ARTIFICIAL INTELLIGENCE CONSULTATION REPORT FOR MADAN BHANDARI UNIVERSITY OF SCIENCE AND TECHNOLOGY DEVELOPMENT BOARD

By

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ABSTRACT

This report describes the potential for AI (Artificial Intelligence) technology relevant for Nepal. It examines this from the context of the developmental needs of Nepal and in enhancing the existing IT ecosystem. The second part of this report provides a comprehensive proposal for MSc in AI, MSc by Research in AI, MSc in Data Science and PhD programs in AI taking into account the background of students entering the program, contextual relevance and the need of high-quality graduates.

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CHAPTER 1- AI APPLICATIONS RELEVANT FOR NEPAL

1.1 Background

It is well known that AI technology is a game changer to leapfrog businesses, industry and government departments into the 21st century (PwC Report, 2017). AI provides a level playing field to bring existing organizations in par with developed nations. Many view AI as the next revolution to truly democratize access to potentially lower cost state-of-the-art solutions that were previously unthinkable (PwC Report, 2017) . However, current AI deployments within businesses have high failure rates with 80-90% of AI projects failing due to low understanding of limitations of current AI technology (VentureBeat, 2019) and black box type deployments without sufficient domain specific adaptation.

As AI applications take up within developing countries increase exponentially, we expect maturity in implementing AI solutions also to improve so that the current very high failure rates of AI deployments decrease. The result would be that there is a deeper contextual understanding of technical knowhow and social factors needed to build complete solutions wherein AI algorithms are only a part of an overall total solution. There is a greater understanding that AI black box solutions have limited success rates unless these are properly situated within the right overall solution that considers multiple relevant factors (Bathaee, 2018).

As IT solutions move towards using big data and citizens demand instantaneous near real time service delivery, organizations will move towards higher adoption of AI technologies to achieve business competence and better customer satisfaction.

Drivers for increased AI adoption in Nepal

Within the context of developing countries, especially Nepal, there are several key drivers that would accelerate the pace of AI enabled solutions. Some key drivers include:

1. Increased adoption of data driven IT solutions
2. Higher workload of office workers resulting is reduced customer satisfaction
3. Increased competitive landscape in businesses

4. Increasing cost of service delivery
5. New business opportunities resulting from use of AI technologies
6. Need for commercialization of previously untapped resources
7. Lack of skilled manpower in key areas (e.g., education, healthcare)
8. Reduced labour force due to increased migration to cities and overseas

There is an increasing adoption of IT solutions in businesses, and it is becoming increasingly difficult for office staff to manage large amounts of data. As customer volume increases, human service agents need to handle an increasing number of customer service requests efficiently. With increased competition within businesses, customer satisfaction, loyalty, and retention become important to stay ahead of the competition. All these factors result in increased cost of service delivery and automation becomes a 'must have' technology.

There is an increased migration of labour from Nepal into the Middle East, South Korea, South-East Asia (Ministry of Labour, Employment and Social Security, 2020) As a result, many villages in Nepal lack sufficient manpower for agriculture and other labor-intensive activities that impact livelihoods.

The AI hype is penetrating every business globally and Nepal is no exception. Despite the lack of skilled knowledge within businesses of the capabilities and limitations of AI, there is substantial desire to implement AI technologies. Many of these have resulted in failed attempts of AI adoption. There are now several AI startups in Nepal that are aiming to provide AI driven solutions albeit that most of these are publicly available (e.g., GitHub, Google, Facebook) open source pretrained black box AI solutions that have been used with varying degrees of adaptation within the local Nepalese context. Nevertheless, these are important first steps of AI adoption in Nepal and as the AI talent pool increases one would expect increased maturity and sophistication of home-grown AI solutions.

Key areas for AI adoption

This report identifies several key AI applications areas relevant for Nepal. Some of these include:

- AI driven healthcare
- AI driven education
- Resource allocation, Supply chain management and planning

- Epidemic monitoring and management
- Efficient farming methods
- Workflow automation and Business Process Automation

Current IT landscape in Nepal

Most IT companies in Nepal focus on software outsourcing i.e., they develop bespoke software for clients within or outside Nepal. There are few products, e.g. Pumori[1] for core banking, Midas[2] for hospital management currently available within the Nepalese market. There are few software companies in Nepal developing products for the international market. e.g., Logpoint[3], Fusemachines[4].

The potential for Nepalese startups and IT companies in competing in the Asian or International market is seriously hampered by multiple factors:

1. Lack of skilled graduates in IT, Computer Science, AI
2. Unfavorable conditions and difficult bureaucratic hurdles for foreign direct investment (FDI)
3. Lack of product maturity to compete in the international market

Despite these challenges, there is tremendous opportunity for AI startups and IT companies in Nepal to get ahead in AI based products and technology. This is an area for creating new jobs in the IT sector and for developing IT software exports. IT services and products in combination with AI is relatively new and hence there is opportunity for new players to enter this market.

AI applications in healthcare

Access to quality healthcare in remote regions is lacking. Even when such facilities are present, these facilities are poorly staffed with a small number (if any) of qualified doctors, surgeons, nurses, and

[1] https://pumori.com.np/information/3
[2] https://www.midastechnologies.com.np/hmis-detail.php
[3] https://www.logpoint.com/en/
[4] https://fusemachines.com/#overview

other healthcare professionals. While telemedicine facilities have been initiated within Nepal in many regions (Ministry of Health, 2017), they have limited success due to several reasons:

- high infrastructure cost and high running costs
- requires high speed internet
- requires doctor (typically in a city) and patient (in a remote village) synchronization
- requires patient to travel to the telemedicine center even when home-based consultation is feasible

Most existing telemedicine centers in Nepal rely on high-speed video connection to connect a (specialist) doctor with the patient in a remote location. In a country where both electricity and high-speed internet is scarce, provisioning a telemedicine center is costly both in terms of initial investment and running costs. Typically, a patient needs to walk several miles to reach the telemedicine center making it difficult for the patient. Additionally, both the doctor and patient need to arrive at their respective telemedicine centers at the same time which may not be always feasible for both parties.

Achieving equitable and universal access to healthcare is an important SDG goal (National Planning Commission, 2020) where quality healthcare is available to all regardless of income and geographical location. For AI to play an effective and important role in reducing the cost of healthcare delivery and help in achieving SDG goals, there are certain prerequisites that need to be met. Although, smartphone based single use case point solutions can be deployed without these prerequisites, for wider adoption of AI driven systems at a national level, the following prerequisites are key:

- Digitization of patient medical records i.e., storing patient data as Electronic Medical Record (EMR)
- Using standards compliant interoperable standards (e.g., FHIR[5], UMLS[6]) for data coding for EMRs

[5] https://www.hl7.org/fhir/

[6] https://www.nlm.nih.gov/research/umls/index.html

In Nepal, few hospitals if any at all, employ electronic records for storing patient data. Current digitization is primarily limited to patient registration, patient discharge summary, lab reports, x-ray reports, MRI reports, EEG reports etc. Few hospitals employ PACS[3] systems. Even if some digitization is present, hospital EMR systems are often siloed paying little attention to data interoperability and adherence to open data exchange standards (Ministry of Health, 2017). This results in fragmented systems that do not talk to each other. For the patient, this means keeping paper copies when moving from one hospital (or healthcare center) to another.

HL7/FHIR is a health data interoperability standard that is widely being adopted across healthcare systems (HL7 FHIR, 2019). FHIR defines all the key concepts related to patient medical data allowing patient-doctor encounters to be documented using a semantic data vocabulary as defined by FHIR Ontology. Health data interoperability puts patients in control of their medical records. Currently, healthcare data is heavily siloed with vendor lock-in being common across hospitals. This prevents faster adoption of AI technologies in the health sector. It also makes it difficult for new players to penetrate this sector with cheaper and better solutions.

Increasingly governments are recognizing this issue and health data interoperability is becoming a legal requirement. The US government is introducing a health data interoperability bill[7] that requires healthcare providers and health insurance providers to require that patients are able to download their health data into their smartphones in a fully interoperable standard such as FHIR.

Modern deep learning systems within healthcare employ NLP (Natural Language Processing) technology in combination with large scale medical ontology such as UMLS for a myriad of AI driven applications within healthcare. UMLS is a large-scale ontology comprising a network of relations between disease, symptom, gene, medication, biological process etc. It comprises our

[7] https://www.foley.com/en/insights/publications/2020/03/health-data-interoperability-patient-access-rules

distilled knowledge of the interactions between these entities comprising Millions of nodes and edges.

