On Multi-modal Data Mining and Advanced Machine Learning Research

A SHORT INTRODUCTION TO THE INTELLIGENT DATA ENGINEERING AND ANALYTICS LAB

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Abstract

The Intelligent Data Engineering and Analytics (IDEA) Laboratory at Wuhan University of Technology (WUT) is a joint effort aiming to research and teach on data science and artificial intelligence. IDEA has intensive research collaboration with well-known industry partners. Leading by Professor Lin Li, the founding director, IDEA currently has nine academics and 50+ research students. In the past few years, the lab has secured over 10 million CNY competitive research grants from provincial and national research schemes funded by governments and corporations. IDEA conducted world-class research and had outcomes published in premier journals, such as VLDBJ, TOIS, TKDE, TSC, TOIT, IPM, and world-top conferences, such as AAAI, WWW, ICDE, ICDM, CIKM, ICMR, ICASSP. IDEA also received many national and international awards for their achievements in Information Management, Big Data, and Web Intelligence, including Top 1 of OpenLive QA Task at NTCIR-13, Best Student Paper Award in CCF Big Data 2020, and Best Student Paper Award in WISE 2020.

I. INTRODUCTION

The Laboratory of Intelligent Data Engineering and Analytics (IDEA) was founded by Professor Lin Li in 2011. The lab has intensively researched on topics of text mining, recommender system, Question & Answering, social computing, multi-modal machine learning, sequential prediction, Lightweight/Parallel Machine Learning. In the past few years, the lab has received over 10 millions RMB competitive research grants from provincial or national funding schemes offered by governments, corporations, and private sectors, such as National Natural Science Foundation of China (NSFC), National Social Science Fund of China, China Scholarship Council Project (CSC), Department of Science and Technology of Hubei Province, China, and Deloitte[1]. Supported by these funds, IDEA's research has been productive and sustainable, with outcomes published in top-tier data science and artificial intelligence conferences and journals, such as VLDBJ, TOIS, TKDE, TSC, TOIT, IPM, AAAI, WWW, ICDE, ICDM, CIKM, ICMR, and ICASSP.

The IDEA lab has received many awards at national and international levels. The work on Community Question & Answer (CQA) was awarded *Top 1 Online Test Results of OpenLive QA Task* at NTCIR-13[2]. The study on traffic flow forecasting received Best Student Paper Award in CCF Big Data 2020[3]. In the 21st International Conference on Web Information Systems Engineering (WISE 2020), IDEA's work on legal judgment prediction was also highly praised and awarded with Best Student Paper Award, too.

With a glance given in the Introduction, more details about IDEA will be provided below. Section II describes the research areas focused by IDEA. In Section III, the impact delivered by IDEA by its research to the real-world will be discussed. After that, some research activities conducted by IDEA will be highlighted in Section IV. Finally, in Section V IDEA's vision on future research will be presented.

II. RESEARCH AREAS

The IDEA lab is mainly focused on data science and artificial intelligence research and extensively involved in interdisciplinary research, such as computing social science, LegalAI, and intelligent transportation systems. The key research areas include:

- Recommender system
- Deep clustering
- Sequential prediction
- Cross-modal retrieval
- Multi-modal machine translation
- Question&Answering
- Social computing, multi-modal user profiling
- Law intelligence, legal judgment prediction
- Lightweight/Parallel machine learning

A. Recommender System

Recommender System, an active domain of information filtering, takes advantage of information from various sources to provide users with predictions and recommendations of products and services (e.g., movies, books, applications, websites, and travel destinations). The recommendation aims to facilitate user decision-making, improving user experience in Web services, achieve revenue increase for online businesses and merchants, and so on.

