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10 Impact of Artificial Intelligence on Library Services: Reflections on a Practical Project

Abstract: The industrial revolution typology has been used to describe the impact of various technologies on all aspects of society. The fourth industrial revolution (4IR) denoting the rapid technological change which has occurred in the 21st century is seeing a transition to the fifth industrial revolution (5IR) which promulgates the integration of traditional and new technological systems along with sustainability. The technological changes and fresh perspectives have enabled a paradigm shift within libraries from the provision of traditional services to online services with implications for future library operations including the application of robotics. This chapter describes a project on the development of an autonomous robot assistant as part of new eservices and technological infrastructure integrating library systems and services to improve efficiency and effectiveness at the North-West University in South Africa. The project explored the impact of artificial intelligence (AI) within the University, examined the views and perceptions of stakeholder groups in determining and implementing innovative tools suitable for supporting teaching, learning, and research, and investigated the process and impact of implementing AI along with the legal and ethical issues and administrative concerns. The findings indicated that AI enables creative thinking that can transform library and information services to enhance user experiences. AI presents an opportunity to develop self-help tools for library users and add value to the library's online presence. Embracing automated business processes using AI within the Library improves operational efficiency. AI has the potential to transform library services and operations.

Keywords: Artificial intelligence – Library applications; Robotics – Academic libraries; Chatbots

Introduction

Schwab (2017) characterises the fourth industrial revolution (4IR) as a fusion of technologies that blurs the lines between the physical, digital, and biological spheres. Technology is everywhere and embedded in every aspect of society with global connectivity. The 4IR has had a major impact on the services provided by libraries as they seek to integrate technology to improve the student experience and

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match new approaches to learning. In the application of artificial intelligence (AI), academic libraries are reimagining their services and exploring new ways of providing information resources and services to meet user needs and support teaching, leaning and research activities on and off campus. Many libraries have adopted AI and robotic process applications to respond innovatively to digital transformation and to maintain competitiveness in the higher education learning landscape. Although the digital world enables the competent use of innovative technologies in various sections of the library, financial implications such as affordability, budgeting, and sustainability are of concern.

This chapter provides an overview of some of the developments in AI, describes practical applications, and examines the impact of AI on academic libraries through a project examining the use of AI in North-West University (NWU) in South Africa. The project involved the study of a humanoid robot with visual intelligence using natural language processing (NLP) algorithms to facilitate communication between library users and a knowledge-generated database. A literature review on human-like AI machines was first conducted followed by a qualitative approach to collect data on different integrative AI tools that encouraged interaction, fostered deep machine learning (ML) and addressed language diversity. The resulting data was analysed to develop an increased understanding of AI phenomena. The findings were interpreted through reflection to identify optimal applications of AI in library reference and marketing services. The aim was to implement technological solutions that would result in a measurable improvement of efficiency and effectiveness with researchers and students. The self-help tools identified included a chatbot whose components could be tightly integrated into a physical robot. The physical robot exhibited chatbot capabilities that could interact with staff and clients in a live chat environment 24/7. The chatbot could engage in small conversations. The physical robot was an autonomous assistant making use of open-source hardware and software and could freely move around the library to help patrons.

The Context

The North-West University (NWU) is a multi-campus university with eight faculties which was formed from a merger of the former University of North-West, the Potchefstroom University for Christian Higher Education, and the Sebokeng Campus of another university, Vista, in 2004 as part of the South African government's plan to transform higher education. NWU enrolled over 45,000 students in 2021 of whom 5000 were postgraduates, with just under 10% distance students. The University emphasises transformative initiatives. It has a strong values system and focus on

excellence: “Where the willow trees grow and the thorn tree spreads its shade, there you will grow in knowledge”. The Library and Information Service at NWU is committed to partnership in student success, open scholarship and research, and its strategic priorities for 2024 and beyond are: content discovery, innovate and integrate, inform, educate and communicate, enable and disseminate, encourage and empower, and engage and position (North-West University. Library and Information Service 2021). The Library emphasises its digital and online services and is working with the Faculty of Engineering on a prototype library robot.