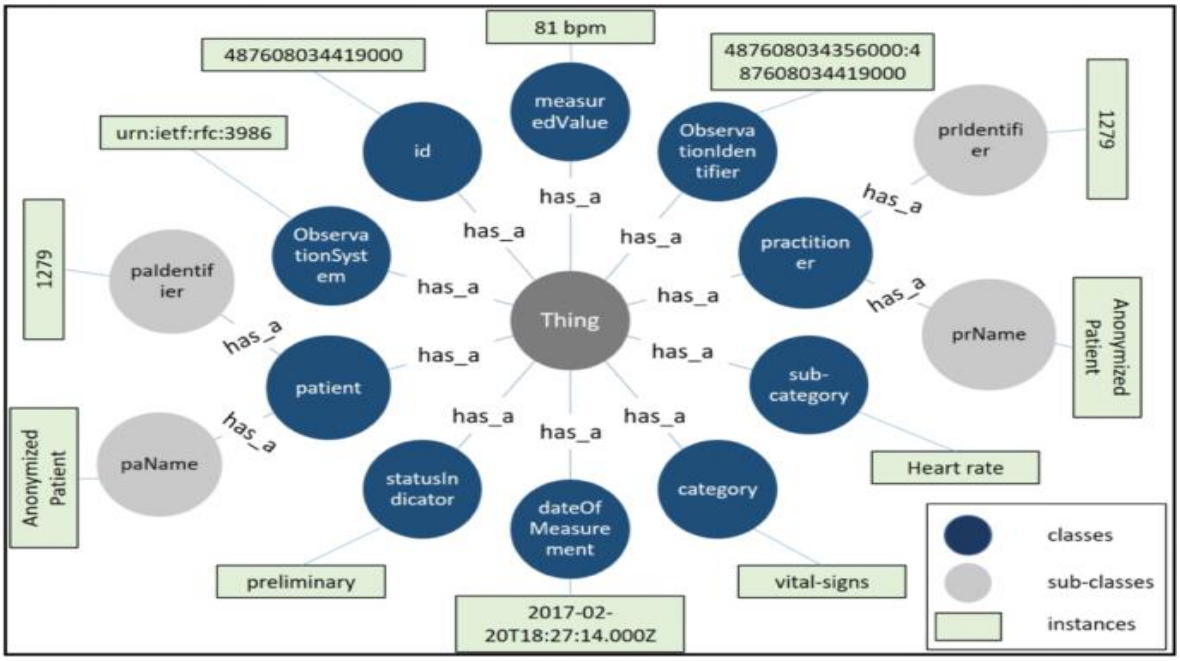

Figure 1 Structurally mapping healthcare data to HL7 FHIR through ontology alignment (Kiourtis, Mavrogiorgou, Menychtas, Maglogiannis, & Kyriazis, 2019)

MIMIC is a database storage system that permits all patient related information to be stored within a unified machine interpretable coded system (Johnson, et al., 2016). MIMIC technology has evolved from the need to convert unstructured (text) and non-standard database information containing patient medical data into an AI interpretable storage system that employs coding standards such as UMLS. There have been several research challenges (Elhadad, et al., 2015) aimed at automatically converting patient data (typically written by doctors) in natural language into a knowledge graph representation suitable for machine interpretation (Rotmensch M. , Halpern, Tlimat, & Sontag, 2017). The steps involved in doing this translation involves Named Entity Recognition (NER), Relation Extraction (RE) and entity linking into a concept knowledge base such as UMLS (Perera,

Dehmer, & Emmert-Streib, 2020). Knowledge graphs[8,9] are commonly employed for answering voice driven questions such as in Google Assistant and Apple Siri.

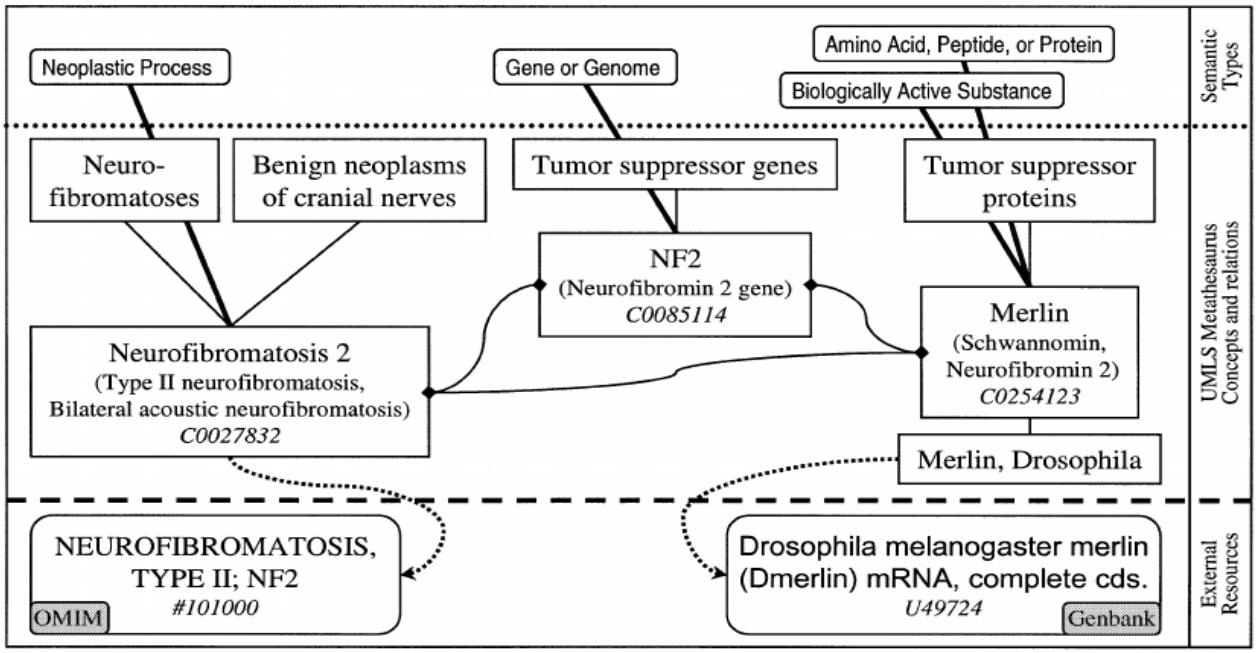

Figure 2 NF2 and related proteins and diseases in the UMLS (Bodenreider, 2004)

