Health Card Retrieval for Consumer Health Search

An Empirical Investigation of Methods

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ABSTRACT

This paper investigates methods to rank health cards, a domain-specific type of entity cards, for consumer health search (CHS) queries. A key challenge in this context is which card(s) should be presented to the user. In particular, little evidence exists to determine the effectiveness of retrieval and ranking methods for health cards in CHS. CHS is a challenging domain, where users lack domain expertise and thus are often unable to formulate effective queries, and to interpret the retrieved results. In addition, unlike in other contexts, CHS presents the opportunity to exploit a number of domain specific characteristics and features.

In this paper, we focus on difficult queries with self-diagnosis intents. Our study makes the following contributions: (1) it assembles and releases the first test collection of health cards for research purposes, and (2) it empirically evaluates a large range of entity retrieval methods adapted to health cards retrieval, including features specific to health cards for learning to rank. This is the first study that thoroughly investigates methods to rank health cards.

KEYWORDS

health cards, consumer health search, entity retrieval, learning to rank

ACM Reference Format:
Jimmy[1,2], Guido Zuccon[1], Bevan Koopman[3], Gianluca Demartini[1]. 2019. Health Card Retrieval for Consumer Health Search: An Empirical Investigation of Methods. In *The 28th ACM International Conference on Information and Knowledge Management (CIKM '19), November 3–7, 2019, Beijing, China.* ACM, New York, NY, USA, 4 pages. https://doi.org/10.1145/3357384.3358128

1 INTRODUCTION

An entity card is an information object within a search engine results page (SERP) that encapsulates a variety of information on a particular entity [3, 7, 12, 15, 17]. Entity cards have been used to support user search activities in the context of a user's formulated query [7, 12], as well as in proactive systems where relevant entity cards are shown before any query is submitted [15]. Presenting relevant entity cards is known to increase user engagement with the search results and reduce the number of queries issued, thus improving the overall user experience [7].

In the context of consumer health search (CHS), a health card is a specific type of entity card which presents information about a specific health concept in a coherent and easy to read form [2, 10]. Health cards are beneficial to users in the context of self-diagnosis and health decision making [10]: they reduce the effort and workload required to complete the search task, and help less knowledgeable users to take well informed health decisions.

However, while previous work has considered whether the display of a health card allowed users to make better health decisions, and if so under which conditions. Our own previous research [11] has shown that the display of multiple health cards (up to 4) better supported health search users in specific circumstances, e.g., to make differential diagnosis, when the relevance of a single health card was uncertain [11].

Research on retrieving and ranking entity cards (or even deciding if displaying a card at all) is limited – even more so in the context of health cards and health search. No previous work has directly investigated the retrieval and ranking of health cards. While related to the general problem of retrieving entity cards, health cards and health search present its own challenges. Effective search is hindered by vocabulary mismatch and lack of domain expertise by users. These issues affect both health search in terms of query formulation and result interpretation and health card retrieval and ranking in terms of matching and deciding the utility of the health card (and thus whether to display the card) [5, 6, 18]. This may explain why, for example, commercial web search engines currently limit the display of health cards to queries that explicitly contain the card's title (i.e., the entity name) [2], although health cards have been shown to be valuable also in the presence of less "navigational" and more explorative health queries [10]. For example, health cards are commonly triggered when the query is a condition such as "meningitis"; while they are not displayed when the user queries using observed symptoms (e.g., "headache fever neck stiff light sensitivity"). This is despite the search results do suggest a relationship between the queries with the observed symptoms and the health condition, e.g., 70% of the search results in the first Google SERP for the symptoms query above relate to "meningitis".

In this paper we study the problem of ranking health cards in answer to explorative, self-diagnostic consumer health search queries. These are difficult queries for search engines to answer, as they are often underspecified and ambiguous [6]. They are also difficult for users to formulate and appraise results for. Thus, for these queries, the display of relevant high quality health cards could most benefit users' health information acquisition and decision [10].

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CIKM '19, November 3–7, 2019, Beijing, China
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ACM ISBN 978-1-4503-6976-3/19/11…$15.00
https://doi.org/10.1145/3357384.3358128

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Table 1: Example health scenarios and correct diagnoses.

Topic 5, Diagnosis: Deep vein thrombosis
Scenario (Topic): Your 65-year-old aunt has had leg pain and swelling over the last 5 days. She has had a high blood pressure, mild congestive heart failure, and recent hospitalization for pneumonia. She had been recovering from the pneumonia at home but when beginning to move around and walk, her right leg became painful, tender, and swollen. Her veins in the right leg are enlarged and her right leg is slightly redder than her left. The back of her knee also fells tender.
Topic 10, Diagnosis: Meningitis
Scenario (Topic): Your 18-year-old nephew is experiencing a very bad headache and fever over the last 3 days. He also complaints of light sensitivity and neck stiffness.

On the other hand, these are queries for which identifying the correct health card(s) to display is particularly challenging. Showing multiple cards may appear to be relevant to the user's ambiguous query as multiple possible diagnoses may be relevant to a medical case, until further analysis of evidence does not lead to the iterative exclusion of the least likely, i.e., the process of differential diagnosis. In this context, we make the following contributions:

(1) We assemble and release the first collection of health cards for research purposes. The considered health cards are related to a large set of queries for medical cases used for evaluation, associated ground truth diagnoses, and other possible diagnoses a user may hypothesise on the basis of (real) search results for the queries.
(2) We empirically evaluate four general entity retrieval methods adapted to the problem of ranking health cards, providing the first quantitative evaluation of entity retrieval techniques in this context. In doing so, we consider specialisations of such techniques to the specific settings of health card retrieval.

2 METHOD

2.1 Creation of Topics and Query Variations

We used 45 standardised patient vignettes from a survey of symptoms checkers [8] as basis of our health search topics. These vignettes were compiled from various medical sources such as education material for health professionals and a medical resource website. Each vignette contained age, gender, symptoms, correct diagnosis and correct category of triage urgency for a given condition. Of the 45, we discarded 4 vignettes since there were no health cards in our collection that match their correct diagnosis.

For each vignette, we created a health search task scenario by removing clinical observations which would be not possible for a user to know (e.g., imaging findings, chest auscultations, etc.). We also replaced medical terms with their appropriate layman terms (e.g., "rhinorrhea" was replaced with "runny nose"), to make the scenarios more realistic. Table 1 shows 2 of the 41 scenarios used in this study. Each scenario constituted a topic in our experiment. Each topic has only one relevant health card based on the correct diagnosis for the topic's scenario.