Artificial Intelligence within the University and the Library

Artificial intelligent technology entails machines that perform tasks normally undertaken by human intelligence. The new technologies offer positive benefits for all. AI incorporates a range of techniques and has emerged as an agent for use in multiple environments including universities and libraries.

Artificial Intelligence within the University

Introducing AI into the university environment has resulted in innovative changes in higher education and a repositioning of the focus on learning analytics with real time dashboards that assist with decision making, optimise workflows offered through inter-connected smart devices, and support evolving curricula leading in some instances to authentic learning. There are also improved learner capabilities by use of Virtual Reality (VR) which is a computer-generated environment with scenes and objects that appear to be real, making learners feel they are immersed in their surroundings. The combination of Augmented Reality (AR) and VR, along with AI, has the potential to assist students that are struggling to understand difficult academic concepts. An enhanced version of the physical world is offered, using digital visual elements, sound, or other sensory stimuli delivered via technology. There is some evidence that the combination of the technologies improves student results. Learners embark on a learning journey and engage with experiences in ways not previously possible and obtain real-time feedback from their instructors. Appropriate use of technology can provide differentiated student experiential learning. Expert systems have been used to understand student learning needs by analysing information use patterns together with visualisation data techniques. Students can be provided with learning experiences focused on individualised

learning outcomes with appropriate resources and contextual directions. Students can access digital learning resources at times and in places where they are needed.

AI has had considerable impact on research activities, primarily through improved data analysis where AI algorithms can speedily analyse vast amounts of data to identify patterns and trends. The research process can be enhanced through knowledge synthesis leading to improved research outcomes. Data mining tools can be used to transform data into knowledge. Data virtualisation techniques using dashboards can simplify data analysis as well as promote data science principles for better interpretation, use and reuse of data through the integration of various processes.

Other applications of AI are in the workforce where it has been used to automate simple lower-level tasks. Frey and Osborne (2017) stated that at least 65% of work activities could be automated with an achievement of 30% the most likely. However, it seems unrealistic that certain tasks will be completely done by machines; instead, they will be enhanced by AI and the people involved will have the opportunity to focus on the creative and social aspects of work. Seamless workflows will reduce costs and improve service delivery. AI has the potential for improving professional development through enhanced training and development opportunities, targeted personalised learning, content curation, and new learning management systems. AI can be used to identify gaps in knowledge, and to provide programmes containing content targeted to new skills and expertise required. Training can be focused and differentiated according to individual learning needs. AI can help accelerate learning and create a more productive workforce.

Artificial Intelligence within the Library

The library must respond to new directions being taken in teaching, learning and research and lead the way in encouraging innovative AI applications. Librarians are already familiar with the use of some AI applications, such as search engines that use AI, conversational agents, social networks, chatbots, and AI applications in library systems. The existing knowledge and experience of librarians provide the basis for further experimentation and implementation of AI. Incorporating innovative technologies is a unifying approach and some applications can be integrated into existing services using simultaneous discussions and online chats for enhanced eservices support. There are many AI applications of interest to the library with potential for use in process automation, collection management, online reference services with the use of chatbots and robots.

Process Automation

AI can be used with radio-frequency identification (RFID) technology to locate individual items in library collections or to track items using tags, improving the security of collections. The introduction of RFID technology has facilitated faster issuing, sorting and returning of books and the addition of robotic functionalities has added further improvements. Automated storage and retrieval systems (ASRS) are being enhanced with AI applications. Self-issue systems have become more popular as libraries adopt new technologies. Using AI tools within circulation and lending can assist in making suggestions for loans based on users' previous searches and borrowing patterns, and ensure more personalised services as well as greater accessibility to information content in both print and digital formats. Cox emphasises that "the diffusion of innovation takes time" (2021, 8). Physical access to library resources will remain significant for the foreseeable future. There are also continuing benefits to be gained from personal interactions between users and library professionals, which can be encouraged by interactive systems.

