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"Robots in libraries: challenge or opportunity?"
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I – Robot, to help You – Librarian

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Abstract:

Modern librarians are called to become information and knowledge managers, however they are also requested to deal with a lot of routine tasks, like labeling, shelving, doing inventory. Shouldn't we delegate these repetitive assignments to robots and save our time for more important missions? Will many of our tasks be taken by 'increasingly capable machines', as predicted by prof. Richard Susskind in his book "The Future of the Professions"?
Since the 1980s we witnessed libraries to continuously ceding their traditional territories. Machine-readable catalogues replaced the card catalogues in the 80s, the Internet enabled the online public access catalogue (OPAC) in the 90s, while the RFID allowed in the 2000s borrowing, returning and sorting library items even in the absence of a librarian. Libraries embrace technology to offer better, faster and continuous services to their users.

The Library of the Max Planck Institute (MPI) Luxembourg for Procedural Law explores the present and future use of robots in libraries. In 2016 the Library tested the Tory robot, MetraLabs Germany, to make an inventory. In only one hour the RFID tags of 35,000 books were read by Tory with an accuracy of 99,11%. The methodology and results will be presented, followed by a live demonstration of the new Tory model.

The paper discusses new areas of robot implementation in libraries. In addition, the results of the 'Robots in Libraries' survey 2018-2019 will be discussed. The survey was conducted in 2018 in big university and public libraries in 9 European countries and continued in 2019 in 9 Asian countries. It gives a snapshot of the current robot implementation, the future expectations and concerns of the librarians. With the introduction of robots, library staff will be relieved of certain repetitive tasks and as a result will have more time to get to know their users and to devote themselves to service-oriented work.

Keywords: Insert up to five keywords here, Times New Roman font, 11-point size, left-justified. Library robots, RFID robots, library automation, Robots in libraries survey, future libraries

Libraries develop and function with the mission to preserve, process and deliver the knowledge to the future generations. Technology development has a parallel development, building on the knowledge of previous centuries, while always taking a step further to ease peoples' lives, or even taking a giant leap sometimes. Technology influences all life spheres and is hence closely intertwined with libraries.

1.Technology development and impact on libraries

1.1 Technology trends

Since the beginning of the 21st century technology development is marked with the widespread of powerful computers and mobile devices, enhanced with telecommunications. As we approach 2020, some trends become obvious.

Miniaturization. The exponential growth of computer power is related to the miniaturization of transistors on an integrated circuit chip. According to *Moore's law*[1], the number of transistors in a dense integrated circuit (a chip) doubles about every eighteen months, hence your computer power doubles. The last 50 years were continuously witnessing the manifestation of this law. Today a Pentium chip may have several hundred million transistors. Is there a limit of this?

According to prof. Michio Kaku, a Japanese-American professor in physics, one transistor will reach the size of 5 atoms by 2020. Moore's law will finally collapse when you hit transistors the size of individual atoms. Gordon Moore himself said in 2007 that the law would end in ten to fifteen years. Around 2020 or soon afterward, Moore's law will gradually cease to be valid.

Ubiquitous computing. The term '*ubiquitous computing'* was first coined by Mark Weiser from Xerox in 1988, The need of a desktop computer is eliminated and computing can happen in any device and location – a camera, a car, a tablet or a mobile telephone.

IoT. Combined with the multitude of sensors and increased connectivity, a new trend is also fast developing – the *Internet of Things*, or *IoT*[2]. IoT is the network of physical objects—devices, vehicles, buildings and other items—embedded with electronics, software, sensors, and network connectivity that enables these objects to collect and exchange data. We can look at IoT as a mixture of hardware, software, data and service. Gartner, Inc. forecasts that 20.8 billion connected things will be in use worldwide by 2020.

Big data. We all witness that information is more than abundant today. According to IBM every day we create 2.5 quintillion (17 'Zeroes' after 2,5) bytes of data — so much that 90% of the data in the world today has been created in the last two years alone. This data comes

[1] This law was first stated in 1965 by Gordon Moore, one of the founders of Intel corporation.

[2] This term was introduced by Kevin Ashton back in 1999, when he was referring to a global network of objects, connected to RFID (radio frequency identification).

from everywhere: sensors, social media, digital pictures, videos, purchase transaction records, and cell phone GPS signals to name a few. This data is big data.