Amazon Mechanical Turk (AMT) workers were recruited to complete HITs based on the 41 topics. In each HIT, we asked workers to use a custom web search engine interface we developed, which mimicked a typical web search engine and allowed users to enter queries and retrieve web pages. Search engine results and snippets were acquired using the Bing Web Search API; only organic results were shown (no advertisement and entity cards). AMT workers were asked to identify the most likely health condition for the given topic and indicate what should the person in the scenario do next (e.g., self-treat, seek attention from a medical professional, etc.).

Table 2: Query variations for topic id 10.

migraine	headache fever light sensitive stiff neck
migraines	light sensitivity neck stiffness headache
migraine symptoms fever	light sensitivity neck stiffness is it the flu
bad headache with fever cause	light sensitivity, headache, stiff neck, fever
headache. fever, neck stiffness	headache fever light sensitivity neck stiffness
headache and fever self treatment	headache fever light sensitivity neck stiffness feber
how often do migraines cause fevers	headache fever light sensitivity neck stiffness fever
headache and fever, light sensitivity	bad headache and fever light sensitivity and neck stiffness

At minimum, workers were asked to submit a query before they could submit their answers. We enforced this by asking workers to mark a search result that they considered as most useful when completing a task. We allowed workers to submit as many queries as required to complete the task.

For each topic, we recruited U.S. based AMT workers; they were paid \$0.2 for completing a HIT (1 HIT = 1 topic), with a bonus of \$0.5 for submitting a correct diagnosis[1]. For quality control, initially, we offered 12 HITs for each of the first 10 topics. Then, we evaluated the worker submissions. Workers who submitted poor results were blocked and their submissions discarded. Finally, we sent invitations to the remaining workers to complete the 31 topics left (10 HITs per topic). In total, we accepted 372 submissions for 41 topics (average of 9.1 submissions per topic). Some topics have less than 10 submissions since poor results were discarded and some HITs were left unfinished. 45.58% of the accepted submissions have the correct diagnosis.

From the 372 submissions, we collected 626 query variations of which 586 were unique, but we removed two queries which failed to retrieve any health cards ("rantidine" and "excema"), thus in total we considered 584 query variations. The average length for unique query variations is 6.78 ± 5.31 words. Table 2 shows query variations for topic 10 (see Table 1).

41 out of 584 query variations had "navigational" intent targeting a specific health condition that is not the correct condition for the topic. While these queries are part of the user attempts to identify the correct diagnosis (e.g., "meningitis"), the correct health cards for these queries (query-based relevance), e.g., "migraine", may not be the one for the correct diagnosis (topic-based relevance), e.g., "meningitis". Thus, we considered two types of relevance judgements: topic-based and query-based. For topic-based, the relevant health card is the one that matches the correct diagnosis for the topic. For query-based, the relevant health card is the one that matches the health concept for the query – query-based relevance judgements were considered only for the 41 navigational queries. The query-based judgement results are available online[2].

2.2 Creation of the Health Cards Collection

To create the health cards collection, we crawled pages within the "Diseases and Conditions" sections from Mayo Clinic[3], as of April 16, 2019. In total, we harvested information for 1,142 health conditions, resulting in as many health cards. Our collection is comparable in size to that of web search engines like Bing[4]. For each condition, we extracted its name (title), aliases, overview, symptoms, and

[1] Paid after the diagnosis was verified against the ground truth.
[2] http://ielab.io/publications/jimmy-2019-healthcardretrieval
[3] https://www.mayoclinic.org/diseases-conditions
[4] To verify this, 377.942 health condition phrases extracted from the UMLS were submitted to Bing: 38.958 phrases retrieved a total of 1.330 health cards.

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treatments. This ensured that each card contained fielded information similar to those health cards that are commonly shown by commercial search engines, e.g., Google health cards.

2.3 Considered Ranking Methods

The health cards catalogue was indexed with respect to the fields title, aliases, overview, symptoms, and treatments. Stop words were removed and Porter stemmer applied.

Then, we considered three common entity ranking models [9, 12, 16]: BM25F, LM with Dirichlet smoothing and Fielded Sequential Dependence Model (FSDM). In addition, we investigated the effectiveness of Learning to rank (LTR). For this, we used LambdaMart, a listwise ranking algorithm as implemented by QuickRank [4]. As features for LTR, we adopted all term-based features for entity ranking listed by Balog [12]. Then, we added health-entity-based features which are akin to the term-based features. However, instead of terms, we used health concepts to represent queries and health cards. For example, for query length for the health entity feature, instead of counting the number of words in a query, we counted the number of health concepts. To obtain health entities, we used QuickUMLS [14] to map terms in queries and health cards to UMLS concept identifiers. Because of the primarily self-diagnosis intent of the considered topics and search queries, we retained only health entities for which the concept identifiers belonged to the following semantic groups: disorders, chemicals & drugs, devices, procedures, and anatomy. Finally, we considered features that specifically exploit the characteristics of health cards:

- Sum of the similarity between health entities in query & field f
- Sum of the similarity between health entities in query & card

These features attempt to measures the similarity between health entities in queries and in cards. We used word2vec clinical concept embeddings [1] to measure the similarity between health entities.

For all methods, we performed parameter tuning using the same 5-fold cross validation split at topic level. For LTR, for each fold we used 80% of the training data for learning and 20% for validation and tuning, with the held out fold used for testing. For BM25F, LM and FSDM, we tuned the field weights between 0 (ignored), 1, and 2 (twice more important). For BM25F, we tuned the field length normalisation b for long fields (overview, symptoms, and treatments), considering the values 0.25, 0.5, and 0.75. We did not tune for title and aliases fields as b has minimum impact on short fields. We did not tune k as the term frequency statistic across health cards are unlikely to significantly vary. For LM and FSDM, we tuned μ for long fields with values 500, 1000, and 1500.

2.4 Measures and Statistical Analysis

We used success at rank 1 (S@1), i.e., how many times the correct health card was retrieved at rank 1, as primary evaluation metric because it is common practice for current commercial search engines to display only one health card for a query. We also considered S@4 to investigate effectiveness when multiple health cards (4 cards) were shown: this was because of recent work showing the display of multiple cards better supported health search users in exploratory tasks like those considered here [11]. In addition, we considered reciprocal rank (RR) to track at which rank position the correct health card was retrieved: this provides a measure of the gap between the current and the expected performance (i.e., RR=1 means the correct card was successfully retrieved at rank 1). Finally, we also computed session-based success measures; i.e., whether the correct health card for the search task was displayed at the targeted ranks at any point throughout a user's search session.

Statistical significant differences were measured using pairwise t-test with Bonferroni correction. These are reported in results tables using lower case superscripts for $\alpha < 0.05$ and upper case for $\alpha < 0.01$.

Table 3: Experiment results for user queries and scenarios. Win, Tie and Loss show the number of queries that performed better, equal, or worse than BM25F.