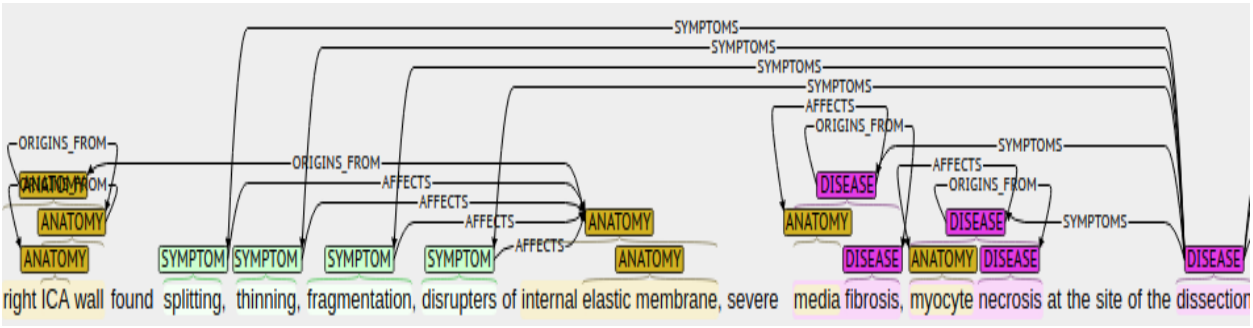

Figure 3 Entity recognition and Relation extraction of Medical Data

[8] https://www.youtube.com/watch?v=mmQl6VGvX-c

[9] https://paperswithcode.com/search?q_meta=&q_type=&q=knowledge+graph

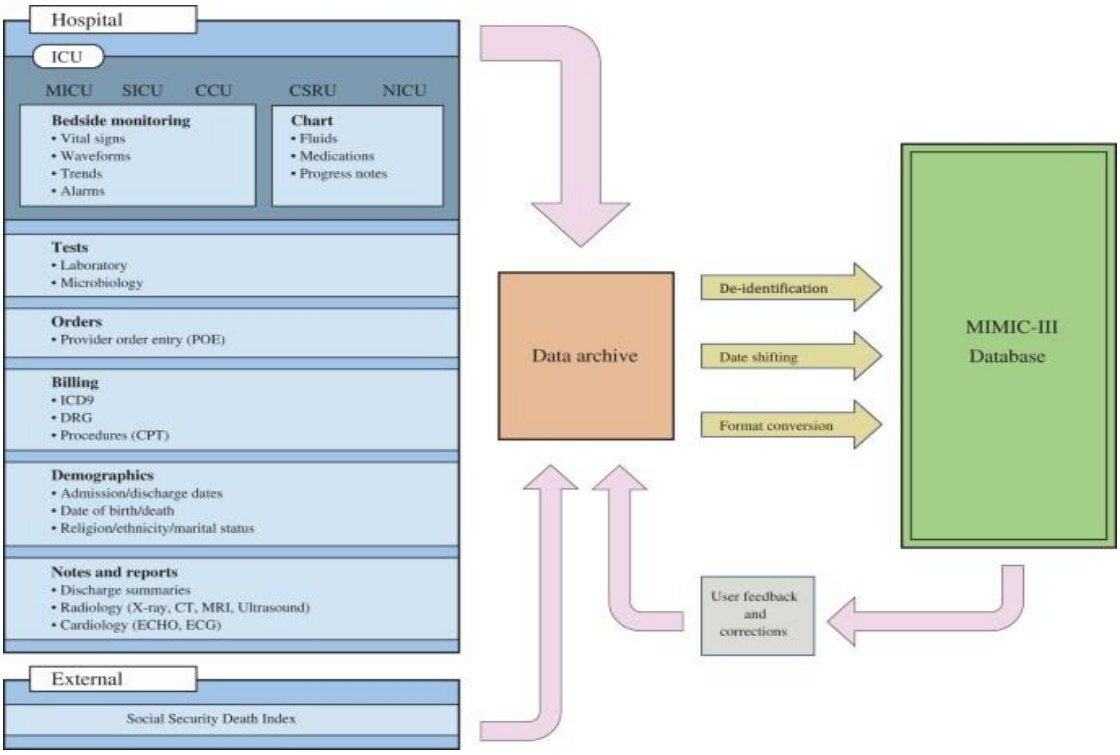

Figure 4 Overview of the MIMIC-III critical care database (Johnson, et al., MIMIC-III, a freely accessible critical care database, 2016)

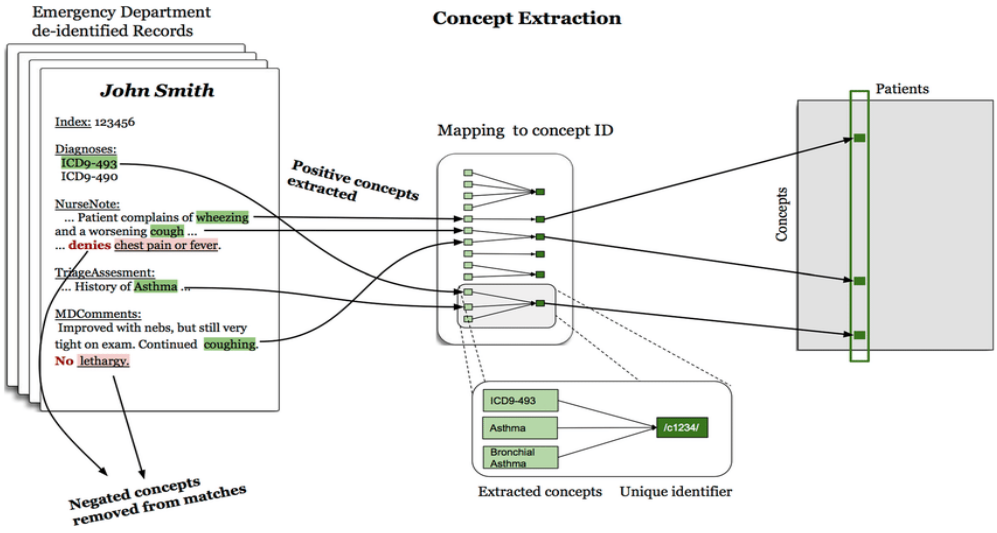

Figure 5 Learning a health knowledge graph from electronic medical records (Rotmensch M. , Halpern, Tlimat, & Sontag, 2017)

Future AI systems will employ voice recognition and handwriting technology so that unstructured input (either via voice or handwriting) is automatically stored as a knowledge graph. This in turn means that natural language can be employed to query patient records and AI assistants can continuously assist the doctor in the diagnosis process (Li, Maharjan, Xie, & Tao,2020).

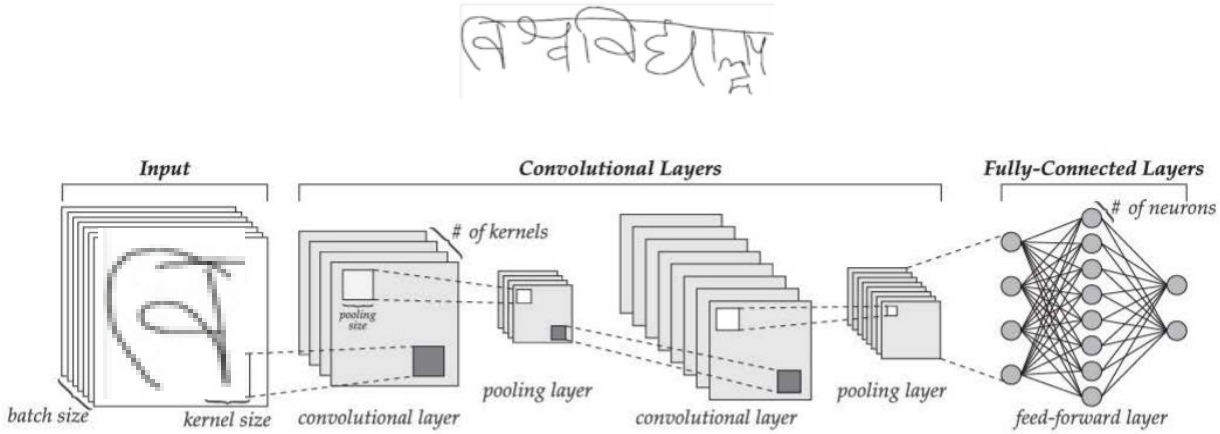

Figure 6 Handwriting Recognition using CNN (Carbune, et al., 2020)

Medical imaging and image-based diagnosis (Wu, et al., 2020) (Hu, et al., 2018) is a fast-growing area for AI applications in healthcare. There is tremendous progress in deep learning solutions for diagnosis of diseases from x-ray images (e.g., breast cancer, lung cancer (Bhandary, et al., 2020), retinal scans (Lam, Yu, Huang, & Rubin, 2018) (e.g., diabetic retinopathy (Gulshan, et al., 2016), photographs (e.g., melanoma (Li & Shen, 2018). With smartphones becoming more powerful each year, it is now feasible to install and run complex deep learning models with millions of parameters on smartphones (Zhang, Patras, & Haddadi, 2019). It is now possible to make this technology available to the masses. Early diagnosis and personal health monitoring are some of the areas where AI can make a huge impact in improving the health of a nation, particularly in addressing the healthcare needs of the rural masses.