Collection Management

Use of natural language processing (NLP) which combines rule-based modelling of human language with statistical and machine learning models can facilitate automated collection management through indexing, subject classification, and assignment of subject headings as well as improving cataloguing processes. One AI application is Robotic Process Automation (RPA) which can be integrated into library processes for mundane and repetitive tasks like shelving, and book circulation. Such developments improve workflows and outcomes and contribute to the creation of a smart library that uses digital services to enable accessibility for users anywhere and everywhere. Use of intelligent techniques with services like document delivery can improve efficiency.

Online Reference Services

Expert systems were one of the early AI applications. An expert system comprises a knowledge base and an inference engine and seeks to replicate the decision making of a human expert using if-then rules. Expert systems have had many applications in libraries and have been in use since the 1980s. In some instances, they provide user interfaces for accessing existing online systems and have facilitated improved search strategies providing an intelligent front-end interface. Some expert systems

provide management services, such as analytical details about users. Omame and Alex-Nmecha (2020) postulate that an expert system could manage subject indexing and reference services that would speed up accessibility of library resources. Expert systems can also be used to provide intelligent gateways to online sources.

Machine and deep learning algorithms generate patterns to facilitate relationships between different data sets for ease of information retrieval. Virtual library assistance can be made available using AI and conversational agents are able to provide virtual support through tutorial platforms with the potential to transform traditional reference library services in academic libraries (Ali, Naeem, and Bhatti 2021, 14, quoting Rubin, Chen, and Thorimbert 2010, 496) "it is both timely and conceivable for … libraries to consider adopting conversational agents to enhance – not replace – face-to-face human interaction. Potential users include library web site tour guides, automated virtual reference and readers' advisory librarians, and virtual story-tellers". Use of digital services can exploit mobile technology, social media services like Facebook, and text messaging applications and allow librarians to communicate effectively with their users.

Chatbots and Robots

Web-based tools and chatbots or virtual assistants coupled with wider availability of Wi-Fi in public spaces and wider internet access are indeed transforming the library. Robotics and chatbots are commonly used as intelligent technology to answer student queries and can promote teaching, learning, and research in support of digital scholarship. Nawaz and Saldeen (2020) posit that chatbots are cost effective as they can easily link into the library website. Libraries can expand their information services and offer virtual assistance. Chatbots appear to be convenient for undergraduates; the anonymous interface is less threatening. They are able to provide virtual assistance, especially in relation to distance learning support and are operational outside of library opening hours. They can be linked to Ask-a-Librarian services and through automated question-answering algorithms generate responses to support users seeking guidance, support, and expertise in navigating the vast sea of information. The result is improved workflows with an automatic handover of chat responsibilities between the bot and human librarians. The chatbot can assume some, albeit not all, human librarian functions. If users obtain speedy answers to enquiries through improved customer engagement, user satisfaction levels will improve. Chatbots can have a significant effect in ensuring successful user experiences and potentially be used as a useful marketing tool with wide-ranging impact. Routine reference queries can be dealt with by the chatbot, and complex enquiries automatically escalated to library staff. Responses to users

are enhanced and the content of answers provided can assist in generating a valuable knowledge base for future use.

The Project at North-West University

The NWU Library has embraced 4IR by introducing AI systems in the library. The aim was to explore technological solutions that would result in measurable improved efficiency for the benefit of the university community by providing integrated access to library resources. The 4IR cautiously makes virtual spaces infinite (Yang and Cheng 2018) and increasing customer engagement and automating mundane tasks was the main objective. The adoption of 4IR strategies propagates inclusive use and interconnected technologies and emphasises blending all activities through smart technologies rendering services accessible anytime, anywhere. Recent developments involving AI refer to the use of large amounts of data and of machines with the ability to perform repetitive tasks with limited persistent human guidance. Many useful guidelines have been provided for the implementation of AI and provided a valued approach for the NWU project.

Governance and ethical issues must be addressed. A three-phase implementation plan including discovery to ensure assessment of the most suitable AI technology for a particular purpose, an alpha phase involving training and validation, and a final beta phase for testing will ensure success. A FAST track approach involving fairness, accountability, sustainability and transparency is deemed helpful (Peets et al. 2019). The guidelines provided by Peets et al. are helpful to interested institutions such as NWU in understanding, planning, and managing AI projects and considering ethical use.