	User Queries (n=584)			Win/Tie/Loss		
	S@1	S@4	RR	S@1	S@4	RR
$BM25F^a$	$.2252^{bCd}$	$.4426^{BC}$	$.3411^{BC}$	-	-	-
LM^b	$.1798^{aCD}$	$.3493^{ACD}$	$.2774^{ACD}$	22/512/50	36/457/91	164/132/288
$FSDM^c$	$\mathbf{.2928}^{AB}$	$\mathbf{.4991}^{ABD}$	$\mathbf{.4003}^{ABd}$	67/488/29	55/507/22	269/159/156
LTR^d	$.2748^{aB}$	$.4332^{BC}$	$.3610^{Bc}$	69/476/39	51/475/58	189/112/283
	Scenario Query (n=41)			**Win/Tie/Loss**		
	S@1	S@4	RR	S@1	S@4	RR
$BM25F^a$	**.3415**	.4634	**.4362**	-	-	-
LM^b	.2927	.4390	.3909	2/35/4	1/38/2	12/13/16
$FSDM^c$	.2195	**.5122**	.3796	1/34/6	5/33/3	13/11/17
LTR^d	.2195	.3658	.3015	3/30/8	2/33/6	6/6/29

3 EXPERIMENT RESULTS

3.1 Retrieval performance

Table 3 reports the retrieval results obtained by the different methods. Along with the results for user queries, we also report (for completeness) the results obtained when the verbose (layman) scenario was used as the query. While it is not expected users would query with the complete scenario in real situations, we observe that the best methods on the scenarios obtain higher effectiveness than the best methods on the user queries. This is understandable as the user queries generally contain less details than the scenarios, highlighting both the difficulties by users in formulating effective queries and by systems in retrieving the correct cards.

In terms of overall retrieval effectiveness on realistic user queries, methods based on FSDM and LTR are comparable (with FSDM being generally better than LTR); both significantly better than LM, while only FSDM exhibits statistical significant differences with BM25F. This may be because FSDM does explicitly address expressions with sequential words that are commonly seen in the user queries (e.g., "neck stiffness" in Table 2), while BM25F does not.

Table 3 also reports a summary of query-by-query comparison between each method and BM25F (e.g., a *win*: better than BM25F on one query). This shows that while FSDM and LTR achieve a similar number of wins over BM25F for S@1 and S@4 (for user queries), LTR does have more losses.

3.2 Search session based evaluation

Within the search sessions obtained via AMT, users submitted multiple queries when completing a task (Section 2.1). Different search styles were displayed. For example, Table 5 reports a querying session of a user, displaying progressive reformulation of queries as the session goes on. In this example, the user concluded the search task with a clear query and obtained the information which lead them making the correct diagnosis.

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Table 4: Session-based results: success is measured over the whole search session for a single user, rather than for each query separately.

	User Sessions (n=372)		Win/Tie/Loss	
	S@1	S@4	S@1	S@4
$BM25F^a$	$.2997^{bd}$	$.5269^{BC}$	-	-
LM^b	$.2406^{aCD}$	$.4462^{ACd}$	18/313/41	22/297/53
$FSDM^c$	$.3548^{B}$	$\mathbf{.5860}^{ABD}$	49/294/29	34/326/12
LTR^d	$\mathbf{.3683}^{aB}$	$.5134^{bC}$	57/286/29	34/298/40

Table 5: A query session and simulated card retrieval effectiveness for Scenario 38 (correct diagnosis: "canker sore").

	q_1 mouth ulceration	q2 mouth herpes	q3 mouth herpes ulcer	q4 canker sore
S@1	0.0000	0.0000	0.0000	1.0000
S@4	0.0000	0.0000	1.000	1.0000
RR	0.1667	0.1429	0.5000	1.0000

Table 6: Experiment results for user queries using LTR with only basic features (42 Features) vs. LTR with also health specific features (90 features). * and ** indicates statistical significance difference with regard to LTR-basic at $\alpha < 0.05$ and $\alpha < 0.01$ levels.

	User Queries (n=584)			Win/Tie/Loss		
	S@1	S@4	RR	S@1	S@4	RR
$LTR-basic$	.2166	.3947	.3187	-	-	-
LTR	$\mathbf{.2748}^{**}$	$\mathbf{.4332}^{*}$	$\mathbf{.3610}^{**}$	66/488/32	65/478/43	174/116/296

This motivated us to investigate session-based evaluation – i.e., consider the effectiveness of methods over a whole session for each single users. We report session-based evaluation results in Table 4 for S@1,4. These results show that over a session, LTR is better than other methods at retrieving the correct card at rank 1 (although significant differences are found only with respect to LM); if multiple (4) cards were displayed, then FSDM is best.

3.3 Features importance for Learning to Rank

RankEval [13] was used to study the effect different features had on LTR performance; the tool ranks features based on their importance and usage statistics. Figure 1 reports the top ten most important features for each query set based on importance gain. This analysis suggests that for LTR, the features we introduced based on specific health cards characteristics (entity based representation and entity similarities) are amongst the features that contribute most to the LTR effectiveness.

We further investigate the gains obtained in LTR from including health cards specific features as opposed to considering only the generic features for entity retrieval [12](LTR-basic). Table 6 shows that the health card features we introduced in this work provide significant gains in performance, with the LTR using basic features even performing worse than BM25F.

4 CONCLUSION

In this paper, we empirically investigated methods to retrieve health cards in the context of consumer health search with self-diagnosis intents. Queries were often ambiguous and generally difficult, as they often did not contain an explicit mention of the target health card title. As part of this investigation, we assembled the first test collection of health cards containing information for 1,142 health conditions. Furthermore, we collected 373 search session for a total of 626 queries (586 unique) for 41 self-diagnosis search tasks. This data is released to the research community[5].

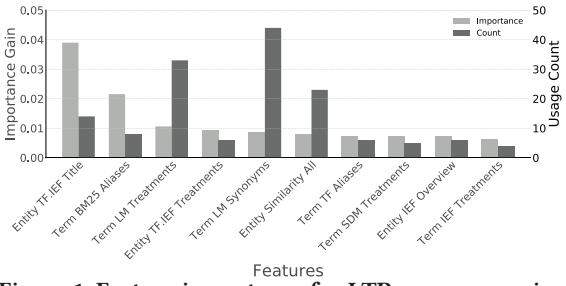

Figure 1: Feature importance for LTR on user queries.

The retrieval methods considered were BM25F, LM, FSDM and LTR. Our results suggest that FSDM and LTR are comparable and performed best across a large set of realistic user queries for the task at hand. For LTR, we introduced features specific to health cards (health entities and health entities similarities), which were found to have a statistically strong impact on the effectiveness of this method.