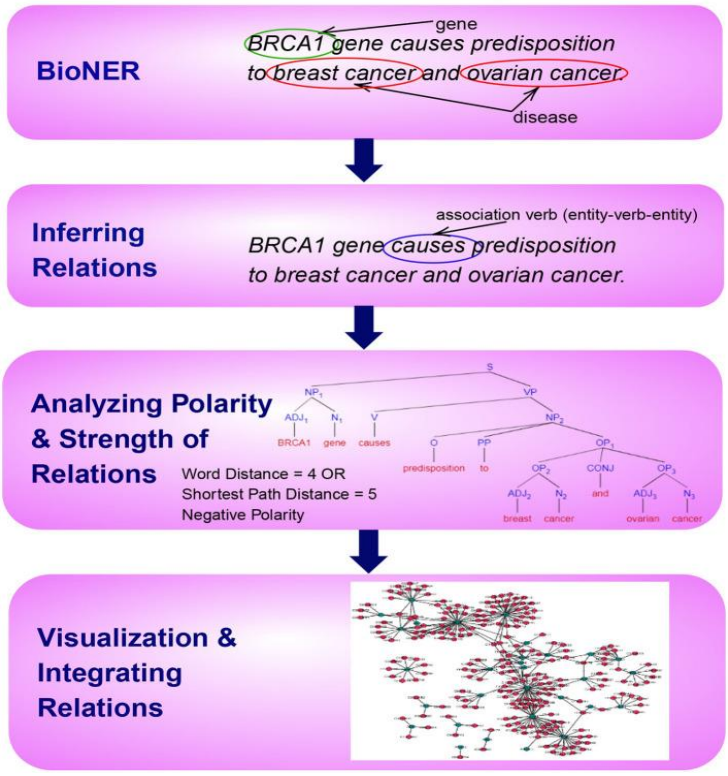

Figure 9 Principle steps for BioNER and Relation Detection and Analysis. (Perera, Dehmer, & Emmert-Streib, 2020)

Developing better AI diagnosis deep learning models requires high quality labelled data. Thus, having standards compliant EMR systems in hospitals will permit collecting large amounts of annotated data for free as a byproduct of using a standard compliant EMR system. This in turn will help in developing more accurate diagnosis systems. This is an area where hospitals and AI startups can partner to co-develop better AI diagnosis systems. Additionally, it will pave the way for hospitals (and patients) in generating additional income from selling (suitably anonymized) data. There is potential for use of blockchain technologies (e.g., Ocean protocol[10]) for providing a decentralized, secure, privacy preserving, market place.

[10] https://oceanprotocol.com/

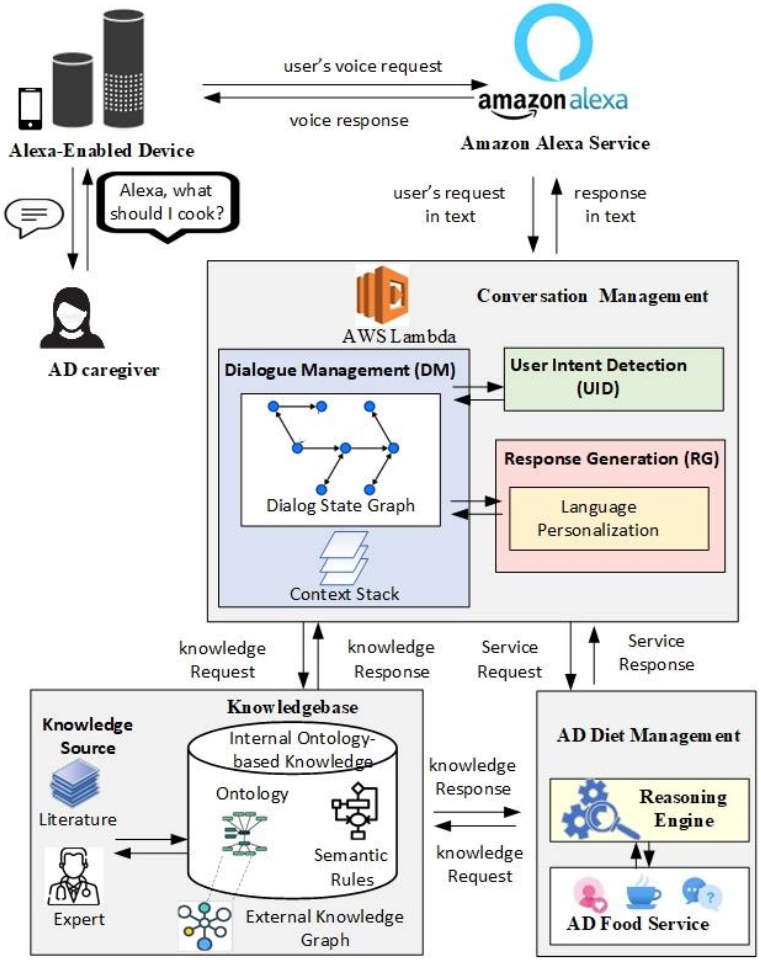

Figure 12 A Personalized Voice-Based Diet Assistant (Li, Maharjan, Xie, & Tao, 2020)

AI applications in agriculture

As the human population grows, technological innovations are needed to increase agricultural productivity and efficiency. In a country like Nepal where arable land resources are becoming scarce this pressure will become even more pronounced in the coming years. In this context, the use of digitization and AI driven methods for agricultural monitoring and production holds promise in Nepal. Agricultural information systems that capture contextually relevant data to enable smarter decision making and knowledge sharing should have high priority. Existing IT technology can be easily leveraged to develop

such systems (e.g., merokishan[11]). Additionally, the focus on low-cost digital/IoT and AI systems for agriculture will provide an abundant set of opportunities for the development of novel solutions. Smartphone apps are increasingly replacing the need for costly server-based systems that are traditionally needed for running applications. As the CPU horsepower of smartphones increases, the benefits of decentralized computing infrastructure can be fully leveraged where server systems are needed only for collecting data, sending software updates, and running complex models. These are excellent areas where Nepal can be part of the nascent low-cost high tech agricultural technology business.

This report identifies several key high priority areas within agriculture that are suitable for academic research and business investment:

- Agricultural information systems including phone-based services (e.g., Satellite based large scale agriculture monitoring)
- IoT Sensor integration with monitoring
- Smartphone based AI technologies e.g., plant disease detection, decision support systems
- Low-cost robotics

The above technologies can serve multiple use cases. In the table below, we list technologies/methods that can be adapted to better serve the potential use cases within the entire agriculture value chain.

Table 1 Use Case and Methods in Agriculture value chain

Use case	**How this can be achieved**
Agro Chemicals	AI/IoT driven precision chemical usage
Water usage	IoT & Weather driven usage
Farm Equipment	Low-cost robotic equipment

[11] https://www.merokishan.com/

Agri Processing	AI imaging for sorting/packaging
Government	Optimal resource allocation based on weather, demand, and supply
Agri Finance	AI driven credit risk scoring
Farmer	Agriculture analytics and profit estimation
Retailer	Demand forecast and pricing/profit
Supply Chain	Data fusion and analytics

Resource allocation and supply chain management is a key problem for the government and private sector. In developing countries where resources (e.g. food, medicine, fertilizers, fuel etc.) are limited, there is a need for the government to distribute these fairly and economically throughout the population. Similarly, for businesses, matching demand with just in time supply reduces inventory costs and saves on perishable goods that remain unsold. Forward planning based on seasonal demands, weather and other factors can help reduce supply chain costs and optimize delivery schedules.

For an economy such as Nepal where much of the population depend on agriculture for their livelihood, achieving improved efficiency within the agricultural value chain is an important priority. Human labour, land, fertilizer, pesticide and water are becoming increasingly more valuable than before as cost increases impact each one of these. Similarly, easier universal access to micro credits is a necessity to improve the livelihoods of the rural poor.

AI applications in education delivery

Within developing countries, only private schools can afford skilled teachers creating a huge disparity to equal education opportunity for all. Despite being in the 21st century, village schools are poorly provisioned not just in terms of infrastructure but also in terms of quality teachers. Although

equal access to quality education is an important sustainable development goal (SDG) , it does not seem to be within reach in the next 10 years within Nepal (National Planning Commission, 2020).

AI driven education delivery beyond current generation e-learning frameworks have a huge potential globally and especially within developing countries such as Nepal. Current generation e-learning delivery platforms (e.g., Moodle[12], Blackboard[13] etc.) employ limited AI capabilities if any. Most e-learning frameworks are digital delivery platforms for learning materials and electronic collection mechanisms for student submitted work. They provide mechanisms for timed release of teaching materials (e.g., videos, lecture pdfs, exam papers and quizzes etc.). Additionally, they provide automated marking of multiple-choice questions. In the future, we expect precision education delivery where the AI system acts as a personal tutor to achieve a stated individual learning objective as an important future goal for AI driven education systems.

In this report, we identified lack of skilled teachers as a key differentiator between schools in rural areas of Nepal and better off private schools in cities. Of course, there are additional challenges in delivering high quality education for all. These challenges include:

- Availability of talented teachers in remote areas
- Difficult to address needs of individual students
- Lack of mentoring help from home
- Lack of internet
- Lack of immediate feedback on student work
- Lack of access to large pool of relevant teaching resources

Current classroom-based education alone does not address the individual needs of the student. The individual needs of students can potentially vary from needing emotional/social support to clearing simple misconceptions/misunderstanding of concepts. Such needs cannot be met within a classroom setting alone. Having at hand a go-to person to provide a personalized mentorship and tuition can

[12] https://moodle.org/
[13] www.blackboard.com/

result in substantially faster learning. Within a classroom setting, availability of such help can be a make-or-break situation for the student. Clearly, the pace at which classroom education is delivered caters for the majority while not necessarily addressing the individual needs of the minority. In addition to these challenges to traditional education delivery, students have difficulty in tailoring self-help teaching resources to address their specific learning difficulties. All these factors result in a less than efficient education system that is not fit for the 21st century (NIRT, 2016).