In 2012 the Harvard libraries released their big data on books. During 1-day test 15 hackers played with the data and tried to get some meaning out of it. They created:

- visual timelines of when ideas became broadly published,
- maps showing location of different items, and
- a 'virtual stack' of related volumes from different locations.

AI. Scientists also deploy their efforts to the development of *artificial intelligence (AI)*. Development of AI traditionally follows a more 'mechanical' approach, based on the digital computer processes.

IBM Watson[3] is a successful project, where IBM supercomputer is constantly fed with large portions of unstructured data to enable natural language interaction and machine learning. According to IBM, "The goal is to have computers start to understand the questions that humans ask and providing answers that humans can understand'. Watson is considered highly suitable for law research and implemented by Thomson Reuters in Westlaw.

Disruptive technologies. With the ubiquitous computing, we also witness the so-called 'disruptive technologies'[4]. Disruptive technology is an innovation that creates a new market, and eventually disrupts the existing market, displacing the market leaders. It offers new products or services which are at the same time better, cheaper and more customized.

Robots. According to Deloitte, by 2020, robotics is a $100 billion industry, which generates 2 mln additional jobs in 2017-2020. The biggest share belongs to industrial robots, while rehabilitation, medical and home robots are under demand and increase quickly. Robots are used in different services – as a policeman in Dubai, musical composer in Luxembourg, in hotels in Japan or educational help elsewhere. Libraries are still seen as a traditional place for books, even though now extending to e-books. There are a few developments and implementations, hence our conference is a timely debate. According to our survey, only three of one hundred European libraries have any experience with robots.

1.2 Technology impact on libraries

Since the 1980s we have witnessed libraries to continuously ceding some of their traditional territories. Machine-readable catalogues replaced the card catalogues in the 80s, the Internet enabled the online public access catalogue (OPAC) in the 90s, while the RFID allowed borrowing, returning and sorting library items even in the absence of a librarian. Libraries embrace technology to offer better, faster, and continuous services to their users. The contemporary world of mobile communications and disruptive technology creates a new type

[3] Watson was built in 2006 and named after IBM's first CEO.

[4] The term has been first introduced in 1995 by Clayton Christensen in his article in Harvard Business Review.

of library user. Which other services could the libraries delegate to machines or systems, to inform, inspire, or please[5] the modern age user and in a seamless way?

In their seminal book 'The Future of the Professions'[6] Richard and Daniel Susskind explore how the professions of lawyers, consultants, teachers, doctors and other 'traditional gatekeepers' of knowledge will be transformed due to the new technologies in what they call 'Internet society'. The authors mark some existing signs of moving from craft to externalization and commons, as parts of the traditionally delivered services within a profession, are now entrusted to machines, systems, and even AI. They conclude, that 'increasingly capable machines will take on many of the tasks, that have been the historic preserve of the professions". The book does not reflect on the future of librarians, still, it is not difficult to reflect on our own profession along those lines. We should ask ourselves what are the tasks that we can delegate to increasingly capable machine, and more importantly, what is the core mission which still remains ours as librarians. The authors think that innovation should be practiced daily and that the introduction of robots in libraries is imminent.

2. Tory

In our library environment, the inventory is something that calls for a robot, as it is a robust and repetitive work. One might ask why do libraries perform an inventory and whether they still do it. Apart from confirming the presence of physical items in the collection, the inventory finds out which books are missing or shelved at a wrong place, which practically makes them impossible to find or 'missing' too. If books are missing, but we only discover that after many years, it is much more difficult and costly to replace them. Our recent survey[7] shows that 49.85% of the libraries still conduct a full or partial inventory. According to the survey respondents, that exercise might take 400, 800, or in some cases more than 1,000 hours!

What is the problem?

If you look for a certain book or other media in a library, you'd expect to find it in a particular position, and of course, you'd like to know if it's available or already borrowed, or even lost. To reliably know that information, one, usually librarian staff, has to conduct systematically inventory taking, examining item by item. This is relevant for small libraries but a fortiori for large archives. Stock-taking, even performing a selective inventory to sustain an overview of portfolio, is a time-consuming task and requires significant human resources. Can you imagine how long it must take to complete the inventory of The Library of Congress in the USA which carries over 36 million books?

In times of digitalization and raising efficiency, how can this seemingly insurmountable task be done in a better way, even releasing librarians' inventory-allocated valuable working time to more relevant and user-oriented tasks?