Acknowledgments: Jimmy is sponsored by the Indonesia Endowment Fund for Education (Lembaga Pengelola Dana Pendidikan / LPDP) (20151022014644). Guido Zuccon is the recipient of an Australian Research Council DECRA Research Fellowship (DE180101579) and a Google Faculty Award; both these grants funded this study.

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Welcome from General Chairs

It is my great honour to welcome you to CIKM 2019, the 28th ACM International Conference on Information and Knowledge Management, will be held in Beijing, China from the 3rd to the 7th of November 2019. Beijing, the capital city of China, is a major historical and cultural centre, as well as China's largest science and technology hub.

CIKM is an annual conference in the computer science research field. Since it was first held in the United States in 1992, 27 conferences have been held in 8 countries around the world. The research areas it primarily focuses on include database management, information retrieval, and knowledge management. It has been evolving into a major conference in these research areas. Our theme this year is “AI for future life”. Since the term “artificial intelligence” was first proposed by John McCarthy in 1955, artificial intelligence has been evolving for more than half a century. It is gaining greater significance in our daily lives, and the importance of scientific research in the area is becoming increasingly prominent.

We are proud to present four distinguished keynote speakers to CIKM 2019 attendees: Steve Maybank, Jiawei Han, Jian Pei and Jianping Shi. We are also honored to have about ten spectacular industry talks in this year’s conference. To allow the participants to better understand the most cutting-edge work in today's research field, we will arrange 9 tutorials, 9 workshops, and 26 demos. World renowned experts from academia and industry have been invited to give keynote speeches to showcase and disseminate the latest research outcome in related research fields.

We are honored to announce that this conference has received 1676 submissions. All these submissions were assigned to qualified reviewers and area chairs for review and acceptance. Reviewers and area chairs were selected by Program Committee Chairs through checking their research fields and publications in recent years to avoid conflict with their work throughout the review process. Finally, 202 long papers, 107 short papers and 37 applied research papers were accepted. The number of long, short and applied research papers account for 21% of the total number of accepted papers. The proceedings of CIKM 2019 will be published by ACM.

We wish to thank the organizers and reviewers who provided their time and effort to facilitate this event, every enthusiastic speaker, every participant come from all over the world to attend the event. We also want to express thankfulness for our awesome organizing committee for their great efforts in supporting the conference. Last but not least, we would also like to thank all the sponsors for their warm support, your generous donation will be apricated. Finally, we wish you all have fruitful connections with the community, we wish CIKM2019 all success.

We look forward to seeing you in Beijing. We wish CIKM2019 will bring memorable experiences to our lives.

Wenwu Zhu
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Welcome from Program Chairs

It is our great pleasure to welcome you to the 28th ACM International C1onference on Information and Knowledge Management (CIKM 2019), held in Beijing, China, from November 3–7, 2019. CIKM is a top-tier ACM conference in the areas of information retrieval, knowledge management and databases. Since 1992, it has successfully brought together leading researchers and developers from the three communities, with the purpose of identifying challenging problems facing the development of advanced knowledge and information systems, and shaping future research directions through the publication of high quality, applied and theoretical research findings.

CIKM 2019 continues to create an outstanding technical program including presentations and posters for long and short research papers, applied research papers and demo papers. In total, we have received 1,031 full paper (10 pages) submissions and 471 short paper (4 pages) submissions reviewed by a group of 90 senior program committee members and 588 program committee members. The research track accepted 202 full papers with acceptance rate as 19.6%. 107 short submissions were accepted as short papers (4 pages) with acceptance rate as 22.7%. In order to promote the application and impact of frontier AI and big data technologies in real industrial scenarios, CIKM 2019 features a new track, named Applied Research Track, to attract submissions from both industry and academia that either solve or advance the understanding of issues related to deploying AI and big data technologies in the real world. We have received 174 submissions this year, and 38 submissions were accepted with acceptance rate as 21.8%. In total, we have received 1,676 paper submissions in research track, which is a record-breaking number.

Besides, CIKM2019 features a broad spectrum of research topics in workshops, tutorials, and demos. We provide 9 co-located workshops, ranging from transportation to bioinformatics, from recommender system to human quality of life. We also provide 6 conventional tutorials covering knowledge graph, social network, database systems etc., and 3 hands-on tutorials in deep learning, recommendation and graph learning. At the same time, there are 26 highly selected demos to demonstrate the power and impact of information technology.

We are grateful to everyone who made this technical program possible. First of all, we would like to thank all the contributing authors who submitted their excellent work. The conference would not exist without your contributions. Second, we would in particular like to recognize the immense efforts of the workshop chairs, tutorial chairs, demo chairs, senior program committee members, program committee members, and external reviewers, who selected the technical program with their great expertise. Finally, we hope to thank all our corporate sponsors for their generous support.

We hope you enjoy the program and the opportunity to interact and collaborate with friends and colleagues from around the world.

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Table of Contents

CIKM '19 Conference Organization xxx1

CIKM '19 Senior Program Committee — Long Track xxx2

CIKM '19 Program Committee Members — Long Track xxx3

CIKM '19 Program Committee Members — Short Track xxx4

CIKM '19 Program Committee Members — Applied Track xxx5

CIKM '19 Program Committee Members — Demo Track xxx6

CIKM '19 Sponsors & Supporters xxx7

Keynote Addressess

- **Autonomous Driving Towards Mass Production** 1
  Jianping Shi *(SenseTime Group Ltd)*
- **The Fisher-Rao Metric in Computer Vision** 3
  Steve Maybank *(Birkbeck College & University of London)*
- **From Unstructured Text to TextCube: Automated Construction and Multidimensional Exploration** 5
  Jiawei Han *(University of Illinois at Urbana-Champaign)*
- **Practicing the Art of Data Science** 7
  Jian Pei *(Simon Fraser University)*

Session: Long - Algorithmic Techniques

- **On VR Spatial Query for Dual Entangled Worlds** 9
  Shao-Heng Ko *(Academia Sinica)*, Ying-Chun Lin *(Purdue University)*,
  Hsu-Chao Lai *(National Chiao Tung University & Academia Sinica)*,
  Wang-Chien Lee *(The Pennsylvania State University)*, De-Nian Yang *(Academia Sinica)*
- **Sketching Streaming Histogram Elements using Multiple Weighted Factors** 19
  Quang-Huy Duong, Heri Ramampiaro, Kjetil Nørvåg *(Norwegian University of Science and Technology)*
- **Improved Compressed String Dictionaries** 29
  Nieves R. Brisaboa, Ana Cerdeira-Pena, Guillermo de Bernardo
  (Universidade da Coruña - Centro de Investigación CITIC),
  Gonzalo Navarro *(University of Chile)*
- **On Transforming Relevance Scales** 39
  Lei Han *(University of Queensland)*, Kevin Roitero *(University of Udine)*,
  Eddy Maddalena *(University of Southampton)*, Stefano Mizzaro *(University of Udine)*,
  Gianluca Demartini *(University of Queensland)*
- **Streamline Density Peak Clustering for Practical Adoptions** 49
  Shuai Yang, Xipeng Shen, Min Chi *(North Carolina State University)*

