Investigating the transformative impact of AI and Robotics on Healthcare

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1.0 Motivation

A new wave of automation related to the development of digital technologies based on robotics and Artificial Intelligence (AI) has taken hold in recent years in both manufacturing and the service sector, with promising applications to healthcare services (Yu et al., 2018). These new technologies integrate robotics, machine learning, cloud computing, and big data analytics; and promise to disrupt workplace practices by increasing productivity and efficiency (Ciarli et al., 2021; Brynjolfsson, 2023). Although the health sector has become a major contributor to the GDP with most advanced countries having total healthcare expenditure relative to GDP ranging between 10% to 17% in G7 countries (OCED, 2023), *there is still limited empirical evidence on the development, adoption and impact of these technologies on hospitals, healthcare facilities, and their healthcare staff*.

2.0 Project Objective

The objective of this long-term project is guided by three specific aims: 1) to map and describe the co-adoption of AI, Robotics and Big Data in Canadian, French, Italian and UK healthcare facilities; 2) to estimate the effects of the joint adoption of these technologies on clinical and healthcare outcomes, health costs and more in general on the productivity of this service sector (linked to the productivity paradox); and 3) to evaluate the implication for workers, doctors, nurses and other healthcare workers, of the rapid adoption of these transformative technologies. This collaborative project will uniquely investigate the development and adoption of medical innovations and their specific outcomes to improvements in population health. We will conduct a comprehensive cross-country data collection and categorization of healthcare robotics and AI and perform analysis of the determinants of technological diffusion and its impact in the healthcare sector. Furthermore, we aim to identify and investigate evidence on the adoption and impact of these technologies on hospitals from the unique perspective of innovation systems. Our hypothesis is that innovation adoption in the health sector critically depends on technical knowledge, interpersonal skills and behavioral propensities of the human actors involved.

3.0 Methods

For Aim 1: We are utilizing OpenAlex (Priem, 2022) to identify the related research, their field of focus, and the geographical region to use as foundation for evaluation of the quality of the outcomes. OpenAlex (Priem, 2022) is an open catalogue of global research containing metadata for over 209 million publications, 2013 million partially disambiguated authors; 124K journal and online repository venues, 109k institutions; and 65K Wikidata concepts that are linked to works via an automated hierarchical multi-tag classifier. This data is categorized into eight entities of Works, Authors, Sources, Institutions, Concepts, Publishers, Funders and Geo. Each entity contains further details and related links to other types of entities. The data have to be cleaned and standardized at the institutional and geographical level. Given the only partial and incomplete disambiguation of authors we do not use individual authors identification.

3.1 Robotics Research in Healthcare

In order to find publications related to robotics and healthcare, four methods of coverage are being considered: 1) Concepts, 2) Search of keywords, 3) Role of robotics in healthcare, and 4) hybrid methods.

3.1.1 Concept

Concepts are hierarchical set of ideas/words that publications contain in their title, abstract, and the title of its host venue. We identified all the robotics related concepts and the publications that were tagged with them using OpenAlex's neural network architecture with an embedding layer and fully connected rectified linear unit (ReLU) layers and multi-head attention layers. It was found that the concepts of "robot", "robotic surgery", "nanorobotics", "transoral robotic surgery" and "robotic arm", which are all level 2 concepts, were the most related concepts with the rest of the related concepts being their descendants.

All the works conducted in Canada tagged with these level 2 concepts paired with healthcare related concepts were found for further analysis. Using this method had some challenges as the concept system of OpenAlex has high precision in finding related works, however, suffers from lack of proficient coverage, as many of the related works were not tagged with the above concepts. Other methods of coverage, explained in later sections, were conducted to address these drawbacks.

3.1.2 Search

The second method involves a direct search method of related keywords such as "robot" in combination with "healthcare" or "biomed" in the body of the works. The relevancy of the works found relies on the efficiency of the keywords used, which cannot be guaranteed, as it is possible that keywords are only mentioned in the literature review and are not directly related to the research objective or methodology of a work. However, this method did provide high coverage despite lack of precision.

