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Building Library AI Infrastructures: Research Data Repositories, Scholarly Ecosystems and AI Scaffolding

ABSTRACT:

AI possibilities for deep learning, machine learning and natural language processing present fascinating new library service areas. These areas are being integrated into traditional academic library information, digital literacy and university research environments. Much of university faculty, graduate students and library staff work outside of Computer Science disciplines and require help to enable their data. This research overviews methodologies, infrastructures and human resources needed for building new AI services within the 'third interdisciplinary space' of the academic library. This work suggests pragmatic steps that may be taken to set up good foundations. Data-centered steps for setting up digital scholarly research ecosystems are reviewed. Setting needed groundwork for library AI services enables research, data and media towards global online possibilities. Library AI external scholarly communications services are discussed as well as educational methodologies. Pathways are clarified and focused steps are forwarded to move library staff researchers and graduate students towards these new AI possibilities. Data-centered ecosystems, retooling and building on existing human resource expertise are reviewed. Data research repositories and programmatic algorithmic literacy are recommended. Library AI working groups and R&D prototype methodologies for scaling future library services and human resource infrastructures are considered. Prescriptive pathways create best in class library infrastructures for a currently occurring global AI paradigm shift.

Keywords: Artificial Intelligence, Deep Learning, Data Research Repositories, Academic Libraries, Research Libraries

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INTRODUCTION

Deep learning, machine learning and natural language processing are fascinating new areas of AI. Most university research faculty, graduate students and library staff work outside Computer Science AI disciplines and don't know where to begin with enabling their research data with new AI paradigms. This research overviews pragmatic steps to set up good foundations for AI possibilities. These steps include data research repository foundations, digital scholarly research ecosystem infrastructures and relevant tools and services to set groundwork for new arising AI possibilities. This research draws upon the pragmatic work of the author over two universities and nine years of AI related projects (2014-2023). This research may be most productively utilized and adapted by any similar-sized medium or large academic library or research institution thinking about beginning AI programs.

Developing AI-related library scholarly services for research faculty, graduate students and library staff begins with education and steps to enable insights and knowledge. Research data gathering and experimental data is plentiful at academic research institutions and in libraries. This research may now be corralled towards new and innovative AI pathways. This article outlines steps needed to enable library staff, research faculty and graduate students towards these possibilities. Technological ecosystems, new hires and retooling possibilities for AI infrastructures for academic libraries will be discussed. How research centers may strategically move into these areas will be reviewed. Methodologies, scholarly communications models and preliminary infrastructures begin with data repositories, scholarly research ecosystems and algorithmic literacy programs. These allow bootstrapping towards AI possibilities and setting foundations for successful new millennia AI library programs.

EDUCATIONAL STEPS AND SCAFFOLDING

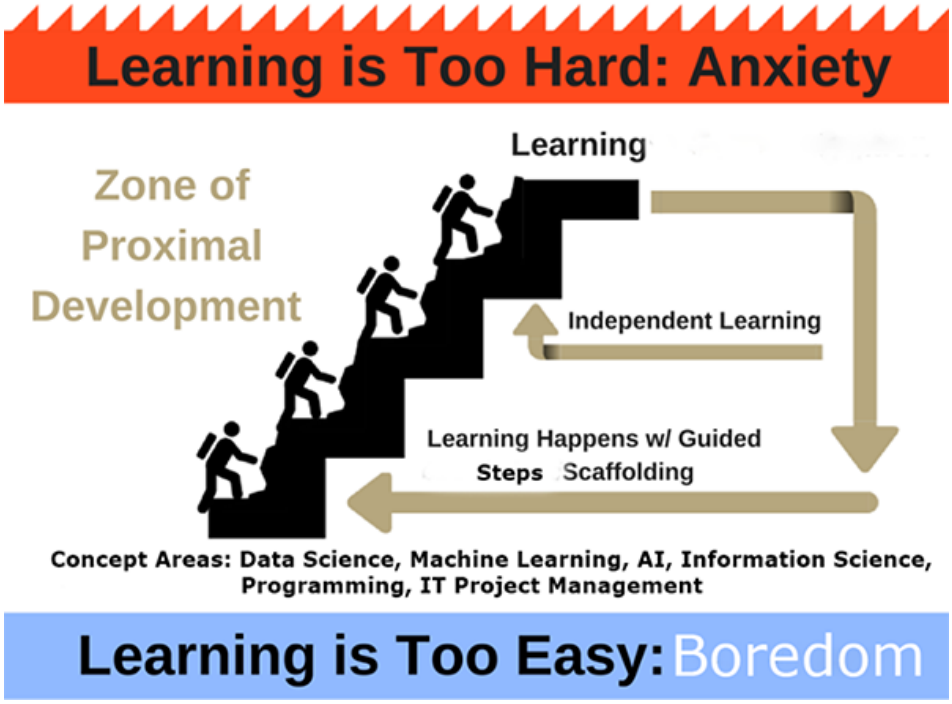

Figure 1. Educational Scaffolding and Steps Towards Learning (Warren, 2021).

To build any successful library AI program, educational steps and scaffolding are needed (Figure 1.) . The learning curve for AI is steep. Staff education should be thought about in detail by library managers and administration. Artificial Intelligence combines areas of data and information science, programming and IT project management. The goals of staff professional development and algorithmic literacy programs are explicitly not to turn disciplinary research faculty, graduate students and library staff into AI experts. Education develops a more sophisticated vocabulary towards AI programmatic literacy enabling larger conversations. The university's learning community becomes familiar with the language of AI paradigms. Later they will be able to converse knowledgably on project possibilities and work with AI engineers and Ph.D.'s.