Session: Long - Analyzing Spatio-Temporal Data

- **Recommendation-based Team Formation for On-demand Taxi-calling Platforms** 59
  Lingyu Zhang *(Didi Chuxing)*, Tianshu Song, Yongxin Tong *(Beihang University)*,
  Zimu Zhou *(ETH Zurich)*, Dan Li *(Didi Chuxing)*, Wei Ai *(University of Michigan)*,
  Lulu Zhang, Guobin Wu *(Didi Chuxing)*, Yan Liu *(University of Southern California)*, Jieping Ye *(Didi Chuxing)*
- **DeepIST: Deep Image-based Spatio-Temporal Network for Travel Time Estimation** 69
  Tao-yang Fu, Wang-chien Lee *(The Pennsylvania State University)*

- **Personalized Route Description Based On Historical Trajectories** 79
  Han Su, GuangLin Cong, Wei Chen *(University of Electronic Science and Technology of China Chengdu, China)*,
  Bolong Zheng *(Huazhong University of Science and Technology)*,
  Kai Zheng *(University of Electronic Science and Technology of China Chengdu, China)*
- **Geolocating Tweets in any Language at any Location** 89
  Mike Izbicki *(Claremont McKenna College)*,
  Vagelis Papalexakis, Vassilis Tsotras *(University of California, Riverside)*
- **SeiSMo: Semi-supervised Time Series Motif Discovery for Seismic Signal Detection** 99
  M Ashraf Siddiquee, Zeinab Akhavan, Abdullah Mueen *(University of New Mexico)*

Session: Long - Biomedical Informatics

- **UA-CRNN: Uncertainty-Aware Convolutional Recurrent Neural Network for Mortality Risk Prediction** 109
  Qingxiong Tan *(Hong Kong Baptist University)*, Andy Jinhua Ma *(Sun Yat-Sen University)*,
  Mang Ye, Baoyao Yang *(Hong Kong Baptist University)*,
  Huiqi Deng *(Hong Kong Baptist University & Sun Yat-Sen University)*,
  Vincent Wai-Sun Wong, Yee-Kit Tse, Terry Cheuk-Fung Yip, Grace Lai-Hung Wong,
  Jessica Yuet-Ling Ching, Francis Ka-Leung Chan *(The Chinese University of Hong Kong)*,
  Pong C. Yuen *(Hong Kong Baptist University)*
- **Learning More with Less: Conditional PGGAN-based Data Augmentation for Brain Metastases Detection Using Highly-Rough Annotation on MR Images** 119
  Changhee Han *(National Institute of Informatics, National Center for Global Health and Medicine, & University of Cambridge)*, Kohei Murao *(National Institute of Informatics & National Center for Global Health and Medicine)*,
  Tomoyuki Noguchi, Yusuke Kawata, Fumiya Uchiyama *(National Center for Global Health and Medicine)*,
  Leonardo Rundo *(University of Cambridge)*, Hideki Nakayama *(The University of Tokyo)*,
  Shin'ichi Satoh *(National Institute of Informatics & The University of Tokyo)*
- **Domain Knowledge Guided Deep Atrial Fibrillation Classification and Its Visual Interpretation** 129
  Xiaoyu Li, Buyue Qian *(Xi'an Jiaotong University)*, Jishang Wei *(HP Lab)*,
  Xianli Zhang, Sirui Chen, Qinghua Zheng *(Xi'an Jiaotong University)*
- **Question Difficulty Prediction for Multiple Choice Problems in Medical Exams** 139
  Zhaopeng Qiu, Xian Wu, Wei Fan *(Tencent Medical AI Lab)*
- **GRAPHENE: A Precise Biomedical Literature Retrieval Engine with Graph Augmented Deep Learning and External Knowledge Empowerment** 149
  Sendong Zhao, Chang Su, Andrea Sboner, Fei Wang *(Cornell University)*

Session: Long - Computer Vision

- **Video-level Multi-model Fusion for Action Recognition** 159
  Xiaomin Wang, Junsan Zhang, Leiquan Wang *(China University of Petroleum (EastChina))*,
  Philip S. Yu *(University of Illinois at Chicago)*, Jie Zhu *(The National Police University for Criminal Justice)*,
  Haisheng Li *(Beijing Technology and Business University)*
- **Large Scale Landmark Recognition via Deep Metric Learning** 169
  Andrei Boiarov, Eduard Tyantov *(Mail.ru Group)*
- **Multi-stage Deep Classifier Cascades for Open World Recognition** 179
  Xiaojie Guo, Amir Alipour-Fanid *(George Mason University)*, Lingfei Wu *(IBM Research AI)*,
  Hemant Purohit, Xiang Chen, Kai Zeng, Liang Zhao *(George Mason University)*
- **Inferring Context from Pixels for Multimodal Image Classification** 189
  Manan Shah *(Stanford University & Google Research)*,
  Krishnamurthy Viswanathan, Chun-Ta Lu, Ariel Fuxman, Zhen Li *(Google Research)*,
  Aleksei Timofeev *(Waymo)*, Chao Jia, Chen Sun *(Google Research)*
- **Multi-Target Multi-Camera Tracking with Human Body Part Semantic Features** 199
  Mingkun Wang *(National University of Defense Technology)*,
  Dianxi Shi, Naiyang Guan, Wei Yi *(National Innovation Institute of Defense Technology & Tianjin Artificial Intelligence Innovation Center)*, Tao Zhang *(University of Illinois at Chicago)*,
  Zunlin Fan *(National Innovation Institute of Defense Technology & Tianjin Artificial Intelligence Innovation Center)*,

Session: Long - Database and System

- **Efficient Join Processing Over Incomplete Data Streams** 209
  Weilong Ren, Xiang Lian *(Kent State University)*,
  Kambiz Ghazinour *(State University of New York & Kent State University)*

- **Inclusion Dependency Discovery: An Experimental Evaluation of Thirteen Algorithms** 219
  Falco Dürsch, Axel Stebner, Fabian Windheuser, Maxi Fischer, Tim Friedrich,
  Nils Strelow, Tobias Bleifuß, Hazar Harmouch, Lan Jiang, Thorsten Papenbrock,
  Felix Naumann *(Hasso Plattner Institute)*