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[1] https://www2.deloitte.com/cn/en.html
[2] http://research.nii.ac.jp/ntcir/workshop/OnlineProceedings13/NTCIR/toc_ntcir.html
[3] http://bigdata2020.swu.edu.cn/beststudentpapers/

IDEA's strengths on recommender systems include:

- Geo-based and group recommendation
- Cross-domain, cold-start and long-tail recommendation
- Streaming recommendation
- Knowledge and content driven recommendation
- Interpretable, Interactive and dynamic recommendation

IDEA's research on recommender systems can be showcased on [1], [2], [3], [4], [5], [6], [7], [8], [9].

B. Cross-modal / Multimedia Retrieval

Besides the development of content-based multimedia retrieval, cross-modal retrieval - one of the most desired services in data powered machine learning application - focuses on the multi-modal datasets which contain more than one modality, such as Twitter tweets, Instagram messages, yelp dish recommendations and the information on other social platforms. Cross-modal retrieval aims to give users a multi-modal view on information acquisition, and promote advertising effectiveness to increase sales for online business and offline stores.There are many challenges, such as feature representation, semantic gap between image visual features and semantical meaning, and the lack of training samples. IDEA has made many significant achievements in this area, especially in:

- Image-text, Image-video cross-modal retrieval
- Implicit alignment cross-modal retrieval
- Dataset generation for specific areas (as shown in Figure 1)
- Effective automatic image annotation.
- Deep hashing for multi-label image retrieval

These research outcomes can be found on [10], [11], [12], [13], [14], [15], [16], [17], [18].

C. Sequential Prediction

Sequential Prediction focuses on modelling diverse kinds of interaction patterns across a series of elements in chronological order (e.g. purchase history, urban event, air quality index) to obtain hints about future elements. It is a basic technology for helping organizational and social entities in resource allocation and decision-making. Our strengths include:

- Spatial-temporal sequence prediction
- Cross-correlation based sequence prediction
- Knowledge distillation based sequential learning

See [19], [20], [21] for examples of our research in this area.

D. Multi-modal Machine Translation

Multi-modal machine translation (MMT) can use the image information corresponding to the source text and improve the translation quality. Since text and image belong to different data modality, bridging the modality gap between them is one of the challenges of MMT. Our studies include the following:

- Multi-modal Machine Translation with Attention
- Multi-perspective Multi-modal Machine Translation
- Machine Translation Enhancement with Multi-modal attention

See [22], [23], [24] for examples of our research in this area.

E. Question&Answering

QA is a classic natural language processing (NLP) task, which aims at building systems that automatically answer questions formulated in natural language, such as community question answering services(CQA), document-based question answering, question answering over knowledge base (KBQA), etc. Our strengths include:

- Cross-lingual Open QA.
- Translation based CQA
- Context enhanced KBQA.

See [25], [26], [27], [28] for examples of our research in this area.

F. Multi-modal User Profiling

Multi-modal user profiling means exploiting the technology of machine learning and the multi-modal data (e.g., text, image, code) generated by users to predict attributes of users, such as demographic attributes, hobby attributes, preference attributes, etc. The key work of multi-model user profiling is to label users with some highly refined features that can summarize user characteristics through analysis of various user information - in a sense, digitizing users. The potential applications of user profiling includes precision marketing, data statistics, decision support, etc. Our strengths include:

- Sentiment-based gender classification
- Multi-modal cooperative gender classification
- Emotion classification

See [29], [30], [31] for examples of our research in this area.

G. Legal Judgment Prediction

Legal Judgment Prediction (LJP) is one of the most critical tasks in LegalAI, especially in the Civil Law system. In the Civil Law system, the judgment results are decided according to the facts and the statutory articles. One will receive legal sanctions only after he or she has violated the prohibited acts prescribed by law. One of the LJP tasks mainly concerns how to predict the judgment results from both the fact description of a case and the contents of the statutory articles. Our strengths include:

- Legal framework-driven interpretable charge prediction.
- External knowledge enhanced multi-label charge prediction.
- Multi-type legal machine reading comprehension.

See [32], [33], [34] for examples of our research in this area.