1 AI PARADIGMS AND ORIGINS

AI has many origins, each with unique algorithmic paradigms (Table 1). Some paradigms are better suited than others to solve particular problem areas. It is best for any algorithmic literacy program to begin generally. Introduce university faculty, graduate students and library staff to the field before delving into particular areas. There are many good introductory texts, documentaries, online courses and YouTube videos to inspire before beginning Deep Learning's back propagation and matrix mathematics and calculus cribs needed to understand processes (see Reference bibliographies).

Carnegie Mellon's Tom Mitchell or Karoly Zsolnai's 'Two Minute Papers' YouTube videos (Mitchell 2022, Zsolnai 2022) both provide inspiring overviews of recent AI development and progress. Pedro Domingos, *The Master Algorithm,* provides an excellent categorization of the different AI schools, origins, algorithms and best solutions for various problem areas or tasks (Domingos 2015).

AI Paradigm	Origin	Algorithm	Problem	Solution
Deep Learning Machine Learning	**Neuroscience (Neural Nets)**	**Back Propagation Neural Nets**	Complex Tasks, Hidden Patterns	Back propagation
Symbolic AI	Logic, Philosophy	Inverse Deduction	Knowledge Composition	Inverse Deduction

Bayesian Inference	Statistics, Probability Theory	Probabilistic Inference	Uncertainty	Probabilistic Inference
Evolutionary Computation	Evolutionary Biology (Complexity Theory)	Genetic Algorithms	Structure Discovery	Genetic Programming
Reasoning by Analogy	Psychology	Kernel Machines (Support Vector Machines)	Similarity	Kernel Machines

Table 1. AI Paradigms, Origins and Algorithms (Domingos, 2015).

The idea is to build awareness in a larger university community and library staff so that there is desire and inspiration for further knowledge to build skillsets. Present AI attention is largely focused on deep learning, machine learning and neural nets. (Carnes 2019; Coldfusion 2020; Lecun, 2022; Mitchell, 2022; Fridman, 2022) While there are other important areas, this is an excellent place to focus on beginning a wider program. There is a lot of current attention in this area of AI and many significant and inspiring gains.

The last ten years of deep learning or neural net algorithms have shown incredible progress (Figure 2). There have been significant results in natural language processing, conversational chatbots and cybersecurity to strategic reasoning (AlphaGo), computer vision and object recognition (Mitchell, 2022). Here, it is best to briefly overview the field but also set scalable limits. Progress may be made incrementally with both algorithmic paradigms and pragmatic application for library staff, research faculty and graduate students so that projects may be achieved, and core research and data enabled.

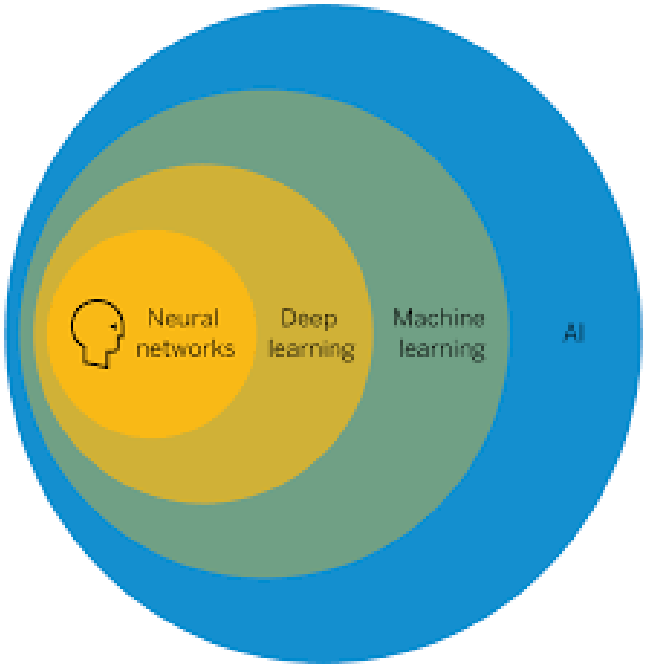

Figure 2. Fields and subfields of AI: machine learning, deep learning and neural networks

By focusing on a particular area after a group is inspired, gaining of skills may be achieved (Figure3). This enables library projects and faculty and graduate student research to new levels.

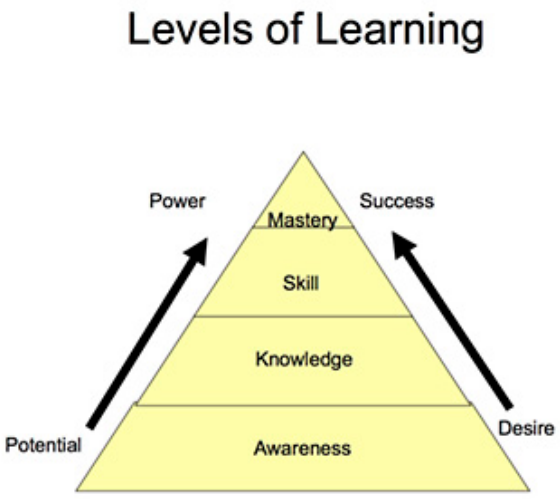

Figure 3. Levels of Learning

ONLINE DATA RESEARCH REPOSITORIES

With any Library AI program, it is best to begin pragmatically. There is a clear trajectory in academic libraries from data and data collection to data science, analytics, visualization and AI. Everything begins with the data and its organization and centre - a good online data

research repository. An academic online research data repository will allow a university library to consolidate and share online faculty and graduate student research (Figure 4). A data repository will organize university research data and provide important online data archiving and publishing strategies for research data. It will provide library staff, surrounding research faculty and graduate students important entry level skills needed towards AI. These foundational skills surround important tasks of data organization, cleaning, creating structured data, data citation and creating metadata schemas, among other skills. These skills will all be important building blocks needed towards AI's larger pathways.