- **Constructing a Comprehensive Events Database from the Web** 229
  Qifan Wang, Bhargav Kanagal, Vijay Garg, D. Sivakumar *(Google Research)*

- **Deploying Hash Tables on Die-Stacked High Bandwidth Memory** 239
  Xuntao Cheng *(Alibaba Group)*, Bingsheng He *(National University of Singapore)*,
  Eric Lo *(The Chinese University of Hong Kong)*,
  Wei Wang, Shengliang Lu, Xinyu Chen *(National University of Singapore)*

Session: Long - Domain Adaptation and Transfer Learning

- **Partially Shared Adversarial Learning For Semi-supervised Multi-platform User Identity Linkage** 249
  Chaozhuo Li *(Beihang University)*, Senzhang Wang *(Nanjing University of Aeronautics and Astronautics)*,
  Hao Wang *(Southwest Jiaotong University)*, Yanbo Liang *(Facebook)*,
  Philip S. Yu *(University of Illinois at Chicago)*, Zhoujun Li *(Beihang University)*,
  Wei Wang *(Ping An Bank Co., Ltd.)*

- **Adversarial Domain Adaptation with Semantic Consistency for Cross-Domain Image Classification** 259
  Manliang Cao, Xiangdong Zhou, Yiming Xu, Yue Pang, Bo Yao *(Fudan University)*

- **ATL: Autonomous Knowledge Transfer from Many Streaming Processes** 269
  Mahardhika Pratama, Marcus de Carvalho, Renchunzi Xie *(Nanyang Technological University)*,
  Edwin Lughofer *(Johannes Kepler University)*, Jie Lu *(University of Technology Sydney)*

- **Knowledge Transfer based on Multiple Manifolds Assumption** 279
  Pengfei Wei *(National University of Singapore)*, Yiping Ke *(Nanyang Technological University)*

- **Cross-domain Aspect Category Transfer and Detection via Traceable Heterogeneous Graph Representation Learning** 289
  Zhuoren Jiang *(Sun Yat-sen University)*, Jian Wang, Lujun Zhao, Changlong Sun *(Alibaba Group)*,
  Yao Lu *(Sun Yat-sen University)*, Xiaozhong Liu *(Indiana University Bloomington)*

Session: Long - E-Commerce and Advertising I

- **A Deep Neural Framework for Sales Forecasting in E-Commerce** 299
  Yan Qi, Chenliang Li *(Wuhan University)*, Han Deng, Min Cai, Yunwei Qi, Yuming Deng *(Alibaba Group)*

- **An Active and Deep Semantic Matching Framework for Query Rewrite in E-Commercial Search Engine** 309
  Yatao Yang *(Sun Yat-sen University)*, Jun Tan, Hongbo Deng *(Alibaba Group)*,
  Zibin Zheng, Yutong Lu *(Sun Yat-sen University)*, Xiangke Liao *(National University of Defense Technology)*

- **AIBox: CTR Prediction Model Training on a Single Node** 319
  Weijie Zhao, Jingyuan Zhang *(Baidu Research USA)*, Deping Xie, Yulei Qian, Ronglai Jia *(Baidu Inc.)*,
  Ping Li *(Baidu Research USA)*

- **Improving Ad Click Prediction by Considering Non-displayed Events** 329
  Bowen Yuan, Jui-Yang Hsia *(National Taiwan University)*, Meng-Yuan Yang *(ETH Zurich)*,
  Hong Zhu, Chih-Yao Chang, Zhenhua Dong *(Huawei Noah's ark lab)*, Chih-Jen Lin *(National Taiwan University)*

- **Approximation Algorithms for Coordinating Ad Campaigns on Social Networks** 339
  Kartik Lakhotia, David Kempe *(University of Southern California)*

Session: Long - E-Commerce and Advertising II

- **Regularized Adversarial Sampling and Deep Time-aware Attention for Click-Through Rate Prediction** 349
  Yikai Wang *(Tsinghua University)*, Liang Zhang *(JD.COM)*,
  Quanyu Dai *(The Hong Kong Polytechnic University)*, Fuchun Sun *(Tsinghua University)*,
  Bo Zhang, Yang He, Weipeng Yan, Yongjun Bao *(JD.COM)*
- **Conversational Product Search Based on Negative Feedback** 359
  Keping Bi, Qingyao Ai *(University of Massachusetts, Amherst)*, Yongfeng Zhang *(Rutgers University)*,
  W. Bruce Croft *(University of Massachusetts, Amherst)*
- **Learning to Ask: Question-based Sequential Bayesian Product Search** 369
  Jie Zou, Evangelos Kanoulas *(University of Amsterdam)*,
- **A Zero Attention Model for Personalized Product Search** 379
  Qingyao Ai *(University of Utah)*, Daniel N. Hill, S. V. N. Vishwanathan *(Amazon Search)*,
  W. Bruce Croft *(University of Massachusetts, Amherst)*
- **Learning to Generate Personalized Product Descriptions** 389
  Guy Elad *(Technion)*, Ido Guy, Slava Novgorodov *(eBay Research)*, Benny Kimelfeld, Kira Radinsky *(Technion)*

Session: Long - Network Embedding I

- **Fast and Accurate Network Embeddings via Very Sparse Random Projection** 399
  Haochen Chen, Syed Fahad Sultan, Yingtao Tian *(Stony Brook University)*,
  Muhao Chen *(University of California, Los Angeles)*, Steven Skiena *(Stony Brook University)*
- **Hierarchical Community Structure Preserving Network Embedding: A Subspace Approach** 409
  Qingqing Long, Yiming Wang *(Peking University)*, Lun Du *(Microsoft Research & Peking University)*,
  Guojie Song, Yilun Jin *(Peking University)*, Wei Lin *(Alibaba Group)*,
- **Collective Link Prediction Oriented Network Embedding with Hierarchical Graph Attention** 419
  Yizhu Jiao, Yun Xiong *(Fudan University)*, Jiawei Zhang *(Florida State University)*,
  Yangyong Zhu *(Fudan University)*
- **Discerning Edge Influence for Network Embedding** 429
  Yaojing Wang, Yuan Yao *(Nanjing University)*,
  Hanghang Tong *(University of Illinois at Urbana-Champaign & Arizona State University)*,
  Feng Xu, Jian Lu *(Nanjing University)*
- **Constrained Co-embedding Model for User Profiling in Question Answering Communities** 439
  Yupeng Luo, Shangsong Liang *(Sun Yat-sen University)*, Zaiqiao Meng *(University of Glasgow)*,