H. Lightweight/Parallel Machine Learning

The lightweight machine learning models accelerate the models to achieve efficient inference by simplifying the structure, pruning or optimizing the construction unit. Parallel machine learning models use multiple processors to improve the efficiency and computational power of the model. Our strengths include:

- Object detection based on lightweight backbone.
- Semantic segmentation based on lightweight backbone.
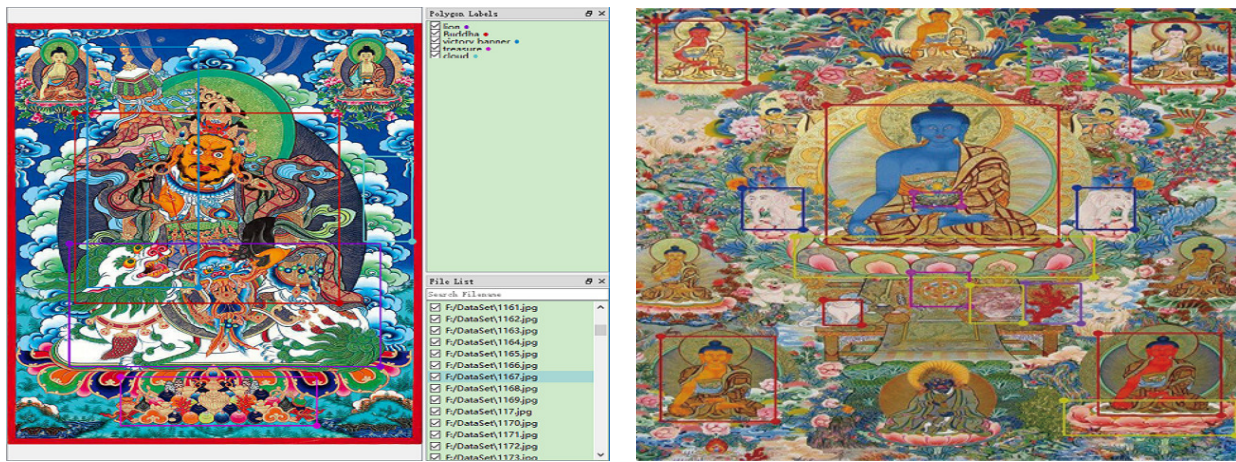- Video stitching based on GPU parallel acceleration.

Fig. 1. The example of Dataset generation.

- Fast reduction and parallel processing of big data.

See [35], [36], [37], [38], [39] for examples of our research in this area.

I. Deep Clustering

Clustering aims to group data without label information, which is a crucial and challenging task in pattern analysis and machine learning. Deep clustering, a novel clustering method joints clustering and deep feature representation learning, has shown remarkable performance with real-world data (e.g., image, text documents, and graph-structured data). Our strengths include:

- Variational deep clustering
- Deep graph clustering
- Deep multi-view clustering

See [40], [41] for examples of our research in this area.

III. RESEARCH WITH REAL-WORLD IMPACT

This section summaries how the lab's research is applied when dealing with real world applications, improving business outcomes and benefiting society.

A. Rank Optimization of Personalized Web Information Retrieval

Personalized Web information retrieval is an effective way to improve the precision of traditional information retrieval, and then satisfy the information needs of Internet users. With the appearance of various types and large amount of information on the Web, users not only require retrieval precision, but also the retrieval efficiency and the privacy protection of their personal information. Funded by NSFC, this project focuses on how to improve the overall quality of Web information retrieval, including precision, efficiency and privacy protection. Our research includes query and time dependent re-ranking algorithms, the update mechanism of user profiles, the approaches to improving the efficiency of re-ranking algorithms, privacy protection based user profile modelling, privacy protection based re-ranking algorithms, and so on.