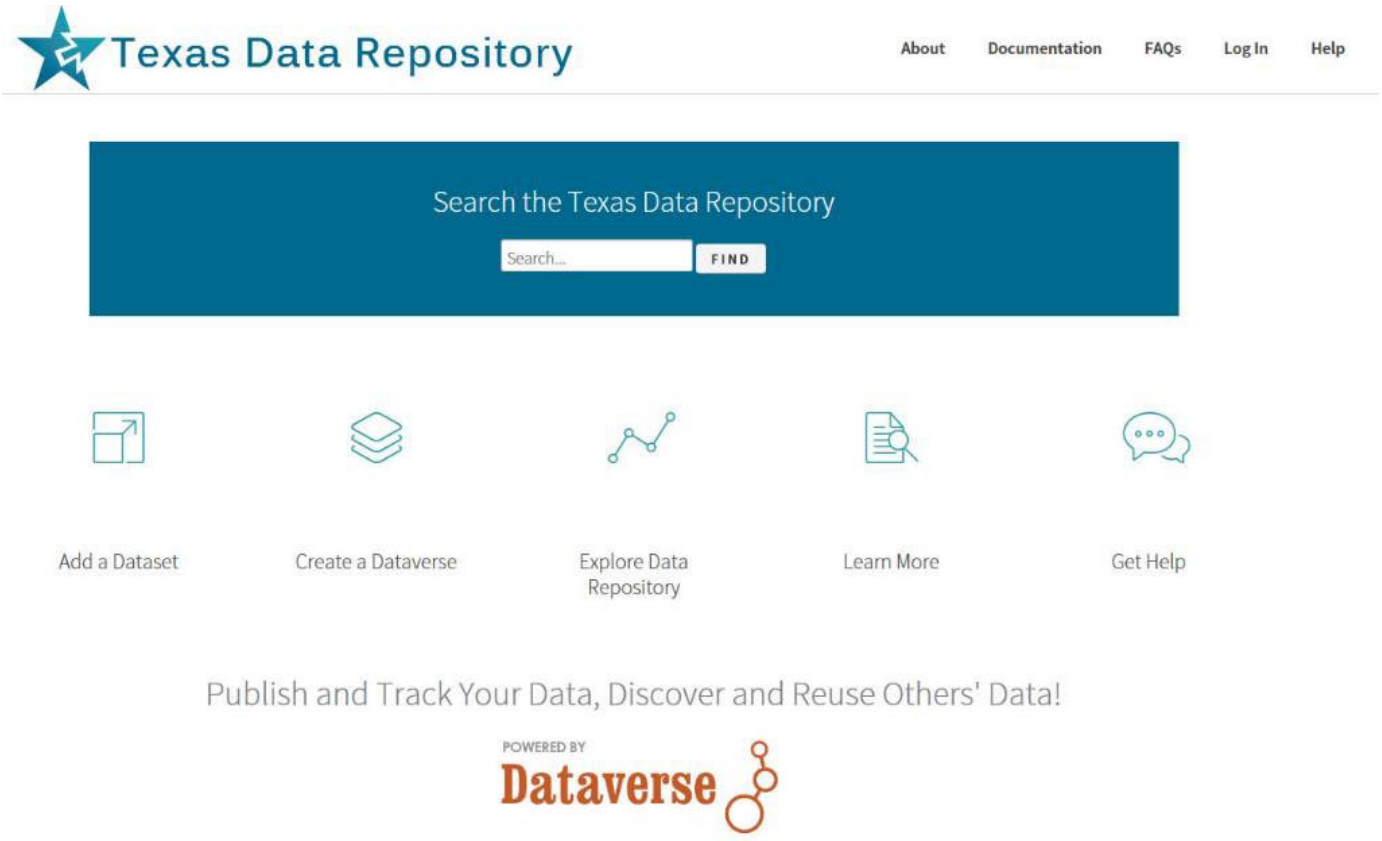

Figure 4. Original Homepage for Texas Data Repository (Uzwyshyn, 2016)

A data repository is a needed step to begin any AI program. The Texas Data Repository reconfigures Harvard's open source Dataverse as a consortial, environmental, aggregating research data repository from various Texas universities, collaborating together. Setting up this type of open-source software on an individual, institutional or consortial configuration, will build many staff human resource infrastructure skills. These skills will enable library staff in setting up this data-centred service for the university community and for researchers beginning to build their 'data science' skills towards the later 'data' and algorithmic literacy needed to understand and implement AI paradigms.

Enabling a data repository for an institution encourages scholars and library staff to learn basic 'data cleaning' tools such as Open Refine.[1] Open Refine is a powerful tool for working with messy data and transforming it so it will be in a suitable state to be utilized by an AI algorithm for later training and processing.