The conscious investment at NWU was in developing interactive customer platforms such as self-help services, a chatbot, and an interactive robot to provide services for the 21st century. A survey of AI activities being undertaken in libraries in 2019 found that machine learning was being commonly used in most subject fields but that libraries had been slow to introduce AI technologies. The authors encouraged libraries to get involved: “The AI revolution is not on the horizon, it is already here and libraries need to make peace with this fact and begin the process of co-existence” (Wheatley and Hervieux 2019). Wheatley and Hervieux noted that few libraries included AI in their strategic planning, let alone collaborated with other units within the university and further observed in relation to an MIT Library project that “this collaboration resulted in several online tools that are still available today, however no other partnerships have been created to work on the uses of artificial intelligence in the library”. Conversations on AI have been prevalent in

smaller libraries rather than larger universities where one would assume finance would be available for new technologies. In contract, NWU is a large university and has been engaged in AI conversations with other departments on campus, including the Centre for Teaching and Learning, Graphic Design within the School of Communication who designed the outside shell of the robot, and the School of Electrical, Electronic and Computer Engineering who were involved in the building of the robot, programming, and integration. Introducing digital technologies and rolling out robotics technology to other campuses at NWU is part of the five-year strategic plan. AI has created opportunities for engagement and set the pace for further work given the universities' roll-out plans and concurs with the perspective presented by Wheatley and Herview (2019).

In going forward NWU determined that a chatbot and physical robot tools and use of ML would offer integration of library services and accelerate student success, supporting individual growth and intellectual capabilities in an accessible 24/7 environment. The multiple personality context offered by the physical robot and multilingual capabilities in two other African languages, in addition to English, would provide stimulus for learning and marketing the value of library resources and services. In addition, a physical robot supports equity and inclusion since the display screen can be enlarged and is height-adjustable providing full accessibility for people in wheelchairs. It also allows for verbal and text-based interaction. People with auditory impairment can use text-based interaction through the robot screen.

The Project Details

The goal of the project was to develop an autonomous robotic assistant to answer questions from library users and to provide marketing services for the library. The key requirements were that the chatbot should be able to converse meaningfully with library users, and the physical robot must exhibit chatbot capabilities in simple conversation. The objective was to provide immediate help to library users and a knowledge database was created from the library's store of frequently asked questions (FAQ) and the responses provided to minimise initial failures which could lead to referrals.

The project was conducted by the NWU Library with the Faculty of Engineering. A homegrown artificially intelligent chatbot was chosen because it had more marketing value than a commercially available chatbot. It is easily customisable and provides for continual improvement by means of continuous learning. Since

the chatbot includes machine learning elements it can learn from experience gained while it is in operation.

It was determined that the chatbot of the physical robot must be able to converse with online library users via a suitable communication channel, either WhatsApp or Telegram. Online conversations can be conducted by means of text messages. The chatbot is able to maintain more than one simultaneous discussion. The conversation with a person physically present has priority with minimal latency or response delay and more than one online conversation can be accommodated. The latency in the online chats is influenced by the number of simultaneous conversations. The latency for two simultaneous online chats should be less than 500 milliseconds, excluding communication network related delays.

Methodology

Use of open-source software reduced costs on hardware and software. The software enabled ease of maintenance and upgrades to other versions. The library robot comprised the following: mechanical structure including screen, camera fixture and battery panel, electronics, and electricals; switch panel; depth camera; sensors; software including simultaneous localisation and mapping (SLAM) code, face tracking and object recognition. Other features included a remote control panel and monitoring station. The sensor selection included various tasks, such as obstacle detection and avoidance, environmental mapping, localisation using wheel encoders, navigation, and path planning to ensure the avoidance of obstacles.

Mapping and navigating the target environment were conducted in the library environment; the design interface was finalised by building a robot shell. A controlled deployment phase was also conducted. The robot was deployed in the main campus library first to evaluate user interaction. Feedback was used for improvement in design and functionality. The last phase was to replicate the robot for other campus sites.