Session: Long - Network Embedding II

- **Hyper-Path-Based Representation Learning for Hyper-Networks** 449
  Jie Huang *(Sun Yat-sen University)*, Xin Liu, Yangqiu Song *(The Hong Kong University of Science and Technology)*
- **Multi-Hot Compact Network Embedding** 459
  Chaozhuo Li *(Beihang University)*, Lei Zheng *(University of Illinois at Chicago)*,
  Senzhang Wang *(Nanjing University of Aeronautics and Astronautics)*, Feiran Huang *(Jinan University)*,
  Philip S. Yu *(University of Illinois at Chicago)*, Zhoujun Li *(Beihang University)*
- **Temporal Network Embedding with Micro- and Macro-dynamics** 469
  Yuanfu Lu, Xiao Wang, Chuan Shi *(Beijing University of Posts and Communications)*,
  Philip S. Yu *(University of Illinois at Chicago)*, Yanfang Ye *(Case Western Reserve University)*,
- **MrMine: Multi-resolution Multi-network Embedding** 479
  Boxin Du, Hanghang Tong *(University of Illinois at Urbana-Champaign)*
- **Task-Guided Pair Embedding in Heterogeneous Network** 489
  Chanyoung Park *(University of Illinois at Urbana-Champaign)*, Donghyun Kim *(Yahoo Research)*,
  Qi Zhu, Jiawei Han *(University of Illinois at Urbana-Champaign)*,
  Hwanjo Yu *(Pohang University of Science and Technology)*

Session: Long - Graph Nerual Network I

- **Graph Convolutional Networks with Motif-based Attention** 499
  John Boaz Lee *(Worcester Polytechnic Institute)*, Ryan A. Rossi *(Adobe Research)*,
  Xiangnan Kong *(Worcester Polytechnic Institute)*, Sungchul Kim, Eunyee Koh, Anup Rao *(Adobe Research)*

- **Long-tail Hashtag Recommendation for Micro-videos with Graph Convolutional Network** 509
  Mengmeng Li, Tian Gan, Meng Liu *(Shandong University)*,
  Zhiyong Cheng *(Qilu University of Technology (Shandong Academy of Sciences))*,
  Jianhua Yin, Liqiang Nie *(Shandong University)*

- **Hashing Graph Convolution for Node Classification** 519
  Wenting Zhao, Zhen Cui, Chunyan Xu, Chengzheng Li, Tong Zhang, Jian Yang *(Jiangsu Key Lab of Image and Video Understanding for Social Security & Nanjing University of Science and Technology)*

- **Relation-Aware Graph Convolutional Networks for Agent-Initiated Social E-Commerce Recommendation** 529
  Fengli Xu *(Tsinghua University)*, Jianxun Lian *(Miscrosoft Research Asia)*,
  Zhenyu Han, Yong Li *(Tsinghua University)*, Yujian Xu *(Beibei Group)*, Xing Xie *(Microsoft Research Asia)*

- **Fi-GNN: Modeling Feature Interactions via Graph Neural Networks for CTR Prediction** 539
  Zekun Li, Zeyu Cui, Shu Wu *(Institute of Information Engineering, Chinese Academy of Sciences & University of Chinese Academy of Sciences)*,
  Xiaoyu Zhang *(Institute of Information Engineering, Chinese Academy of Sciences)*,
  Liang Wang *(Institute of Information Engineering, Chinese Academy of Sciences & University of Chinese Academy of Sciences)*

Session: Long - Graph Nerual Network II

- **Key Player Identification in Underground Forums over Attributed Heterogeneous Information Network Embedding Framework** 549
  Yiming Zhang, Yujie Fan, Yanfang Ye *(Case Western Reserve University)*,
  Liang Zhao *(George Mason University)*, Chuan Shi *(Beijing University of Posts and Telecommunications)*

- **Learning to Identify High Betweenness Centrality Nodes from Scratch: A Novel Graph Neural Network Approach** 559
  Changjun Fan *(National University of Defense Technology & University of California, Los Angeles)*,
  Li Zeng *(National University of Defense Technology)*, Yuhui Ding *(Tsinghua University)*,
  Muhao Chen *(University of California, Los Angeles & University of Pennsylvania)*,
  Yizhou Sun *(University of California, Los Angeles)*, Zhong Liu *(National University of Defense Technology)*

- **Multiple Rumor Source Detection with Graph Convolutional Networks** 569
  Ming Dong, Bolong Zheng *(Huazhong University of Science and Technology)*,
  Nguyen Quoc Viet Hung *(Griffith University)*,
  Han Su *(University of Electronic Science and Technology of China)*,
  Guohui Li *(Huazhong University of Science and Technology)*

- **Rethinking the Item Order in Session-based Recommendation with Graph Neural Networks** 579
  Ruihong Qiu *(The University of Queensland)*, Jingjing Li *(University of Electronic Science and Technology of China)*,
  Zi Huang, Hongzhi YIn *(The University of Queensland)*

- **Gravity-Inspired Graph Autoencoders for Directed Link Prediction** 589
  Guillaume Salha *(Deezer Research & Development & École Polytechnique)*, Stratis Limnios *(École Polytechnique)*,
  Romain Hennequin, Viet-Anh Tran *(Deezer Research & Development)*, Michalis Vazirgiannis *(École Polytechnique)*

Session: Long - Heterogeneous Data

- **Discovering Hypernymy in Text-Rich Heterogeneous Information Network by Exploiting Context Granularity** 599
  Yu Shi, Jiaming Shen, Yuchen Li, Naijing Zhang, Xinwei He, Zhengzhi Lou,
  Qi Zhu *(University of Illinois Urbana-Champaign)*, Matthew Walker *(LinkedIn Corporation)*,
  Myunghwan Kim *(Mesh Korea)*, Jiawei Han *(University of Illinois Urbana-Champaign)*