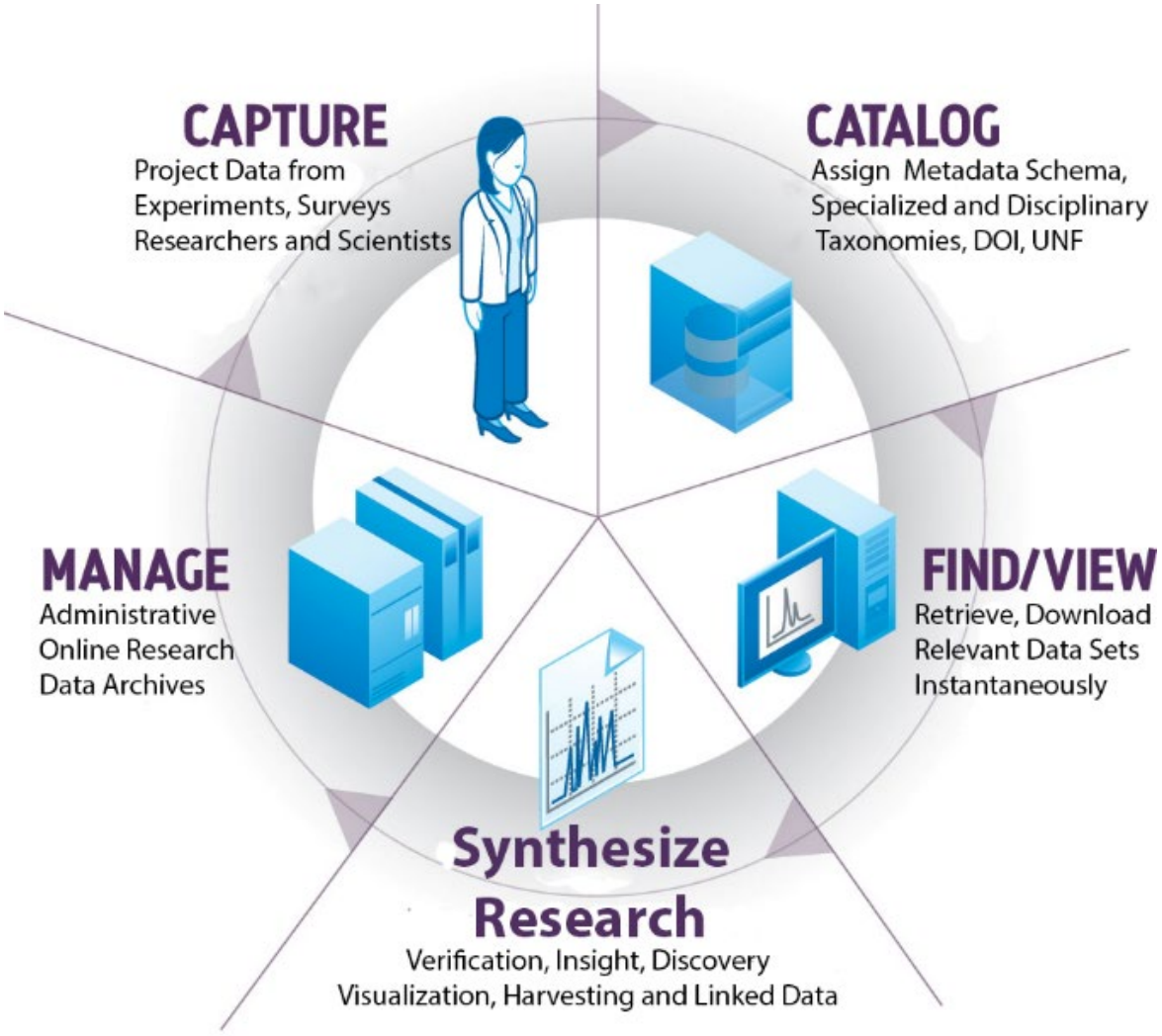

Figure 5. The Online Research Data Repository Lifecycle. (Uzwyshyn, 2016)

Gaining fundamental data literacy with the online research data repository lifecycle (Figure 5) will serve the university community and library staff well for creating excellent foundations on building the next levels of AI projects. To generalize, a university online data repository and research community competence with the data research lifecycle will provide a great foundation for later AI pathways. The data repository will enable this larger ecosystem.

[1] Open Refine https://openrefine.org/

DIGITAL SCHOLARSHIP ECOSYSTEMS

A digital scholarship ecosystem (Figure 6) should also be pursued following development of an online research data repository. While a data repository will always be central, an online institutional collections repository should also not be overlooked, especially for the ability to store and house both the metadata and core data for large textual files. A research data repository and digital collections repository, together, will make up the primary content repositories (data and text). A digital scholarly ecosystem consists of two primary online components for content and four tertiary online components for communication.

The well-known open-source software, DSpace, is used for the university's digital collections repository. For universities and research institutions, the four tertiary components will enable better online global communication and networks. These are an online electronic theses and dissertation management system (ETD System, VIREO), identity management system (ORCID), open academic journal system software (OJS3) and user interface content management software (OMEKA). Together, these function as a unified digital scholarship ecosystem (DSE). This ecosystem allows great facility in later enabling larger AI pathways continuing to build on strong foundations.