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[5] Melvil Dewey (1926) "Our great function is to inform, or to inspire, or to please; to give the public in the quickest and cheapest way information, inspiration, and recreation on the highest plane."

[6] Richard Susskind, Daniel Susskind: The Future of the Professions. New York: Oxford University Press, 2015, p. 271

[7] 'Robots in Libraries' survey, conducted by MPI library. The survey covers academic, national and big public libraries in Germany, The Netherlands, Luxembourg, Lichtenstein, Norway, Sweden and Switzerland. Currently deployed in Singapore and Japan.

How does TORY solve that problem?

The presented mobile robot “TORY”, the name derived from “inventory”, is an efficient inventory taking solution that provides for such a clever share of work. It essentially conducts two tasks simultaneously and without human assistance: Gaining exhaustive inventory information and position of each book or other physical media on the library floor. By silently traversing all aisles of book shelves it captures wirelessly every item by its unique identifiers stored in the attached UHF-RFID (ultrahigh frequency radio frequency identification) transponder and their location to recognize misplacements on a frequent basis, e.g. daily, depending on library size and density of items. Once the inventory has been performed, TORY returns back to its charging dock.

Radio-frequency identification technology applies electromagnetic fields (in this case at about 868/ 915 MHz) to wirelessly identify objects by their attached transponders (tags) in which its exclusive identifier and possibly other inventory information is electronically stored. These passive tags don’t have a battery. They “wake up” and tell their stored information when they are energized from interrogating radio waves of a nearby RFID reader. These transponders are usually created as adhesive labels to be easily attached to objects, e.g. into books, and contain an etched aluminium antenna structure and a tiny semiconductor chip with the stored identifying information. Contrary to barcode-based identification, the tag (nor the physical item) don’t need to be visible to obtain that data, but it must be situated within the read range of the RFID reader, for UHF usually several meters. And TORY can be seen as a self-driving RFID reader, that automatically scans your inventory.

Description of TORY

The fully autonomous TORY robot in its latest version is depicted in Figure 1. At a total height of 2 ..2.5 m (adjustable antenna pole), it comprises 16 UHF patch antennas that are arranged all around its body to cover virtual all directions up to acquisition distances of theoretical 10..12 m under ideal conditions, in reality ca. 6 to 7 m, and from ground level to shelf heights of up to 3 m. The incorporated robot technology is approved by Germany inspection agency TÜV to be safe around people that share the same workspace. The applied industrial grade components provide for high reliability and low maintenance. The complete robot weight about 60 kg and has an operational time is 16 to 20 hours, depending on floor structure and density of items to be captured. TORY will automatically return to its charging station where its safe Lithium battery is recharged within 3 hours

TORY’s unique shape is designed for high manoeuvrability and RFID read performance. The circular laid out driving platform has a small diameter of 50 cm. The durable chassis contains of a differential drive system with two active powered wheels and four supporting castor wheels that allows for turning on the spot without rerouting. TORY can drive everywhere a wheelchair can go on the library or archive floor.

With its specific navigation software and sensors for perception like long range 2D laser range finders, 3D cameras and odometry sensors, TORY localizes itself using the driven path (wheel information), the surrounding natural land marks like walls, pillars, door frames and shelves etc. as well, and, of course, avoids dynamic obstacles like walking people while driving. To integrate with library inventory management software and databases, it contains a powerful personal computer with standard wireless LAN (WiFi) interconnectivity.

Fig. 1: Autonomous inventory taking robot TORY for RFID-tagged items (MetraLabs GmbH, Germany, 2019).

Automated inventory taking process using TORY

The initial step is a mapping procedure where the robot learns its environment. That can be done by pushing the robot along the aisles or by remotely driving it through a game pad or joystick using an intuitive mapping tool. To adapt for layout changes, the autonomous inventory taking runs will also be used for automatic map updates without any user input.