Given the above considerations, we expect next generation education systems to be totally disruptive and transformative. And we expect that AI systems will have an increasingly major role to play in precision individually tailored education delivery, assistance, progress monitoring and feedback.

We believe that digital systems together with AI technology can be built to address some or majority of the above identified challenges. As AI technology matures, we expect AI for education to be the next technological hotspot in the same way that AI for object detection and recognition is currently.

While AI technology is getting better in shallow understanding of natural language, current NLP systems yet cannot do precise and detailed understanding of natural language in the same way that humans do. Similarly, joint understanding of language and diagrams is still at its infancy. And likewise, understanding school mathematics and geometry is at a very early stage. In summary, in the short term, we cannot expect AI systems to act as 'digital' teachers. And realizing such a vision is still not within reach at least in the foreseeable horizon (say within the next 5 years). But since AI technology is making exponential strides, the advent of AI driven teaching would be inevitable in the next 10 years and beyond.

Notwithstanding the limitations of current AI driven education technology in its ability to replace human teachers, current AI technology can add strong value to existing digital education delivery platforms and enable sufficient market differentiation. Hence, there are ample opportunities both from a governmental perspective and business perspective to improve current education delivery.

We identify several technologies that can add value to existing platforms:

- Automated essay marking
- Automated marking of simple mathematical proofs

- Automated assembling of YouTube videos and other teaching materials based on syllabus and student level
- Automated assistance when a student is stuck
- Chatbot systems for conversational assistance
- Automated prediction on grades based on current progress
- Offline availability for scaling to the masses
- Multilingual translation in both offline and real-time settings
- Voice recognition and synthesis

For students, getting immediate and precise feedback on their essay means that they can quickly improve their writing skills without delay. There is a long-established history in the use of NLP technology for automated marking of student essays (Cummins, Zhang, & Briscoe, 2016). ETS (Educational Testing Services) employ automated essay marking tools for marking TOEFL essays (Klebanov, et al., 2016). With modern deep learning methods (Reimers & Gurevych, 2019) (Lan, et al., 2019) (Feng et al., 2020) together with sufficient training data, short essay marking is achievable with acceptable accuracy (Ormerod et al., 2021). The challenge for modern deep learning methods is to extend current progress to few-shot learning setting (Ravi & Larochelle, 2016) (Wu et al., 2019).

Similarly, spotting errors in simple geometric and mathematical proofs can help a student make faster progress in mathematics. Currently progress is being made in developing neural network architectures for learning simple mathematical and geometric proofs (Wang et al., 2015) (Benzmuller et al., 2005) (more papers can be found at AAAI[14], IJCAI[15]).

Ability to automatically suggest targeted tutorial videos and reading materials to assist a student will greatly make the learning process much smoother especially when the suggestions are very targeted towards addressing the student's specific knowledge gaps. Recommender systems that have traditionally been applied for shopping recommendations. Variations to such architectures have also

[14] https://www.aaai.org/

[15] https://www.ijcai.org/

been successfully applied for suggesting tutorial, video recommendations, question recommendation (Li & Manandhar, 2010) and expert recommendations (Yang & Manandhar, 2014).

Monitoring of student progress based on feedback (e.g., from multiple choice questions or essay marking) and level of engagement (e.g. via timely submission of homework) can aid an AI system to automatically forecast student's performance (Li et al., 2020) (Hussain et al., 2018). This in turn will help the student avoid failing an exam by timely intervention. Chatbots and conversational assistants provide a convenient interface for students to access a multitude of options available in modern e-learning systems (Kerry et al., 2008) (Hobert et al., 2019).

For a developing country such as Nepal where internet access is not yet universal and affordable for all, e-learning systems that do not require constant internet access is a must. Such e-learning systems can be deployed on cheap tablets or smartphones that can be made available within villages alleviating the need for expensive server infrastructure. As the computing power of smartphones grow exponentially, e-learning apps that incorporate substantial AI capabilities will have a bright future. For example, English learning apps for children is very popular in China. Some of these apps feature voice recognition to help children improve their English pronunciation skills (eg, Mondly[16], Babble[17], Busuu[18]).

Figure 14 Use of tablet for e-Learning

According to Wikipedia[19], Nepal has 120+ languages and 250+ dialects including language isolates (not belonging to any known language family). Natural language technology can be leveraged for preserving languages by making available products, services, and teaching materials in multiple languages. The Government of Nepal has mandated that Government services should be

[16] https://www.mondly.com/

[17] https://www.babbel.com/

[18] https://www.busuu.com/en/hello-new

[19] https://en.wikipedia.org/wiki/Languages_of_Nepal

accessible in all the official languages of Nepal (currently: Nepali language in Devanagari script is used for Nepal government work). However, this goal is currently unmet. There is a huge need to build voice recognition, voice synthesis, language translation, handwriting recognition systems for the languages of Nepal. Thus, there is a big opportunity to develop NLP technology to address these.

AI integration within Workflow automation

Digitization and smartphone-based service delivery has successfully transformed the banking sector in Nepal. At least, in terms of customer experience, most banks in Nepal now provide phone apps and web apps. However, similar transformation is yet to be seen in other sectors. Despite these initial successes, the digitization within banks in Nepal is extremely limited and does not utilize the full potential of process automation especially business process automation (BPA[20]), robotic process automation (RPA[21]) and other types of workflow automation. Workflow automation and related technologies automate routine tasks that require human decision making. Examples include processing applications (e.g. for opening a bank account, citizenship application, driver license etc.), customer email forwarding based on content to the right department or person, automated marketing campaigns based on customer segmentation[22], improving employee retention and satisfaction. Human decisions can be part of workflow automation that will help improve accountability and efficiency.

[20] https://www.laserfiche.com/ecmblog/what-is-business-process-automation-bpa
[21] https://www.uipath.com/rpa/robotic-process-automation
[22] https://openviewpartners.com/blog/customer-segmentation/

CHAPTER 2- DEVELOPING A POSTGRADUATE CURRICULUM IN AI

2.1 Background

The demand for AI education is strong in Nepal as it is globally everywhere else. Young engineers aspire to become ML engineers in ever increasing numbers. Availability of free online ML courses such as Coursera[23] and free online programming environments such as Google Colab[24] and Codacademy[25] has truly democratized access to AI/ML education. This has made it possible for almost anyone (with basic programming skills) to build their first ML model whether it is a CNN model for object recognition or a sequence model for sentiment classification. At its most extreme, developing your deep learning model is becoming akin to assembling Lego blocks albeit using high level deep learning libraries such as Keras. Additionally, latest implementations of state-of-the-art models are available from online software repositories such as Github. On the other extreme, however, there is a lack of teachers/AI scientists who can teach the fundamentals of AI and ML and train the next generation of AI scientists. Most students learn only to tinker with preassembled ML models or play around with simple ones. There is a massive knowledge gap amongst the young aspiring engineers in Nepal that makes it difficult for most to publish high quality research papers, come up with their own ML models to solve specific problems or initiate new AI startups.

AI labs within universities and AI related independent research centers are slowly emerging in Nepal but these are currently insufficiently staffed or under resourced in terms of research facilities (e.g. computing resources) and funding. Within this context, it is appropriate for Madan Bhandari University of Science and Technology (MBUST) to initiate graduate and research programs in AI. These should serve several needs including:

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[23] https://www.coursera.org/search?query=AI&

[24] https://colab.research.google.com/notebooks/intro.ipynb

[25] https://www.codecademy.com/

- developing contextualized high quality academic research capability
- addressing the need for quality education in AI
- identifying cross disciplinary research areas of high impact and relevance for Nepal
- supporting businesses in AI and enabling the AI startup ecosystem

Development of Postgraduate Programs in AI

Madan Bhandari University of Science and Technology is aspiring to be a world class university. Although such a goal may seem too far-fetched, it is a difficult but a realistic goal to strive for. Firstly, the University can take advantage of contextual research that can only be done in Nepal. Secondly, the focus should be on applied and multidisciplinary research taking into account the unique challenges and opportunities available in Nepal. In its initial phase, MBUST is investing into developing Forestry and Agriculture along with AI. Hence, it would be appropriate for the University to focus initially on research and commercial opportunities in applied AI within Forestry and Agriculture. This does not preclude national and international collaborations across other disciplines when such opportunity arises.