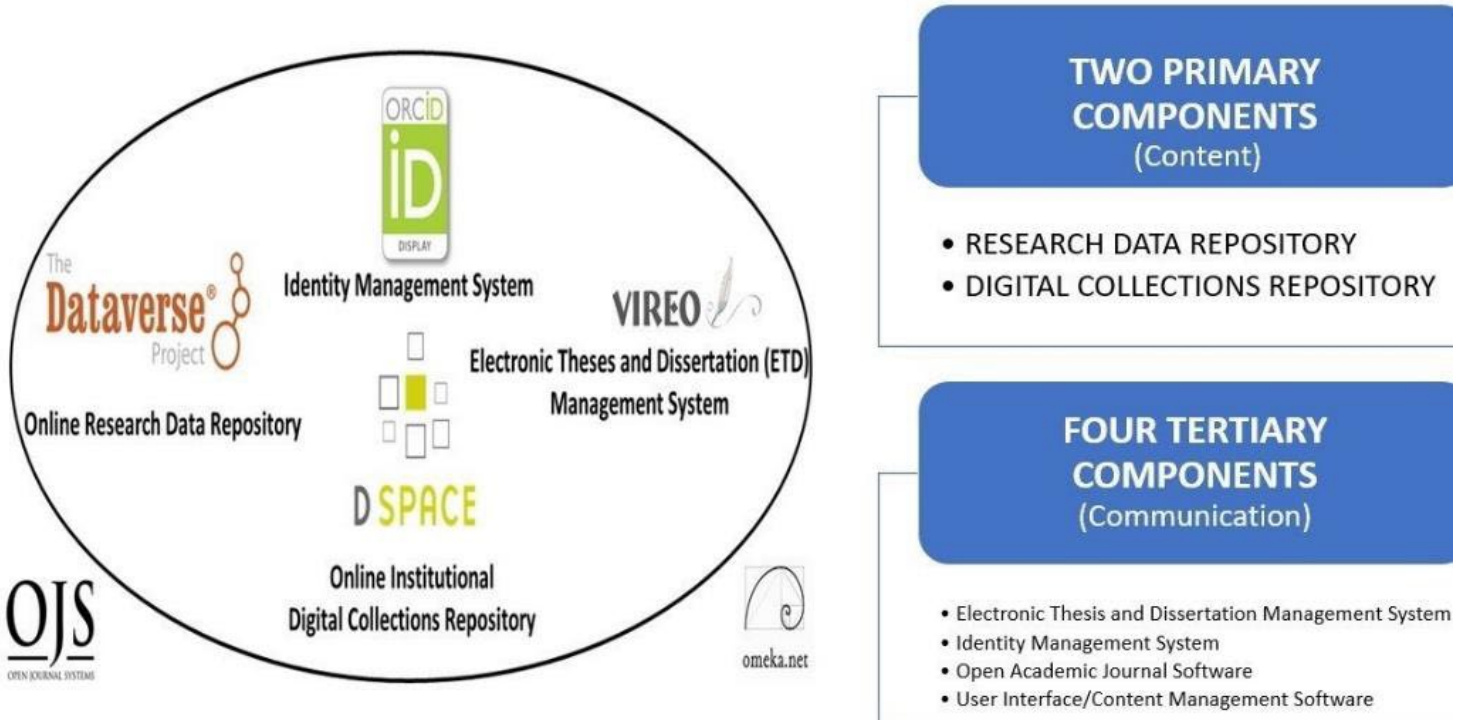

Figure 6. A Digital Scholarship Research Ecosystem, Six Components, Online Content and Communication (Uzwyshyn, 2020).

OPEN SCIENCE, DATA, AI AND DIGITAL SCHOLARSHIP ECOSYSTEMS

Innovative Open Science and AI possibilities are now enabled through affordances and combination of a digital scholarship ecosystem and data research repository. The HAM10000 image dataset is a large collection of multi-source dermatoscopic images of cancerous skin lesions uploaded to Dataverse by Viennesse Dermatologist, Dr. Philip Tschandl (Tschandl, 2018). Because Harvard's Dataverse allows for the uploading of datasets from other universities, appropriate research datasets may be uploaded for later sharing or use by anyone globally.

BRAC University, from Dhaka Bangladesh, uses DSpace as an institutional repository to house theses and dissertations from the School of Data and Sciences, Dept. of Computer Science and Engineering (Islam et al., 2021). Here, the students have downloaded and utilized the image data as material to train a deep learning neural net algorithm to recognize cancer growths with efficiency greater than, or equal to, board certified dermatologists. This is a good example of open science and AI possibilities operating on global levels through the enabling power of digital scholarship ecosystems and data repositories. Content and data, that otherwise would be unavailable, is brought together with new machine learning algorithmic techniques (Esteva et al., 2017). New research and a very good thesis are produced. Geographically dispersed content and knowledge from three different continents has been aggregated to advance the pursuit of knowledge and science.

AI HUMAN RESOURCES

In creating an AI infrastructure, hiring a whole new staff department will not be feasible for most libraries. Many research and academic libraries, though, will have an online digital collections repository, such as DSpace, in place and operational. This will also serve the library well. Many institutional repository content administrative skills gained with the institutional repository are transferrable to the data research repository. This makes AI and data learning curves easier to begin. A staff member, already in place for this repository position, can initially take up a data-centred function with an upcoming data research repository. The staff member will begin by helping faculty and graduate students with their research data and repository functions until a full time 'data scientist' is hired. Other staff skills are similarly transferable. For example, a cataloger, focusing on digital metadata, can easily be transferred part time to begin as the data repository metadata specialist. This will serve upcoming AI functions well, especially with regards to machine learning. Much of the neural net training is about what is called in machine learning terminology 'labeled' and 'unlabeled' data. Essentially, these are simply schema for metadata. Various other data cleaning and metadata skills will also come in useful here. As a tiered gateway towards AI, hiring a data visualization specialist will also be useful to gain support towards more complex AI initiatives. This specialist will initially provide library support for data visualization and analytics projects through dashboards (Figure 7) and information visualization for data-driven decision making and finding insights from library data. This will also translate well from faculty and graduate student research data. Subject liaisons and research and information outreach librarians may communicate with various departmental and school research faculty conveying the library's new data visualization possibilities. Enabling research faculty occurs with their data sets through both the repository and possible further information visualization

help and resources. These possibilities will also introduce the new 'data repository', data/information/research visualization and create bridges toward upcoming 'AI' pathways.