Figure 2 provides an overview of a fully automated inventory taking run of TORY: After the start via a library inventory server, a fixed schedule or by manually pushing a button, the robot traverses the library aisles along with pre-defined waypoints, all or specific and takes the inventory data. The inaudible pace is about walking speed at 0.2 up to 1 m/s (0.7 to 3.6 km/h). The maximum RFID tag-capture rate can be up 400 tags/ s but to reach a consistent inventory quality of typically above >99 % read accuracy (completeness), the driving behaviour like peed and rotation angle of the robot adapts to RFID-tag density and their position. It helps as well as that the robot achieves closer proximity to desired tags compared to fixed installed RFID interrogators like ceiling or overhead mounted RFID readers. By data fusion of various signal strength values of the received signals from each tag and in regard of actual robot position and antenna direction the items are localised within a precision of ca. 50 to 100 cm. Latest developments also incorporating the phase information of the reflected electromagnetic waves into the data fusion process show promising results with a localisation precision of better then 10 cm. Future applications that make use of artificial intelligence and deep learning not only for path planning and obstacle detection will also help to predict areas in need of an inventory as well as higher accurate item position estimation to further enhance the inventory management.

After finishing the stocktaking run, TORY drives back to its charging station and docks to it to be recharged. The list of acquired items and their position in X, Y Z is sent to the library database through WiFi. The robots wait at its charging station until the next inventory taking run is triggered.

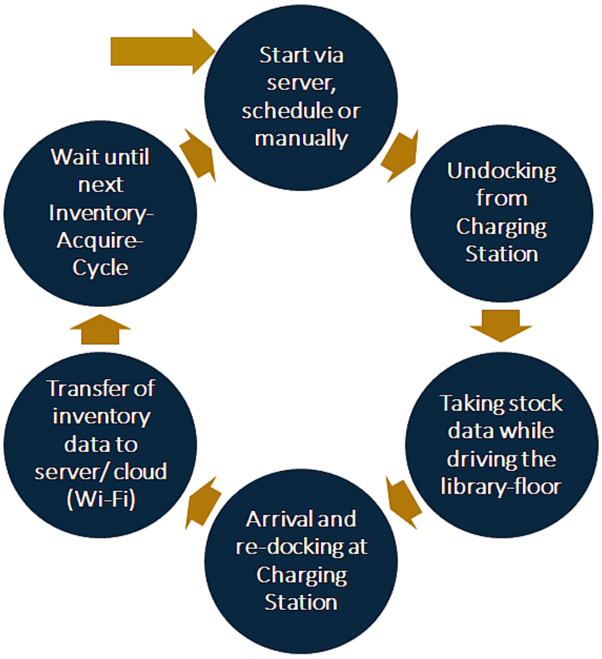

Fig. 2: Standard cycle for automated inventory taking using TORY robot (MetraLabs GmbH, Germany).

Investigation of capabilities of TORY for automated inventory taking in a library.

Originally developed for inventory taking and tracking of goods in fashion retail stores for increased availability of merchandise and streamlined work processes where TORY saves valuable time for employees to spend attending the customer and raise the service quality, TORY was temporarily adopted to accomplish inventory taking in a library. It was brought to the Library of The Max Planck Institute (MPI) Luxembourg for Procedural Law to conduct a test on the 26th of October 2016. At that time 35,000 items were shelved in two halls with a total floor area of 500 sq. m.

To learn the area TORY was initially 'pushed' along the main aisles and the alleys. The derived first map was the basis for path-planning which was done easily at a personal computer by adding so-called waypoints into the map. And then the autonomous robot was able to drive alone as shown in Figure 3. Many of the library users came to meet it and every time someone walked close to it, TORY politely stopped. It confirmed with its actions, that it is certified for safety according to the European standards. The authors were curious to follow and observe it at first, but later gave it the confidence to continue doing its task alone. To great surprise, it finished the full inventory of the collection after only one (1) hour!

The robot's findings were exported as an Excel spreadsheet, containing RFID tag numbers. The gathered data was compared with a list of all available tag numbers in the library database, excluding the loaned items. TORY successfully read 34,805 items out of all 35,118 items, which shows an accuracy of 99.1 %.

In addition, TORY was entrusted to look for eight missing books. Tory found six of the books and presented its findings as red dots on the map as shown in Figure 4, together with the specific tag identifier. This help was precious for the library, as the books were found shelved in a wrong place.

Fig. 3: Standard cycle for automated inventory taking using TORY robot (MetraLabs GmbH, Germany).