The Conceptual Phase

The concept generation was influenced by how 4IR ideas associated with Industry 4.0, synonymous with smart manufacturing (IBM n.d.) and Library 4.0 could be translated into the library of an African university that embraces the humanity to others philosophy of uBuntu App-centric industry 4.0. NWU nurtures the digital integration of all systems to improve efficiency in service operations. The concept of App-centric industry 4.0 contextualises inclusivity to the benefit of not only the

university's internal stakeholders, but also the wider university community. It means that children in the surrounding community may participate in university community projects and have the opportunity to expand their experiences outside the classroom. In addition, the concept extends to include research and scholarship as a proactive response to the changing scholarly publishing landscape in the university. There is increased research output in the form of scholarly publishing, research and innovation endeavours through engaged collaborations.

The introduction of the two intelligent technologies, the physical robot and the chatbot, was in line with the university e-strategy to digitally transform services that would improve efficiency and customer engagement. Tight integration of services emphasised automatic handover of chat responsibilities from the bot to human librarians. The chatbot has added value to the library's online presence rather than merely being a novelty item. Cost factors were reduced by using local supply with more competitive pricing. Some mechanical components were supplied by the partner in the project, the Faculty of Engineering. Local 3D-printers were also used. The software used integrated data from the existing catalogue. The benefits were marginal maintenance and sustainability for future research development and product improvement.

The physical robot was more appealing to physical users of the library and served its marketing function, attracting more users to the library. The chatbot enhanced the discoverability of library resources with 24/7 availability across the globe and catered for distance learning students by providing virtual access. The chatbot harnessed the power of machine learning and provided continuous access to library resources.

The Development Phase

The development phase included aspects that extended robot longevity by incorporating new roles and functionality for the period 2023–2025 in line with the library strategic plan to ensure continuous improvement of the shelf life of the physical robot and updating of the content of the chatbot with 24/7 accessibility. The life of the hardware was estimated to be five to ten years. Since more commercial robots focus on English as a predominant language, product development embraced the multilingual capabilities in languages relevant to the NWU context, Afrikaans, English, Sesotho, and Setswana. All university stakeholders benefitted from the use of intelligent technologies and were able to use languages with which they felt comfortable.

As already noted, the physical robot and chatbot used open-source software. The integration process included the bot based on use of Generative NLP (Google

2022) with the same knowledge base as the library's FAQ. In addition, certain aspects of the library catalogue were incorporated to allow the chatbot to recommend references based on user requests along with library functionalities such as automated directions to specific sections of the library website. The database and software were hosted on a fast server, to prevent delays during verbal communication.

User requirements were determined through meetings held with library staff to obtain the exact specifications that would yield the desired product output. Building the physical robot involved meeting the specific requirements which have already been mentioned and included the mechanical drivetrain with electrical motors, wheels, chassis, and power supply, sensor arrays, and relevant control systems for object avoidance, human-machine interface/interaction (HMI), and mapping.

The exterior appearance of the robot was locally designed by students from the School of Electrical, Electronic and Computer Engineering within the Faculty of Engineering and graphic design students from the Faculty of Arts. Each of the three campus library robots reflected a unique feature of the campus while at the same time showcasing the university.

Multiple personality sentiment analysis was incorporated to correspond and adapt to the chatbot approach to each conversation depending on the language used. Improved customer satisfaction has been a driving principle, and the chatbot was able to escalate complex enquiries to library staff. Generation of a knowledge base for future use has allowed room for further development.

Lessons Learned

4IR has changed the way academic libraries provide services to patrons. AI is likely to replace repetitive forms of knowledge provision and service, as well as routine tasks undertaken. As a result, libraries will reengineer their operations (Marwala 2022). Implementation of AI in academic library environments could accelerate, with clear strategic positioning guided by an innovative vision and mission, where the online mode becomes the default route for providing library services in most universities in the support of teaching, learning and research. Librarians' skills and expertise must be finely tuned to respond to the level required to support both online and physical library environments. Acquiring digital skills related to the use of intelligent technologies is essential. The implementation of robotics and the chatbot simultaneously at NWU was effective both for educational purposes and access to library resources. An effective knowledge base is also an essential ingredi-

ent because data can be mapped, interpreted, and transferred to multiple environments for meaningful application. The results of the project indicated clearly that the use of intelligent technologies can improve library services given the integrative customer engagement approaches that a combination of a physical robot and a chatbot can deliver.

