]

Science and health care: Investment in the field of AI in science and health care has witnessed a significant uptake, especially after the emergence of COVID-19.[128] Using AI in science has proved to be indispensable, as it allows for cheaper experimentation, enables faster scientific discoveries and improves the effectiveness and efficiency of the health-care system. AI technologies are now able to monitor patients' health, provide automated diagnostic support systems in hospitals and complement the work of physicians in the operation room. They are also being widely used in scientific research and experimentation, especially in magnetic resonance imaging (MRI) segmentation and statistics.

Transportation: The transportation industry is one of the sectors benefiting most from the surge of AI, through research and investment in autonomous vehicles with virtual driver systems by car companies such as Tesla.[129] The sector has also been leveraging AI algorithms to optimize public transport for scheduling, routing and traffic light management.[130]

123 Walch, 2019.
124 Nguyen, 2020
125 Haoyang Li, 2020.
126 Chui et al., 2018.
127 OECD, 2019.
128 Sivasubramanian, 2020.
129 Niestadt et al., 2019.
130 Takyar, 2020.

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