3.1.3 Role

This method is an adaptation from the search method, but instead of using general keywords, it focuses on the role of robotics in healthcare. These roles have been categorized into ten groups (Morgan, 2022): 1) Rehabilitation and Mobility, 2) Surgical, 3) Socially Assistive, 4) Telepresence, 5) Pharmacy, 6) Imaging Assistance, 7) Interventional, 8) Disinfection, 9) Radiotherapy and Delivery, and 10) Transport. We also identified mental health related keywords along with the aforementioned keywords to increase the precision.

3.1.4 Hybrid

We investigated the strengths and weaknesses of the above coverage methods by randomly sampling publications and evaluating the relevancy of their content with the concepts/keywords used to find them. For the *concept* method, it was observed that despite the high precision, as concepts were assigned based on the limited information present in the title, abstract and title of the host venue, the associated concepts occasionally remained unassigned. This observation became more apparent as more higher-level concepts corresponding to works with more limited scopes were investigated. In the *search* method, the searched keywords appeared only in the literature review of a publication, leading to low precision. Contrary to the *concept* method, this method utilizes the body of the publications, leading to better coverage. In order to maximize the strengths of these methods, we are exploring the development and verification of a hybrid coverage method that integrates the positive aspects of the previous methods, addressing the trade-off between precision and coverage. The goal of this approach is to seek an optimal synthesis of the higher precision observed in previous methods with the comprehensive information contained in the text of the body of these works to expand the coverage.

3.2 AI Research in Healthcare

In order to find publications related to AI and healthcare, three methods of coverage are being considered: 1) Concepts including the broadest definition of AI that include also robotics, 2) Concepts identifying only Deep Learning, and 3) Search of keywords.

3.2.1 Concepts – broad definition of AI

We extracted all articles in AI and robotics at the word level. We also retrieved all publications with at least one author affiliated to Canada. We analyzed the data for the period 2000-2021. We classified articles as pertinent to AI and Robotics using OpenAlex ’concepts’. We used the concepts of ’AI’, and ’Machine learning’ that includes articles dealing with both AI and Robotics. Using the author address and the Research Organization Registry (ROR) classification we were able to identify standardized hospitals affiliations. An article with at least one hospital affiliation was classified are an indication of AI capabilities in healthcare.

3.2.2 Concepts – Deep learning

Given the importance that Deep Learning has played in the most recent developments of AI we decided to repeat the analysis focusing only on the concept 'Deep Learning' identified in OpenAlex at the second level of the classification. Clearly this approach gives a much narrower output sample.

3.2.3 Search

As an additional validation for what AI is, we also employed keyword selection based on the lists from European Commission and Directorate-General for Research and Innovation (2023) and Iori et al. (2022). This approach provide a broader understanding of what AI technologies are and their use in hospitals. It is less inclusive of the first approach as it does not include robotics.

3.3 Analysis of Health Classification Data

For Aim 2: We have obtained the Canadian health classification codes to classify the existing data for health intervention services. We will identify codes related to robotics and AI interventions. Then we will cross-reference these codes with admitted patient-level data from 30 Ontario hospitals that will be available to us. In Italy and France, we are developing a collaboration with 20 hospitals to have access to health records and surgical records. Using text mining algorithms, we will try to create codes for the use of specific robotic technologies and AI techniques for the period starting in 2016. We will validate and complement these new original data with existing codes related to robotics and AI interventions available from the health records of admitted patients. We are working to get access to UK data on robotic surgery from the Hospital Episodes Statistics dataset that covers the universe of inpatient discharges from NHS hospitals in England from 2003 onwards.

3.4 Implications of Robotics and AI Technologies

We will conduct a hospital-level survey in Ontario and Italy to determine which hospitals have adopted AI and Robotics technologies, and how they have incorporated them into their workflows. Namely, this will also us to 1) develop a deep understanding of the causes of the diffusion of robotics and AI in the health system, and 2) analyze their impacts on productivity (efficiency of care) and performance (effectiveness of a technology) to ensure beneficial development and adoption of robotics and AI technologies.

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