Figure 7. Library Data Driven Dashboards as Operational Gateways Towards AI

'A data research and information visualization specialist' will also allow university administration, research faculty and graduate students to see the usefulness of the programmatic possibilities with data. Education on research faculty levels should now also develop higher level strategies to clean and normalize data for future AI R&D projects and begin more complex programmatic analytics pathways with Python. A later 'data visualization specialist' or librarian can then be the bridge for transferrable skills towards AI and full-time data repository role.

AI LEARNING PATHS FROM DATA TO CARPENTRIES

As the algorithmic literacy needs of both library staff and the surrounding university research community firm up, there will be needs arising from researchers and library staff for more pragmatically-oriented foundational coding and data science skills. Research academics will obtain an understanding for enabling their research data towards higher level insights through the library's activities. Various areas of the library will also begin to realize the potential of these more algorithmic pathways.

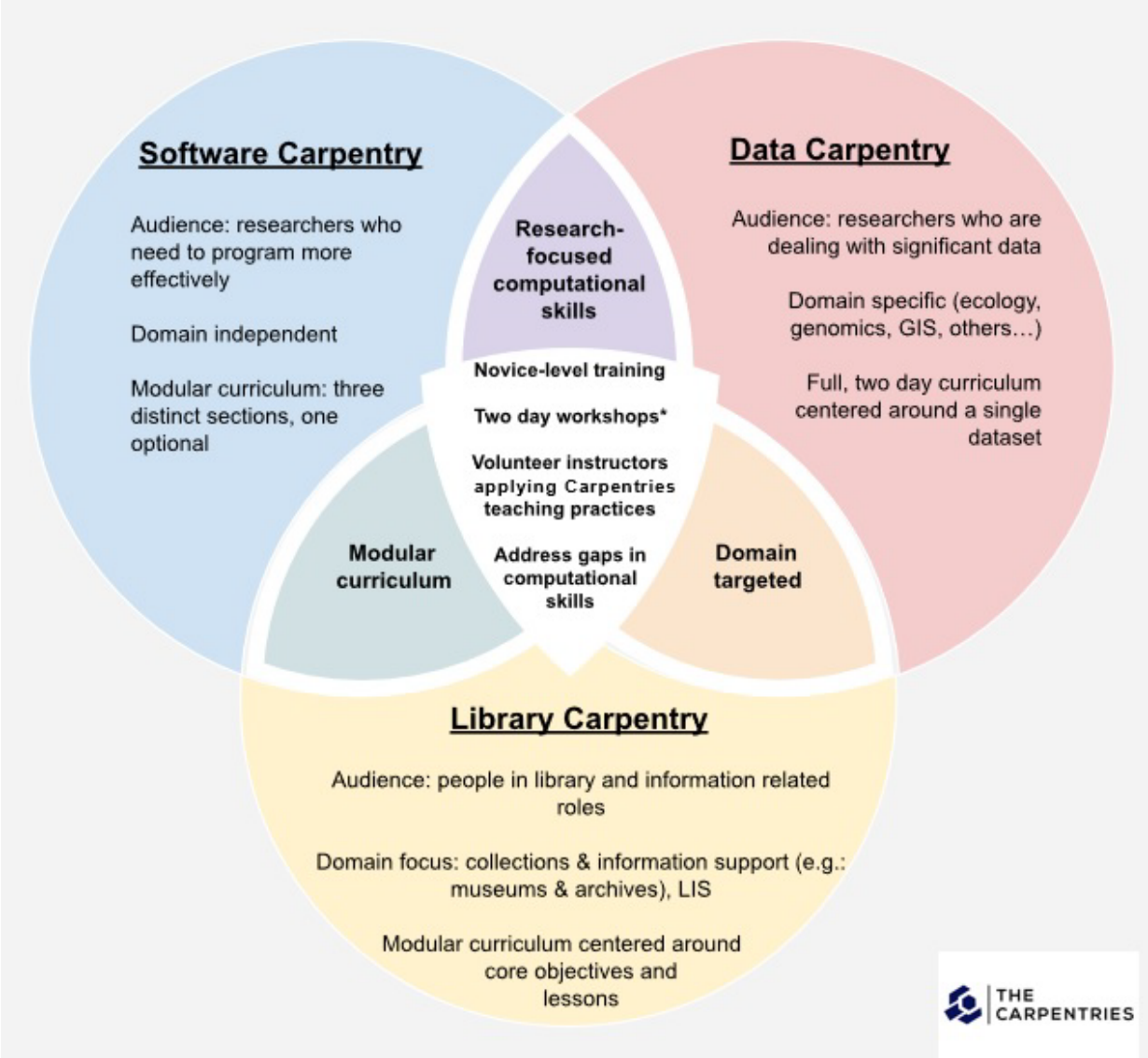

Figure 8 Data, Software and Library Carpentries. (Carpentries, 2022)

Carpentries' workshops combine pragmatic programmatic knowledge needed for university researchers and graduate students with algorithmic literacy needs of library staff (Figure 8). They are also great scholarly communications bridges for dialogue. Collaborative work may begin between research faculty working on learning how to enable their research through data and programming and library staff who are also taking up these new methodologies towards larger library algorithmic literacy AI infrastructures and programs.