B. Small Business Credit Evaluation

With the development of digitization, networking, and socialization, the Internet has accumulated a large amount of information. The understanding of Internet information will help form a new type of credit evaluation method and promote financial innovation research in the Internet age. This project deeply analyzes and establishes a credit evaluation model for small business through the following activities:

1) Deep web data crawling and information extraction technology is studied to solve the problem of how traditional hyperlink-based web crawlers cannot crawl and index the information in the deep web;
2) Sentiment analysis algorithm for review data provides a viewpoint from Internet Word-of-mouth (positive, neutral and negative) to enhance the traditional credit evaluation methods. The main task is based on user reviews text crawled from some e-commerce platforms, and investigating how to transfer the rich sentiment analysis resources of traditional long texts to improve the sentiment classification quality of short texts.
3) Credit scoring algorithm based on enterprise association graph aims to extract the direct or indirect ownership or control relationship of enterprises in terms of capital, operation, purchase and sale, etc., and personal social network data from small business owners on the Internet.
4) A credit scoring model based on hidden factors is built. Because a small business with large amounts of data may be very sparse and missing features, hidden factor analysis is used to decompose sparse high-dimensional data into semantic low-dimensional hidden data, thus enhancing credit evaluation.

C. Multi-modal Machine Learning

With the rapid development of social networks and search engines, lots of interests has been witnessed in jointly dealing with multi-modal data such as text, image, audio and video. To cope with this scenario, information processing has to be transformed from the form of single modality to multi-modality. Therefore, challenges from the "media gap" (such

as how representations of different media types are inconsistent), are gaining increasing attention. Recently, deep neural networks(DNN), a major breakthrough in machine learning, has been employed to learn better multi-modal representations. This project works on multi-modal machine learning from representation, translation, fusion, alignment, and co-learning. Our recent studies in multi-modal representation are presented with new multi-modal algorithms and exciting multi-modal applications.

D. Continuous Querying and Query optimization on Streaming Data

As the volume of streaming data increases in current information era, how to perform efficient and optimized continuous query on streaming data has become one of the most significant problems for Data Stream Management System(DSMS). In the Big Data environment, the existing continuous query solution, including the approximate representation and similarity measure techniques, cannot meet the requirements of data variety and velocity, and current DSMSs fail to theoretically improve the techniques of continuous query on streaming data. Due to this situation, this project explores data characteristics in Big Data environment, and based on the theoretical analysis, aims to design efficient an framework of continuous query on streaming data, and perform query optimization for massive data stream applications. The key points of this project include: (1) customized approximate representation and similarity measure based on actual data stream; (2) the framework of efficient continuous query technique based on approximate representations; (3) multiple query optimization in massive data streams environments based on cost model and queries' structure. The outcomes of this project will theoretically propose the practical continuous query solutions as well as relevant techniques on streaming data, and provide the theoretical bases and key technique support for streaming data processing in Big Data environment.

E. Digital Content Management for Publication Industry

The publishing industry has accumulated a large amount of multimedia content. With the development of digitization, networking, and socialization, the unified and effective management and understanding of digital content will help promote the development of a new type of digital publication industry. This project collaborates with enterprises to industrialize scientific research results and provide software platform support for the digital publication industry. The main research content includes a digital content management platform and a digital content analysis platform.

1) The digital content management platform marks the knowledge fragments in the digital publication knowledge base, and introduces the semantic web technology to mark different types of associated descriptions and rich content tags.

2) The digital content analysis platform analyzes the information used to establish the user's interest model, and based on a deep understanding of digital content, sensitive word filtering technology, topic model analysis,

semantic association and other technologies are studied to monitor online publishing, and discover content prohibited by laws and regulations.

F. AI+5G Service Robot and its Applications

This project explores the key technologies of AI+5G empowered service robot, and its applications for smart community platform: (1) Community service knowledge representation and reasoning methods will combine representation learning and transfer learning methods to study multi-level and multi-scale community service knowledge representation methods, cross-modal information representation methods for relationship analysis between entities/events. (2) The functional modulars are designed on key information extraction, user intention recognition, multi-semantic relationship extraction, automatic report generation, task-based multi-round question and answering, and so on. (3) Cloud-edge based smart community service platform is the integration of data privacy protection, multi-party secure computing, federated learning and other technologies.