Opportunities for creativity abound in the digital transformation process. The questions of capacity, safe use, and security must be addressed. Luca, Narayan, and Cox (2022, 185) highlight the need to take precautions in fair use of applications and freedom of expression that will eliminate bias yet not stifle creativity. The focus must be on accelerating information access for users and professional development for staff in response to opportunities that AI and robots can offer. Understanding copyright legislation and what is legally permissible is essential. Licensing of content, and intellectual property rights are important components of the development of regulatory measures on ethical standards and policy directives concerning legal and educational compliance principles in AI. In the case of collaborative work, agreements should be in place. Reliable and secure IT infrastructure allows efficient system integration. The information architecture and knowledge organisation must be designed to enable good workflows and fast-track content discovery.

AI has the potential for positive impacts on academic libraries and can be used innovatively in reference and information services, and in the promotion of library resources. Chatbots provide numerous advantages, although they pose some limitations associated with the knowledge base and language processing. Nawaz and Saldeen (2020, 444) remark that chatbots respond to input queries previously recorded in the knowledge base which limits the conversational ability to a fixed content base and prevents responses to multiple queries simultaneously. Training for everyone involved is essential to ensure that users feel comfortable using such applications and do so effectively. The changed role of the library has made it more attractive to a new generation of users. Application of AI helps streamline library functions and results in enhanced learning, training, and skills development. Since AI reinforces learning, the quality of the knowledge base data must be updated in line with education needs and relevant library services.

AI applications must be integrated into existing library systems. The development and implementation of new applications must be collaborative working with information technology developers and information architecture and infrastructure experts along with academic support services to ensure seamless accessibility and appropriate responses to user needs. The use of AI and the transition to digitisation of library processes can improve space utilisation and enhance the user experience.

What Lies Ahead?

Varius perspectives may accelerate or slow down the broader application of AI. Developing ethical standards that incorporate intercultural understanding in institutions when adopting AI will have an impact. Design and language capabilities can enhance inclusivity and multiculturalism given the demographics of different backgrounds. Collaboration and partnerships have the capacity to strengthen engagement with AI applications, particularly in the use of robotics and conversational platforms in teaching and learning. In-house products with customisation can yield tight integration of library services and cost-effective benefits when suitably qualified professionals are involved, as in the NWU experience.

There are implications for high-end skills when planning future education strategies and changes in skills and work. AI literacy is an essential prerequisite skill for library users and librarians. Digital intelligence is also necessary for professionals to be able to evaluate the Al tools available to ensure a positive impact on library services.

The effectiveness of implementing AI in any organisation is tied to the organisation's ability to ensure that any application is fit for purpose, can be adapted for use in the environment and is capable of being applied to unfamiliar scenarios. Determining the level of response to AI within the library, and identifying the optimal interventions is challenging. The redesign and reshaping of library services have many facets. New and different types of skills are required to succeed in a fast-changing world. In some circumstances, libraries may have a role in developing new skills for displaced workers and/or improving skills so that workers can transition to new roles and responsibilities.

Conclusion

AI presents multiple options that influence the way information can be accessed, managed, and connected in exciting ways. The role of the library can be innovatively expanded through digital transformation although adversely there are issues in relation to safety and ethics including legal and administrative concerns and user authentication, AI applications have enhanced user support services. AI and big data create immersive opportunities for knowledge sharing and further opportunities for library services. Librarians will continue to play a significant role in helping clients find and use information although some aspects of the role will change. Creating an innovative, interconnected environment with secure authentication will increase the value of library services. Application of robotics and chat-

bots has transformed library services with integration of other technologies and inter-connected smart devices. AI multifaceted capabilities are redefining traditional library operations. AI has a pivotal role in ensuring accuracy and amplifying the efficiency of search and retrieval processes. Smart innovative AI applications tightly integrated into library services can increase customer engagement and improve teaching, learning and research in academic environments.

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