LIBRARY AI CONFERENCES

As the learning curves and paths towards AI are steep, it will be important to keep staff both motivated and inspired with benchmarks and milestones being achieved in our surrounding society (medicine, natural language processing, strategic games). New library AI conferences arising serve these purposes well. Two such conferences are Carnegie Mellon's *Artificial Intelligence for Data Discovery and Reuse* (Carnegie Mellon 2020)and Stanford's *International Conference on AI for Libraries, Archives and Museums* (Stanford 2022). Stanford's Conference has travelled from the US to the Bibliothèque Nationale (France) and then Norway. In subsequent years, Carnegie Mellon has combined efforts with the CMU's

Open Science Symposium. AI presentations are now regular at library technology conferences such as D.C's *Computers in Libraries*, Coalition of Networked Information, IFLA's SIG AI and AI Satellite Conference *New Horizons for AI in Libraries* (IFLA, 2022) and online international groups such as AI4LAM (Libraries, Archives & Museums).

LIBRARY AI PROTOTYPES

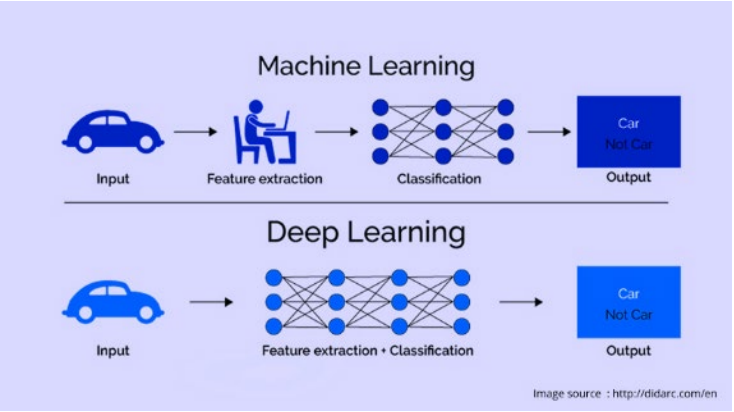

Figure 9. Convolutional Neural Net Figure 10. Image Extraction Classification Prototype (Peters 2022).

It will be important for library staff to also be encouraged with pursuing AI beta projects. These projects will allow staff to gain initial understandings of models (Figure 9) and the various pieces needed for working on machine learning projects. Learning various areas of AI will range from processing power parameters (compute) to new video cards (NVIDIA GPU's) to the Python programming language and vocabulary of pretrained and untrained models, classification, feature extraction (Figure 10), image and natural language libraries. What is important in these experiments is getting the staff thinking about these new models. What can or cannot yet be achieved? Understanding processes and possibilities is more important than large results at this stage. All of this will begin to get library staff working on levels of R&D.

LIBRARY AI WORKSHOPS, INSTITUTES AND FELLOWS PROGRAMS

Library specific AI fellows institutes and workshops are also beginning to appear (Table 2). It is important to write recommendation letters and send motivated employees who apply for these workshops to attend. These institutes motivate staff, but also allow sharing of new curriculum and creating larger networks with other motivated parties.

	
• Weeklong Fellows Program at University of Texas, Austin (20 Fellows) • Onboarding, • AI Institute • Library Centered AI • Programming Workshops • Final Project • AI Specialist Support • Networking with National Library AI Experts • Other Fellows	■ AI challenges and opportunities ■ Ethical considerations and guidelines ■ UX-Human/AI Interaction Lifecycle ■ Existing library, archive, and museum projects ■ AI project planning o Project Design o Data collection, classification, and transformation o Roles and implementation ■ Python Basics, Python for Machine Learning ■ APIs and bibliometrics ■ AI in search and discovery ■ Machine learning and coding ■ Harvesting, evaluating, and training data sets for use in AI ■ Conversational AI – Theoretical Foundations ■ Conversational AI – applications ■ Linked Open Data Machine Learning for text with topic modeling and clustering

Table 2. IMLS IDEA Institute on Artificial Intelligence. https://idea.infosci.utk.edu/

Following these types of institutes, it is important to open the door towards projects that have begun through these opportunities. This will offer leadership opportunities for staff teaching, presenting to fellow staff, sharing curricula and beginning to think about further infrastructures that may be constructed locally to develop out of organic needs.

UNIVERSITY LIBRARY COLLABORATIONS

It is important to embrace change. As the larger library retools for the paradigm shift of AI so, too, will the parent research institution and associated IT infrastructures. As this occurs, unexpected opportunities for collaboration, participation and partnership will arise. For example, there is a current trend of downsizing traditional libraries' research services. The traditional reference and subject librarian services are transforming to online and other modalities but also as a cost-saving measure. Simultaneously, many universities are now adopting new AI ChatGPT-like chatbot infrastructure for the students and faculty campuswide. This new chatbot-infrastructure presents opportunities for the libraries to utilize skills in different ways. Subject librarians may now retrain, train the chatbot, retool and transform previous research skills and expertise towards new paradigm possibilities.