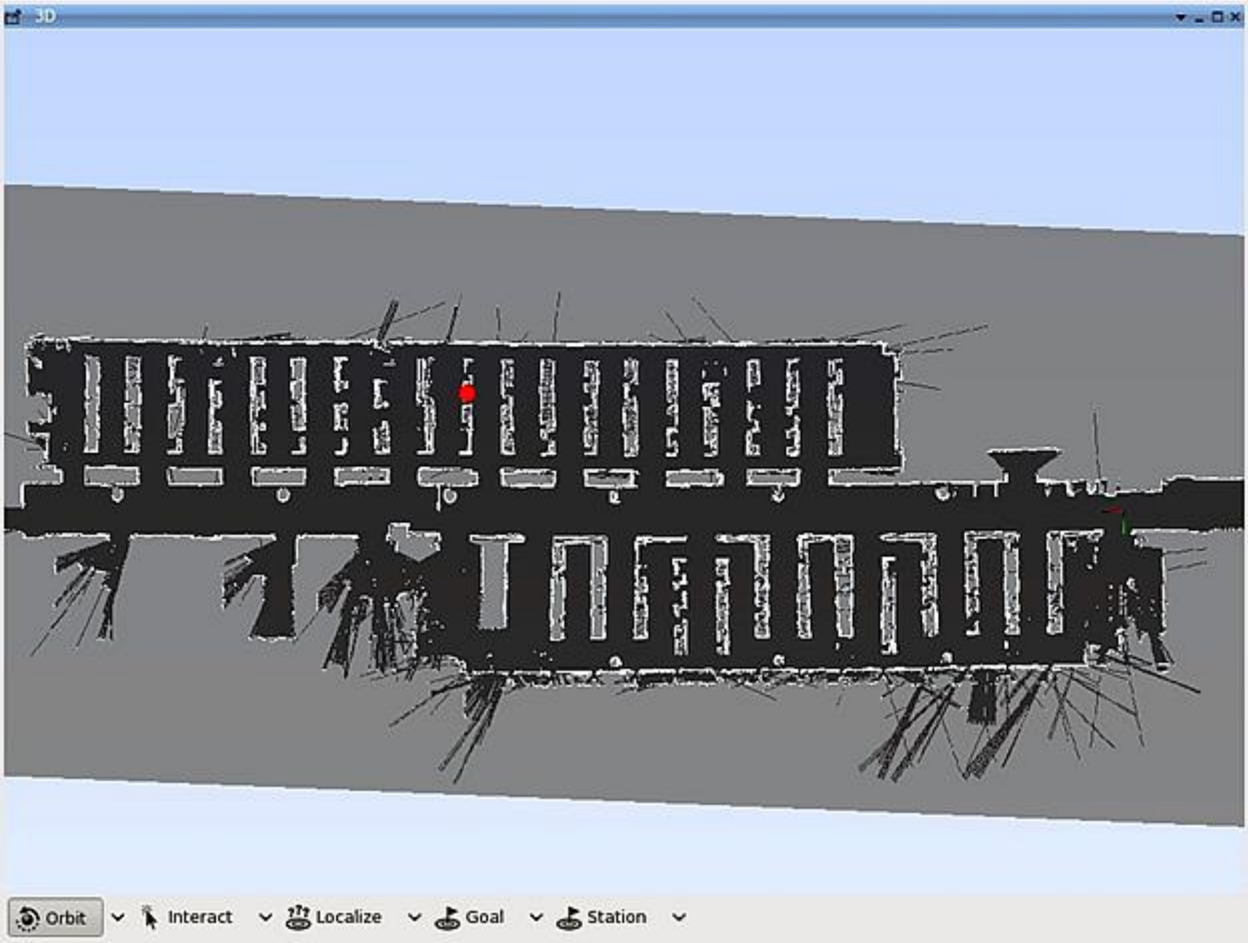

Fig. 4: The red dot on the robots map (top-down-view) represents the specific RFID tag number (or book) that was specifically looked for.

The test of TORY gave very satisfactory results and also a lot of food for thought. Imaging sharing a robot with other libraries, in this case in Luxembourg, for simultaneously improved efficiency and shared costs. Unfortunately, the two biggest libraries were about to choose a different RFID frequency range, namely HF (13.56 MHz). This raises two possible solutions. Either libraries join efforts to become compatible by using the same RFID standard, or developers build a robot with changeable antennas to serve both audiences. UHF tag reading was done very fast, but the precision to point an exact location of a book was low – from 0.50 to 1.00 m. MetraLabs has set as a development goal to reach an average value of localisation precision well below 10 cm.