The first requirement for developing high quality AI research capability is to invest in the development of world class postgraduate programs in AI. Development of such programs requires taking into consideration:

1. the skillset of current graduates those who are potential students,
2. the training needed to embark on a quality PhD program in AI, and,
3. faculty who can deliver such teaching.

Taking the first 2 points into consideration, this report proposes developing MSc and PhD programs in AI. The MSc programs are intended to train students to a level sufficient to enable them in embarking on a PhD program. Secondly, for students not seeking a PhD, the MSc programs offer an earlier exit route into industry or teaching careers.

We propose a holistic view into the training needs of students, the requirements of businesses and startups in developing AI curriculum. Such considerations lead to developing a balanced and broader curriculum. Some common aspects of both the MSc and PhD programs are:

1. Choosing project topics relevant in the Nepalese context
2. Close tie-up with industry in project topic identification
3. Emphasis on developing startups
4. Strong emphasis in communication and leadership skills
5. Focus on career paths beyond MSc and PhD

CHAPTER 3- CURRICULUM DESIGN FOR MSC PROGRAMS

In addition to common aspects for postgraduate programs identified earlier, we take into consideration the following factors in developing the curriculum for MSc programs:

1. Prior background of students
2. Prerequisite knowledge needed for high quality state-of-the-art PhD thesis in AI/ML
3. Integration of interdisciplinary aspects

Computer Science (CS) graduates in Nepal currently lack strong theoretical and programming skills. This is evidenced by the fact that the majority of CS graduates enter careers in web development and IT outsourcing jobs. Rote learning is in common practice that makes it difficult to cultivate original thinkers. In particular, CS graduates lack the following skills:

1. strong knowledge of programming principles including functional and object-oriented programming
2. ability to pick up new programming languages
3. ability in developing algorithms from scratch for given problems
4. good knowledge of computational complexity and its practical application when writing programs

The aim is to develop talent who 1. have a deep understanding of the latest techniques and methods in AI/ML, and, 2. can take on research or commercial projects requiring such knowledge. To enable defending a high-quality PhD thesis, students need to be prepared with sufficient background in AI methods including mathematical, theoretical, and practical prerequisites.

With the above considerations, the following high-level structure is proposed for an MSc in AI program:

1. Two semester long incremental teaching of Probability theory
2. Two semester long incremental teaching of Machine learning
3. One semester course in Bayesian Machine learning (in the 3rd Semester)

4. Once semester course in Advanced AI programming concepts

The above courses are intended to fill-in the existing gap in student's knowledge while at the same time introducing new additional concepts at a slower pace in easily understandable bitesize chunks. In addition to these, the course will cover:

1. Mini project and dissertation projects linked with industrial partner
2. Rigorous introduction to research methodology and AI ethics

Teaching Delivery

MBUST aims to pioneer new ways of teaching with the aim of making its teaching/projects more focused and enjoyable. It aims to move away from the traditional linear model of lecture driven teaching of theory followed by lab sessions. Following this philosophy, all teaching within all AI programs will be problem driven. In particular, teaching will be divided into topics covering a number of problem sessions. Each topic will be taught in the context of a specific problem that needs to be solved. One possible structure for teaching each topic will be:

1. Topic Introduction (e.g., regression models)
2. Problem statement (e.g., forecasting yield of rice harvest from observations + few other problems)
3. Data analysis
4. Approaches to solving the problem (e.g., linear regression, Lasso, Ridge, SVR and kernel methods)
5. Pros and cons of each
6. Application to problem domain
7. Evaluation of the different approaches
8. Conclusions and Summary

Generic Structure of all MSc in Artificial Intelligence Programs

We should be aiming to offer a range of MSc programs to cater for the diverse needs of the students and the industry. Thus, we plan to offer both specialized MSc and broader MSc programs. Additionally, we plan to offer a cross disciplinary program in data science. The following MSc programs are currently envisaged:

1. MSc in Artificial Intelligence
2. MSc in Artificial Intelligence with Specialization
3. MSc in Data Science with Specialization

A generic structure for all MSc in AI programs is proposed (please refer to Table below).

Table 2 MSc in AI Generic Course Structure

MSc in Artificial Intelligence
Generic Course Structure for all MSc in AI programs

Semester 1

Subject	Credits
Advanced Python Programming for AI	4
Linear Algebra - I	2
Probability Theory - I	2
Machine Learning Theory - I	2
Subject Specialization Theme 1 - I	2
Subject Specialization Theme 2 - I	2
Research Methodology, Plagiarism, Ethics	1

Semester 2

Subject	Credits
Deep Learning in Practice	4
Linear Algebra - II	2
Probability Theory - II	2
Machine Learning Theory - II	2
Subject Specialization Theme 1 - II	2
Subject Specialization Theme 2 - II	2
Paper reading and Presentation	1

Semester 3

Subject	Credits
Advanced topics in Deep Learning	4
Bayesian Machine Learning	4
Subject Specialization Theme 1 - III	2
Subject Specialization Theme 2 - III	2
Mini Project	3

Semester 4

Subject	Credits
Dissertation Project	15

Total Credits = 160

The program takes into consideration the current skill set of graduates in Computer Science and aims to fill in the gap in their theoretical knowledge of AI, programming knowledge and subject specific knowledge in a stepwise incremental delivery of taught materials. The delivery of AI/ML theory is spread across 3 semesters covering: Probability Theory, ML theory, Deep Learning and Bayesian Machine Learning. And subject specialization is introduced from Semester 1 to ensure early engagement.

Paper reading and Presentation is aimed towards providing students with a solid knowledge of reading and understanding a variety of papers including both classical papers in the field and the current advances. It is aimed towards developing critical thinking and critical analysis skills where students will be required to do paper reviews and analyse each other's reviews.

Projects and how it helps shape future research

The Mini Project is intended to be a critical component that prepares the student towards the Dissertation Project. The Mini Project and the Dissertation Project will comprise:

1. Literature review in a chosen topic
2. Critical analysis of current literature
3. Identification of gaps in current research
4. Experimental evaluation of current methods
5. And optional for Mini Project but mandatory for Dissertation Project:
    a. Development of a new method
    b. Implementation and evaluation of the proposed method
    c. Comparison with existing methods
    d. Preparation of a journal/conference article for submission into a relevant journal/conference

All projects (Mini and Dissertation) are required to have strong industrial or contextual relevance. The advisor will be responsible for establishing contacts with relevant businesses or stakeholders to ensure that the projects are relevant in the Nepalese context. All advisors are strongly encouraged to develop long running research themes and stakeholder partnerships so that successive project students can continue improving upon earlier research and help establish a center of excellence in specific research topics.

Both the Mini Project and the Dissertation Project will be specialized enabling students to pursue PhD research by expanding in their chosen Project topics. PhD students will be expected to assist MSc students when their research topics overlap. Collaboration will be strongly encouraged while at the same time academic ethics need to be strongly observed.

Structure of MSc in Artificial Intelligence Program

Table 3 MSc in AI Instantiation Options

MSc in Artificial Intelligence Instantiation of Subject Specialization Options	
Semester 1 Options	**Credits**
Subject Specialization Theme 1 - I	
Natural Language Syntax	2
Subject Specialization Theme 2 - I	
Image Processing Fundamentals	2
Semester 2 Options	**Credits**
Subject Specialization Theme 1 - II	
Deep Learning for NLP	2
Subject Specialization Theme 2 - II	
Computer Vision Fundamentals	2
Semester 3 Options	**Credits**
Subject Specialization Theme 1 - III	
Advanced Topics in NLP	2
Subject Specialization Theme 2 - III	
Advanced Topics in Computer Vision	2

The MSc in AI program is intended to be a broader program primarily intended for students who are interested in gaining a wider knowledge of multiple AI topics. A mix of topics in AI/ML will be offered covering the current state-of-the-art. Initially, only courses in Natural Language Processing and Computer Vision are planned and the portfolio of courses can be expanded depending primarily on availability of the teaching faculty who are subject experts.