G. Text mining for Contract Review

For a long time, the traditional contract management system has the problems of complex contract approval procedures and the lack of awareness of contract risk management. Therefore, the efficiency of business processing in the contract management process is low. At the social level, news outlets have reported that many people have signed "unequal" treaties due to lack of legal background. Enterprises and people have an urgent need for smart contract risk review and smart contract management. In order to solve this problem, this project explores natural language processing, deep transfer learning, information extraction, and OCR technology to automatically do contract risk review. Moreover, extracting summary generation and paper contract identification will help users analyze the contract process, avoid "contract traps", and improve the intelligent level of existing contract management.

H. Surveillance Multi-modal Data Mining for Smart City

The centralized mode of cloud computing makes it difficult to efficiently process a large amount of surveillance multi-modal data generated by monitoring equipment. For basic applications such as target recognition, efficient retrieval, semantic analysis, etc., This project will research cloud-side collaboration lightweight target detection model, graph reasoning based cross-modal retrieval, and the generation of video text descriptions associated with multiple events, which will improve the level of smart city safety monitoring, traffic management, and infrastructure operations. This project is based on the surveillance multi-modal data, and in response to the current needs of cloud-side collaboration scenarios in smart cities. The main work will include a fast parallel processing architecture for surveillance multi-modal data, the lightweight target detection model for edge devices, the temporal and spatial correlation action recognition method, cross-modal efficient retrieval based on key frame extraction and graphic
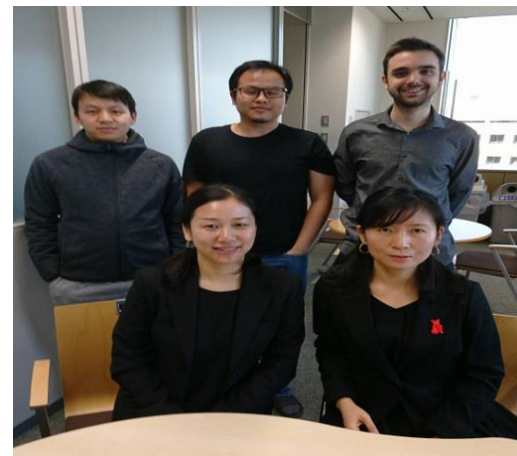
(a) Certificate
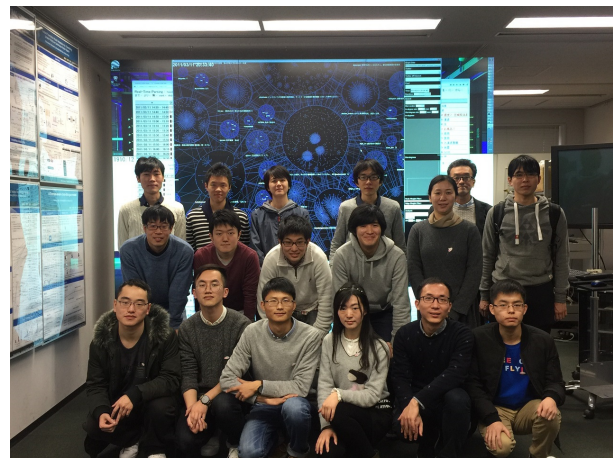
(b) Visiting The University of Tokyo

Fig. 2. Sakura Science Exchange Program

(a) NEC

(b) NII

Fig. 3. Invited Talks

reasoning, multi-event correlation for the video content text description generation. This project will assist government management and decision-making, and improve the service level of smart cities.