There are other solutions for automated inventory taking, e.g. are so-called “smart shelves” with densely integrated RFID-antennas, associated antenna multiplexers and RFID-interrogators (“readers”) to cover each shelf space. This concept might be of interest to a new building or some insular shelving. However, the related installation effort and equipment costs have to be considered, and it is quite difficult to extend already existing shelf infrastructure. TORY has proved that it copes well with existing shelves and infrastructure.

Eighty percent (80%) of our survey respondents are willing to delegate the task of locating misplaced books to a robot, especially university librarians who know well the student’s habit of hiding books for their own use only.

3. Future tasks for robots in libraries

We started at a very practical level of robot involvement in the library, namely performing an inventory and finding books. However, the robot has the potential to perform a much larger range of tasks in a modern library. Currently, there are no robots conceived especially for libraries[8], or in rare cases, they perform only one type of tasks. I envisage, though, the time when robots will be able to multitasking. Let me provide some ideas and examples.

An interesting and easy to implement task will be providing library maps in real time, showing the location of subjects (like law, mathematics, physics) on the library shelves and halls respectively. It will be more than helpful to obtain the update automatically, especially when moving entire sections to a new location, by using a robot scanning the surfaces and updating the shelving plan. This is not a new idea, as this is how the term 'Internet of Things' (IoT) started. Currently, beyond RFID, objects have a wide range of embedded electronics. Having a robot, equipped with sensors, could provide additional information in libraries – for example, humidity, temperature, open windows light comfort, presence of users, etc.

Can we also entrust a robot to interact with the users? Let us call this type of robot a 'social robot', as he is socializing with the users, answering their questions, providing directions and information. The company SoftBank offers the robot Pepper[9], who is fit to be taught such a task. He needs further programming to better act in your specific environment. Pepper is a humanoid and can walk at the speed of a human. The Technische Hochschule Wildau is teaching Pepper how to understand and answer questions. Speech recognition and providing adequate answers are quite a challenging task, but Prof. of robotics Janett Mohnke and Frank Seeliger, Head of the Library, hope that Pepper can become the night shift librarian soon[10].

Japan is a country, which is very open to the introduction of robots in different spheres of life. According to shintoism, every thing, even a non-animated one, has a spirit. This traditional belief may be the reason why robots are so easily accepted. With a quickly growing aging population, the government develops special incentives for the development of nursing and caring robots. The libraries will also soon see robots taking care of the users. According to an article in Robostart[11], the Pepper robot will be deployed in five hundred (500) Japanese libraries.

The introduction of robots in libraries will enable us to stay open 24x7, provide precise and up-to-date information, serve our users in a better way, and even entertain them. A reasonable question is whether the robot will just assist the librarian, or replace her. Asked that question, 91.84% of our survey respondents declare that they do not have such fears. Librarians will be liberated from repetitive tasks and will be able to devote their time to better know and serve their constituency. Tasks involving analysis, innovation, imagination and psychology will

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[8] If such robots exist, the authors will be very grateful to be informed.

[9] Pepper was developed by the French company Aldebaran Robotics, which was acquired by Softbank Group in 2013.

[10] Wildau Roboter übernimmt Nachtschichten in der Bibliothek - "Hallo, ich bin der neue Mitarbeiter der TH Wildau" https://www.rbb24.de/wirtschaft/beitrag/2017/02/bibliothek-der-th-wildau-bekommt-humanoiden-helfer.html (last seen 25.12.2017)

[11] Ryosuke Mochizuki : Pepper answered questions at the library. What is the effort of the library distribution center when aiming to introduce Pepper to 500 libraries operated nationwide? Available at: https://robotstart.info/2016/08/03/trc-pepper.html (last seen 25.12.2017)

still constitute the core of librarian's mission. Our biggest strength is and will be to remain human.

We witnessed the three types of libraries, described by Michael Buckland[12]:

- The Paper library (1800-1970 roughly) – library materials and technical operations were entirely based on paper,
- The Automated library (1970-1990) – where the library's technical operations were computerized, but its collection remained on paper.
- The electronic library (early 1990s through at least the early 2000s) – library operations and library collections are available in electronic form.

Shall we now define the fourth type of library as of 2020 onwards – the 'AI and Robot library'?

[12] Michael Buckland, emeritus professor at the University of California, Berkley School of Information, described in his Manifesto of 1992 the three types of libraries.