Structure of MSc in Artificial Intelligence Program with Specialization

A variant to the more generic MSc in AI Program is the more specialized MSc in Artificial Intelligence Program with Specialization. Specific instantiations of this program can be:

- MSc in Artificial Intelligence Program with Natural Language Processing Specialization
- MSc in Artificial Intelligence Program with Computer Vision Specialization

Table 4 MSc in AI with NLP Instantiation Options

MSc in Artificial Intelligence with Natural Language Processing Specialization **Instantiation of Subject Specialization Options**	
Semester 1 Options	**Credits**
Subject Specialization Theme 1 - I	
Natural Language Syntax	2
Subject Specialization Theme 2 - I	
Language and Meaning	2
Semester 2 Options	**Credits**
Subject Specialization Theme 1 - II	
Morphology and Parsing	2
Subject Specialization Theme 2 - II	
Deep Learning for NLP	2
Semester 3 Options	**Credits**
Subject Specialization Theme 1 - III	
Advanced Topics in NLP (double credit)	4

New faculty will be expected to come up with their own variants of specialization. One possible structure for MSc in Artificial Intelligence Program with Natural Language Processing Specialization is given in the Table (see below). In particular, the program delves deeper into linguistic theory covering syntax, semantics, morphology, and parsing.

Structure of MSc in Data Science with Specialization

While the MSc in AI Programs are intended to produce talent with deeper knowledge of AI/ML, there is in fact an even bigger need for transforming other fields with AI skills. Data science education can be thought as a step towards upskilling other disciplines with AI knowledge.

Table 5 MSc in Data Science with Specialization Generic Course Structure

MSc in Data Science with Specialization Generic Course Structure

Semester 1

Subject	Credits
Programming Principles using Python - I	4
Linear Algebra - I	2
Probability Theory - I	2
Data Preprocessing - I	2
Data Visualization - I	2
Subject Specialization - I	2
Research Methodology, Plagiarism, Ethics	1

Semester 2

Subject	Credits
Python Programming	4
Statistical Methods for Data Science	2
Predictive Analytics	2
Introduction to AI and ML	2
Machine Learning for Data Science	2
Subject Specialization - II	2
Paper reading and Presentation	1

Semester 3

Subject	Credits
Practical Deep Learning for Data Science	4
Subject Specialization - III	2
Subject Specialization - IV	2
Mini Project	3

Semester 4

Subject	Credits
Dissertation Project	15

Total Credits = 160	

The generic structure for a Data Science masters specialization is given (see Table below). The program aims to provide a strong foundation in data science skills that includes - programming for data science, data gathering, data cleaning, descriptive statistics, machine learning methods, practical deep learning together with subject specific applications in the chosen specialization e.g., agriculture.

MSc in Data Science with Agriculture Structure

An initial concept for Data Science with Agriculture specialization is proposed (see Table below).

Table 6 MSc in Data Science with Agriculture Instantiation Options

MSc in Data Science with Agriculture Instantiation of Subject Specialization Options	
Semester 1 Options **Credits**	**Semester 2 Options** **Credits**
Subject Specialisation 1	**Subject Specialisation - II**
Modern Agriculture Methods 2	IoT Sensing for Agriculture 2
Semester 3 Options **Credits**	
Subject Specialisation - III	
Data driven smart farming 4	
Subject Specialisation - IV	
Advanced Topics in AI & Agriculture 4	

The proposal is indicative and not prescriptive. The aim of this degree is to intake graduates with a background in agriculture and embed them with knowledge of data science. In contrast to an existing MSc in Agriculture that may already contain some data science subjects, the proposed MSc in Data Science with Agriculture specialization focusses on data analytics for agriculture and smart farming methods that heavily employ data science. A fully IoT instrumented agriculture lab together with IoT and Robotics assembly lab will be available for students to ensure that taught concepts are translated into real problems in the ground. It is expected that local farmers and entrepreneurs are engaged in the program to help decide topics for the Mini Project and Dissertation Project.

CHAPTER 4- MSC BY RESEARCH AND PHD PROGRAM IN AI

Both the MSc by Research in AI and PhD in AI programs are aimed at producing world class talent in AI while maintaining contextual relevance in terms of the research topics chosen. Several key research areas have already been identified earlier in this proposal. A holistic approach is proposed wherein the requirements for conducting leading edge research is augmented with additional requirements for research leadership skills, networking, communication, grant writing etc. These additional requirements are essential in developing research excellence in the chosen research topics and eventually in establishing MBUST as a leading research center for applied AI in several selected areas.

The core aspects of all research degrees are:

- Research integrity and Ethics
- Supervisor(s)
- Thesis Advisory Board
- Progression points and success criteria
- Thesis Structure
- External courses
- External co-supervisors and collaborators
- Review of supervision and mitigation
- Teaching and Research Assistantships
- Publications
- Networking
- Seminars
- Conferences
- Nomination of External Examiner
- Viva
- Career paths and training
- Grant proposal writing and projects

We elaborate some of the key aspects below while leaving the rest for later.

Research integrity and Ethics training is an integral aspect of all research degrees. It needs to cover at least the following:

- Full understanding of research ethics & research integrity
- Dual use nature of most scientific inventions
- Strict guidelines for academic conduct – referencing, acknowledgements, data ethics and privacy, laws governing experiments
- Understand academic misconduct and how to avoid this
- Ethical approval process – this needs to be designed and made available to all researchers
- Conscious or unconscious bias and how to avoid this
- Replicability of experimental results
- Reporting principles for scientifically validated reporting of experimental results

Supervisor: The role of the supervisor is key in establishing a successful research group. We expect all supervisors to:

- Treat research students as peers
- Build mutual trust and respect
- Allow students to challenge supervisor's opinion
- Challenge student's opinion while respecting their current knowledge
- Build a research team environment where students do not feel isolated
- Strive to turn a research student into established independent and confident researcher
- Understand pressure on students to deliver
- Provide emotional support as needed

Thesis Advisory Board: The progress of a research degree will be monitored by a Thesis Advisory Board that is nominated primarily by the supervisor with consent from the student.

Responsibility:

- Provide broader research support to the research student and supervisor
- Provide oversight in the progress of the research student

- Provide networking help
- Monitor research progress and validate progress against university procedures
- Understand issues facing student and supervisor – assess research supervision
- Suggest mechanisms for mitigation of issues
- Advisory board members, excluding supervisor(s), cannot collaborate in the research project as this generates a conflict of interest

Meeting times:

- Meet at regular intervals at agreed times following University procedures
- Be available for the student and supervisor when advisory assistance is needed

Membership:

- All members must be specialist within the broader subject area but not necessarily in the narrower research topic
- All members need to be approved by the Graduate Research Chair in the respective department
- Supervisor will fill in a nomination form provided by the University
- MRes: Supervisor(s) + 1 additional Advisory Board member
- PhD: Supervisor(s) + at least 2 additional Advisory Board members

5.1 MSc by Research (MRes) in Artificial Intelligence degree structure

The MSc by Research degree is designed as a mini-PhD program lasting 12 months. It contains all the elements of a full PhD albeit compressed within a 12-month time span. The research conducted during the MRes degree is meant to take about 1/3 of the effort compared with a full PhD. And a MRes thesis is expected to contribute at least one new knowledge that is publishable in a leading conference/journal. Students can transfer from a MRes degree to a PhD degree if they wish.

It is expected that requirements for MSc by Research programs will be standardised across disciplines. The key steps are:

- Students will enter the MRes program by completing taught MSc Program with a minimum GPA of 2.0 or equivalent if transferring from another University

- The MRes program will consist of an additional 1-year pure research project
- The research project will run like a mini-PhD program
- The research project will expand on the MSc dissertation project (strongly recommended)

Within the 1-year MRes program, the key progression points are are:

1. Literature Review Report and Literature Review Seminar (Month 2)
2. Research Proposal Report and Research Proposal Seminar (Month 3)
3. MSc by Research Thesis and Research Seminar (Month 12)

The requirements for each of the above progression points are given below. Please note that some of the additional requirements only apply for a PhD degree.

Literature Review Report and Literature Review Seminar

Literature Review Report should contain:

- Critical review of literature within the chosen domain
- Clear identification of research gaps
- How does this build on MSc dissertation, if applicable?
- Identification of knowledge needed to conduct the research
- Identification of student and supervisor gaps in knowledge (PhD only)
- Identification of any training needs or external supervisor help (PhD only)

Success criteria:

- Review is critical, written in authoritative academic style, clearly identifies the current progress in the field
- Research gaps has been identified and clearly specified
- Comparison with MSc dissertation is provided and how new work merits a PhD is clearly identified.
- Does the student have the knowledge to carry out this research?
- Does the supervisor have the knowledge to carry out this research?