These unexpected AI changes should be embraced. They open doorways for exploration and research. Previous research skills can now be retooled towards the investigation and

tuning of future AI natural language processing models ranging from Open AI's GPT4 to Google's DeepMind and other upcoming models. Help is not disappearing in the 21st century but the chatbot may need some fine tuning in understanding its human audiences. This help can now be accompanied by a knowledgeable guide at the side. The previous research and instruction librarian is now newly minted in the role of Chatbot Administrator or Prompt Engineer (Woodie; 2023;YouTube, 2023, Co:Here, 2023) .[2]

LIBRARIES AS COMPLEX ADAPTIVE SYSTEMS

Libraries are complex, adaptive, dynamic systems (Figure 11). As library staff, university faculty and graduate students interact from the bottom, system-wide patterns emerge at the top. As patterns emerge, it is important to formalize this activity through an AI Working Group (AIWG). Ideally, the membership of this group should begin through informal partnerships and collaborations of interested library staff. As this activity ramps up, it should be formalized to continue conversations. This will provide direction, responsibility and accountability for projects arising and related discussion, decisions, policy and ethical oversite. This group can be opened further so both university research faculty and graduate students are invited. This will help guide and offer direction for strategic paths. This group will later add to the innovation, vision and potential.

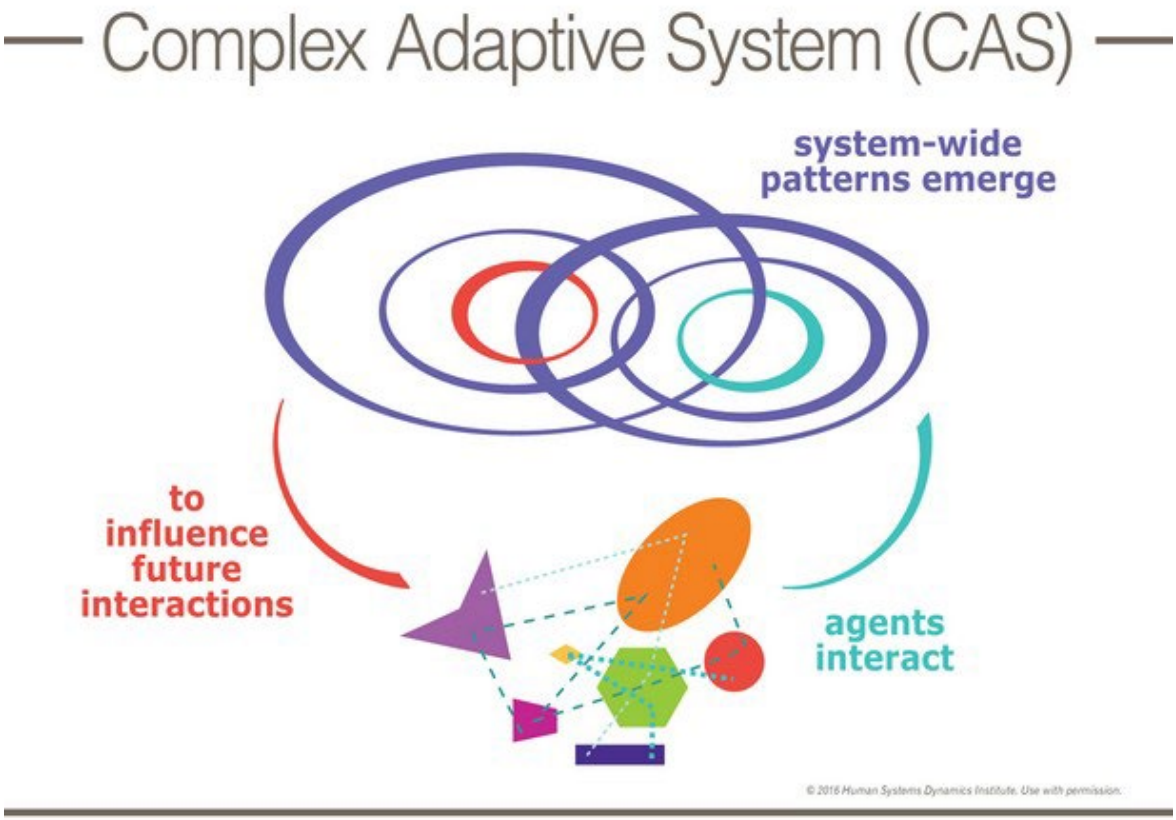

Figure 11. Libraries as Complex Adaptive Systems, Bryant, Dortmund, Lavoie, 2020.

GRADUATE STUDENTS, POST-DOCS, PERMANENT HIRES

At a certain point, library staff will realize they have come to the end of their AI learning journey. This will signal the time to hire a graduate student and eventually, a Ph.D. or Post Doc in Machine Learning or AI. Good graduate students can be found more easily in university engineering schools or computer science departments. Course listings currently have names like *Machine Learning for Engineering Applications* or *Neural Nets and Deep Learning for Computer Science*. Associated research faculty will be glad to assign suitable students to work with library staff. Students may be paid for part time AI research assistant projects or combined theses/dissertation work. Relationships are key here and these will be win/wins for the library, student, professor, and university.

Ph.D's. and post-docs can also be sought. There are even library specific Post-Doc programs through the Center for Library and Information Services on both US and global levels (CLIR 2022). These may be pursued to make use of a recent Ph.D.'s specialized skills and bring new AI skillsets into libraries.

CONCLUSION

The new road to library AI success is largely open. There are trailblazing opportunities for most internal sections of the library. This ranges from special collections and archives to possibilities for better understanding the black box of acquisitions' budgets to metadata with AI and natural language processing. Search and retrieval, library usage data, statistics and deriving insight from vast arrays of data now make up the 21st century academic research library landscape.

There is incredible potential in connecting research faculty and graduate students and their research data collections with AI. Most researchers come from traditional academic disciplines. These are still widely outside of artificial intelligence, machine learning and computer science. The prospects towards the advancement of the next levels of human knowledge and exploration for discovery and insight are incredible. On many levels, it is important for libraries to begin thinking along these paths to enable these new possibilities.

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