IV. RESEARCH ACTIVITIES

The School of Computer and Artificial Intelligence, Wuhan University of Technology, provides hardware and software experimental environment for IDEA lab with 8 Dell and Inspur high-end servers and workstations, and a PC cluster system consisting of 40 high-end PCs and 4 servers. With this support, IDEA lab woks on multi-modal data mining and advanced machine learning.

A. Sakura Science Exchange Program

Japan Science and Technology Agency (JST)invites young, talented people from other countries and regions to Japan through the Sakura Science Exchange Program in a collaboration of industry-academia-government, to introduce and offer experience in Japanese science and technology. Beginning

in 2014, and for a period of 6 years, over 33,000 young people visited Japan on this program. Professor Lin Li has successfully achieved the course of Japan-Asia Youth Exchange program in Science and led the IDEA team to visit The University of Tokyo, 2018, as shown in Figure 2. During the visit, our team members communicated closely with Japanese students in terms of study and life.

B. Invited Talks

IDEA lab was invited by NEC and National Institute of Informatics(NII), Japan to deliver the talk titled "POI recommendation on LBSNs", as shown in Figure 3. This talk presented an insight on the edge research of recommendation system, which drew great interest from both academia and industry.

C. Conference Attending

The members of the laboratory enhanced communication with their peers by participating in national and international conferences, and give oral reports at many conferences with

(a) APWeb-WAIM 2019

(b) BESC 2019

(c) CCF BigData 2019

(d) Oral presentation in ICDCS 2017

Fig. 4. Attending Conferences

topics including big data, social computing, and data mining, as shown in Figure 4.

1) The Asia Pacific Web (APWeb) and Web-Age Information Management (WAIM) Joint Conference on Web and Big Data (APWeb-WAIM 2019)
2) The 6th International Conference on Behavioral, Economic and Socio-Cultural Computing (BESC 2019)
3) The 7th CCF Conference, BigData 2019
4) The 37th IEEE International Conference on Distributed Computing Systems (ICDCS 2017)

D. AI+BigData Competition·and Study

Lab members actively participate in various AI and big data competitions and achieve good results. At the same time, they have in-depth exchanges and discussions with researchers from both academia and industry through related short-course learning, as shown in Figure 5 and Figure 6 .

1) 2017 KDD summer School
2) 2019 National Smart City CUP, China
3) NTCIR-13, Top 1, online test results of OpenLive QA task at NTCIR-13.
4) 2019 China Conference on Knowledge Graph and Semantic Computing (CCKS)

V. LOOKING INTO THE FUTURE

The overall goal of IDEA lab is to develop into a world-class research lab for data engineering and a study community for data analysis talents, leading the research of multi-modal data mining and machine learning. The applications of our studied technologies involve data analysis and mining in multiple fields such as finance, intelligent transportation, medical health, and smart cities. We also welcome research collaborations internationally.
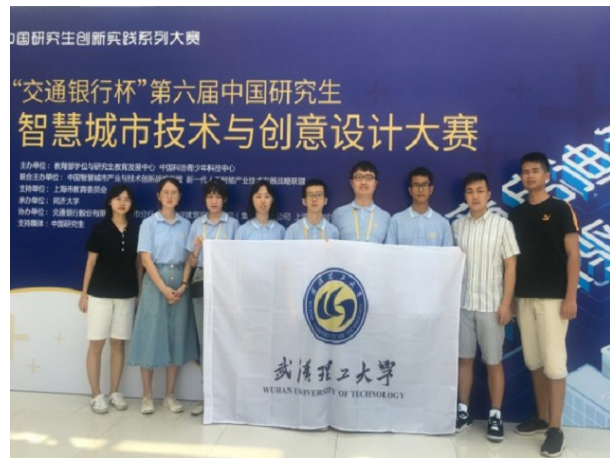
(a) 2017 KDD Summer School   (b) 2019 Smart City CUP

Fig. 5. AI+BigData Competition·and Study-1

(a) NTCIR-13 and CCKS 2019

Fig. 6. AI+BigData Competition·and Study-2

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