- Good delivery and answering questions raised during the seminar
- If there is a gap in required knowledge, has training needs and time required been clearly identified. Similarly, has an external supervisor been clearly identified if needed. (PhD only)

Research Proposal Report and Research Proposal Seminar

Research Proposal Report should contain:

- Clearly defined research proposal that proposes to address a significant gap in current research within the chosen topic area
- Justification of why the proposed approach is going to be novel
- Justification of why the proposed approach is simply not incremental and would not be already published by other researchers
- Justification that the proposed research would represent a step change in enhancing our knowledge of the field
- Clearly defined subjective and objective success criteria
- Research Plan with milestones and timelines have been provided in a chart
- Identification of how the research will impact the field

Success criteria:

- Addressed research gaps are novel
- Proposed approach is sufficiently novel and has potential to generalise over current approaches
- Research Plan is realistic and achievable
- Success criteria for measuring success of the project has been clearly specified and meets currently used criteria within the field
- Good delivery and answering questions raised during the seminar

MSc by Research Thesis and Research Seminar

MRes Thesis should contain:

- Critical Literature review
- Goals of the research
- Summary research objectives and milestones
- For each contribution Chapter:

- Report on the research carried out and results obtained against the set milestones
- Evaluation results
- Summary of research outcomes
- Publication plans

Success criteria:

- Has agreed research targets been achieved?
- Do the obtained results merit a MSc by Research? If not what remedial measures need to be carried out? How much extra time will be needed?
- Good delivery and answering questions raised during the seminar

5.2 PhD in Artificial Intelligence degree structure

The key steps in entering and completing a PhD degree are:

- Students will enter the PhD program by completing taught MSc Program with a minimum GPA of 2.0 or equivalent if transferring from another University
- The PhD program will consist of an additional 3-year pure research project
- The research project will expand on the MSc dissertation project (strongly recommended)

The progression points for the PhD degree are given below.

1. Literature Review Report and Literature Review Seminar (Month 4)
2. Research Proposal Report and Research Proposal Seminar (Month 6)
3. First Year Report and First Year Research Seminar (Month 12)
4. Second Year P1 Report and Second Year P1 Research Seminar (Month 18)
5. Second Year P2 Report and Second Year P2 Research Seminar (Month 24)
6. Third Year P1 Report and Third Year P1 Research Seminar (Month 30)
7. PhD Thesis Seminar (Month 35)
8. PhD Thesis Submission (Month 36)
9. PhD Viva (within 3 months of thesis submission)

After the successful submission of Literature Review (month 4), the PhD progression follows a regular 6-month cadence. Each 6-month progression point is marked by a written report followed by

a seminar. The Thesis Advisory Board will be responsible for monitoring and agreeing to the next progression point.

External courses, co-supervisors and collaborators

External courses

- The supervisor and student have the primary responsibility to identify external (online) courses needed to fill in any identified knowledge gaps
- These should be completed as early as possible during the PhD

External co-supervisors and collaborators

- External co-supervisors and collaborators may be needed depending upon the research topic
- Having external co-supervisors and collaborators should be actively encouraged to build research partnerships both nationally and globally
- There needs to be a University policy document on such engagements
- The University needs to be supportive of such arrangement under some conditions:
- Both supervisors can be co-supervisors
- Can primary supervisors be external?
- There should not be any financial incentives for external supervisors
- The University to initiate visiting faculty programs to encourage external links and collaborations

Review of supervision and mitigation

Review of supervision form

- This should be completed and provided to the Thesis Advisory Board members (excluding supervisor)
- Review of supervision will form part of the responsibility of the Thesis Advisory Board
- The student will have the right to keep the contents of the feedback confidential
- Any issues identified should be mitigated where possible
- With informed consent from the student, unresolvable issues will need to be brought to the attention of Departmental Graduate Research Chair

Mitigation of issues and resolution

- Thesis Advisory Board members should aim to resolve any issues between supervisor and student where possible and suggest remedial measures. These could involve increased/decreased supervision, connecting with other students, emotional support etc.
- When mitigation is not possible, then the Graduate Research Chair will need to be informed who will initiate meeting with the student and the supervisor
- In extreme cases, Thesis Advisory Board can recommend change of supervisor or discontinuation of research degree

Teaching and Research Assistantships

Teaching Assistantships

- Students who have already completed their MSc and demonstrated competence in specific subjects should be encouraged to take up teaching assistantships
- Teaching assistants support running labs and assisting in classrooms
- Teaching assistants are not expected to teach
- Teaching assistants can also support some easy marking tasks while the responsibility of marking quality will rely solely on the lecturer/examiner

Research Assistantships

- Research assistantships are generally only recommended for PhD students whose research topic aligns well with a research project.
- In such cases, the PhD thesis could be an outcome of the research project or directly supported by a research project.
- Since, doing a PhD is a full-time activity, a PhD student cannot be involved in research that is not part of the PhD study.
- In all cases, departmental approval will be needed for PhD students to engage in any research projects.

Policy on publications

- All students are actively encouraged in publishing their research

- PhD students will be expected to publish their papers in established conferences and journals in their respective fields.
- Annual Science Workshop:
- The University will run an annual science workshop
- The workshop will be annual event to celebrate the achievements of its staff and students
- All research students will be required to present their work in Annual Science workshop that showcases research to businesses, government and other academics

Mentoring scheme

- All students submitting posters or papers to the annual science workshop will be assigned an academic mentor
- The mentor will assist the student in improving the quality of the submitted paper
- Annual classes on paper writing will be provided

Networking

- The University recognizes that modern research is very often collaborative
- Collaboration is key for multidisciplinary and interdisciplinary research
- An open environment of idea sharing is essential to generate new research ideas
- Supervisors will be expected to link their students with collaborators both nationally and globally
- The University will conduct regular networking workshops on focused interdisciplinary themes with the aim of generating grant applications or responding specific call for proposals

Seminars

- Students and faculty are expected to attend and present in seminars
- Each department will run a regular seminar series

Conference

- All PhD students are expected to attend at least one conference to present their research during their PhD

- The University will need to provide funding pool for staff/student to present their work

Summer School

- All PhD students are highly encouraged to attend summer/winter schools in their respective discipline as most of these are now available online
- The University will need to provide funding for students to attend such schools

Procedure for nominating external examiner

- For research degrees, to maintain high research standards, it is critical to nominate external examiners that have substantial research experience and are leaders in their respective fields
- For this reason, the university will need to follow strict procedures for nominating external examiners
- **Steps:**
    - External examiners will be initially proposed by the Supervisor at least 3 months prior to thesis submission
    - Nominated external examiner will be vetted by a University Graduate Research Committee to ensure that the examiner meets the University requirements
    - The supervisor will contact the examiner to ensure that the examiner is willing to conduct the examination within a specified time limit
    - The University will contact the external examiner to initiate an external examiner form
    - Once the form is signed, the thesis will be sent to the external examiner

Viva Procedure for PhD defense

- PhD viva will be conducted in the presence of an external examiner and an internal examiner
- The internal examiner will typically be a member of the student's Thesis Advisory Board
- The external examiner will chair the viva session
- A viva can last from anywhere between 2 hrs. to 6 hrs. but most viva are expected to take about 3 hrs.
- The purpose of the viva is to ensure that the student:

- has broad knowledge of the wider research area
- has detailed knowledge of the specific research topic
- can articulate clearly the contribution made within the subject area
- can critically compare the research with the work of other researchers
- can explain the rationale for the research undertaken and the results obtained
- can defend the methods employed

In addition to the above mandatory requirements for completing a successful PhD, there is strong emphasis on career paths beyond PhD. We expect that PhD graduates become leaders within their own field (whether this is academia or industry) and the PhD degree program provides as much of the training as possible to enable such a career path. All PhD students will be expected to:

- do regular seminar presentations within their department, other departments and within the community
- work as TAs
- assist in course design
- mentor other PhDs
- openly communicate new ideas in seminars and group meetings
- organize internal seminars
- organize or assist in organizing workshops
- engage in industrial/commercial projects where appropriate
- initiate grant writing in the final year of PhD

It will be the responsibility of the supervisor to actively mentor, connect and enable the PhD student towards achieving the above. All of these activities are essential in ensuring that a positive and vibrant research culture is developed with strong national and international collaboration across academia and industry.

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