- **αCyber: Enhancing Robustness of Android Malware Detection System against Adversarial Attacks on Heterogeneous Graph based Model** 609
  Shifu Hou, Yujie Fan, Yiming Zhang, Yanfang Ye *(Case Western Reserve University)*,
  Jingwei Lei, Wenqiang Wan, Jiabin Wang, Qi Xiong, Fudong Shao *(Tencent Security Lab)*
- **BHIN2vec: Balancing the Type of Relation in Heterogeneous Information Network** 619
  Seonghyeon Lee *(Pohang University of Science and Technology)*,
  Chanyoung Park *(University of Illinois at Urbana-Champaign)*,
  Hwanjo Yu *(Pohang University of Science and Technology)*
- **Deep Sequence-to-Sequence Entity Matching for Heterogeneous Entity Resolution** 629
  Hao Nie *(Institute of Software, Chinese Academy of Sciences & University of Chinese Academy of Sciences)*,
  Xianpei Han *(Institute of Software, Chinese Academy of Sciences)*,
  Ben He *(Institute of Software, Chinese Academy of Sciences & University of Chinese Academy of Sciences)*,
  Le Sun, Bo Chen *(Institute of Software, Chinese Academy of Sciences)*,
  Wei Zhang, Suhui Wu, Hao Kong *(Alibaba Group)*
- **HeteSpaceyWalk: A Heterogeneous Spacey Random Walk for Heterogeneous Information Network Embedding** 639
  Yu He *(Beijing Advanced Innovation Center for Big Data and Brain Computing & Beihang University)*,
  Yangqiu Song *(Hong Kong University of Science and Technology)*,
  Jianxin Li, Cheng Ji *(Beijing Advanced Innovation Center for Big Data and Brain Computing & Beihang University)*,
  Jian Peng *(University of Illinois at Urbana-Champaign)*,
  Hao Peng *(Beijing Advanced Innovation Center for Big Data and Brain Computing & Beihang University)*

Session: Long - Knowledge Graph I

- **EHR Coding with Multi-scale Feature Attention and Structured Knowledge Graph Propagation** 649
  Xiancheng Xie, Yun Xiong *(Fudan University)*, Philip S. Yu *(University of Illinois at Chicago)*,
  Yangyong Zhu *(Fudan University)*
- **A Fine-grained and Noise-aware Method for Neural Relation Extraction** 659
  Jianfeng Qu *(Jilin University)*, Wen Hua *(University of Queensland)*,
  Dantong Ouyang *(Jilin University)*, Xiaofang Zhou *(University of Queensland)*, Ximing Li *(Jilin University)*
- **Learning Region Similarity over Spatial Knowledge Graphs with Hierarchical Types and Semantic Relations** 669
  Xiongnan Jin, Byungkook Oh, Sanghak Lee, Dongho Lee, Kyong-Ho Lee *(Yonsei University)*,
  Liang Chen *(Sun Yat-sen University)*
- **Bayes EMbedding (BEM): Refining Representation by Integrating Knowledge Graphs and Behavior-specific Networks** 679
  Yuting Ye *(University of California, Berkeley)*, Xuwu Wang *(Fudan University)*,
  Jiangchao Yao, Kunyang Jia, Jingren Zhou *(Alibaba Group)*, Yanghua Xiao *(Fudan University)*,
  Hongxia Yang *(Alibaba Group)*
- **A Benchmark for Fact Checking Algorithms Built on Knowledge Bases** 689
  Viet-Phi Huynh, Paolo Papotti *(EURECOM)*

Session: Long - Knowledge Graph II

- **Online Schemaless Querying of Heterogeneous Open Knowledge Bases** 699
  Nikita Bhutani, H V Jagadish *(University of Michigan)*
- **Enhancing Conversational Dialogue Models with Grounded Knowledge** 709
  Wen Zheng *(University of Nottingham)*, Ke Zhou *(University of Nottingham & Nokia Bell Labs)*
- **MedTruth: A Semi-supervised Approach to Discovering Knowledge Condition Information from Multi-Source Medical Data** 719
  Yang Deng *(Peking University, Peng Cheng Laboratory, & The Chinese University of Hong Kong)*,
  Yaliang Li *(Alibaba Group)*, Ying Shen *(Peking University Shenzhen Graduate School)*,
  Nan Du, Wei Fan *(Tencent Medical AI Lab)*, Min Yang *(Chinese Academy of Sciences)*,
  Kai Lei *(Peking University & Peng Cheng Laboratory)*

- **Look before you Hop: Conversational Question Answering over Knowledge Graphs Using Judicious Context Expansion** ... 729
  Philipp Christmann, Rishiraj Saha Roy, Abdalghani Abujabal, Jyotsna Singh, Gerhard Weikum *(MPI for Informatics)*
- **Learning to Answer Complex Questions over Knowledge Bases with Query Composition** ... 739
  Nikita Bhutani, Xinyi Zheng, H V Jagadish *(University of Michigan)*

Session: Long - Machine Learning Themes I

- **Auto-completion for Data Cells in Relational Tables** ... 761
  Shuo Zhang, Krisztian Balog *(University of Stavanger)*
- **Author Set Identification via Quasi-Clique Discovery** ... 771
  Yuyan Zheng, Chuan Shi *(Beijing University of Posts and Telecommunications)*, Xiangnan Kong *(Worcester Polytechnic Institute)*, Yanfang Ye *(Case Western Reserve University)*
- **AdaFair: Cumulative Fairness Adaptive Boosting** ... 781
  Vasileios Iosifidis, Eirini Ntoutsi *(L3S Research Center, Leibniz University of Hannover)*
- **New Online Kernel Ridge Regression via Incremental Predictive Sampling** ... 791
  Shan Xu, Xiao Zhang, Shizhong Liao *(Tianjin University)*
- **Online Kernel Selection via Tensor Sketching** ... 801
  Shizhong Liao, Xiao Zhang *(Tianjin University)*

Session: Long - Machine Learning Themes II

- **One-Class Active Learning for Outlier Detection with Multiple Subspaces** ... 811
  Holger Trittenbach, Klemens Böhm *(Karlsruhe Institute of Technology (KIT))*
- **AutoGRD: Model Recommendation Through Graphical Dataset Representation** ... 821
  Noy Cohen-Shapira, Lior Rokach, Bracha Shapira, Gilad Katz, Roman Vainshtein *(Ben Gurion University of the Negev)*
- **Batch Mode Active Learning for Semantic Segmentation Based on Multi-Clue Sample Selection** ... 831
  Yao Tan, Liu Yang, Qinghua Hu *(Tianjin University)*, Zhibin Du *(China Automotive Technology & Research Center)*
- **CRUX: Adaptive Querying for Efficient Crowdsourced Data Extraction** ... 841
  Theodoros Rekatsinas *(University of Wisconsin - Madison)*, Amol Deshpande *(University of Maryland)*, Aditya Parameswaran *(University of California-Berkeley)*
- **Deep Forest with LRRS Feature for Fine-grained Website Fingerprinting with Encrypted SSL/TLS** ... 851
  Ziqing Zhang, Cuicui Kang, Gang Xiong, Zhen Li *(Institute of Information Engineering, Chinese Academy of Sciences & University of Chinese Academy of Sciences)*

Session: Long - Machine Learning Themes III

- **N2N: Network Derivative Mining** ... 861
  Jian Kang, Hanghang Tong *(University of Illinois at Urbana-Champaign)*
- **MoBoost: A Self-improvement Framework for Linear-based Hashing** ... 871
  Xingbo Liu *(Shandong University)*, Xiushan Nie, Xiaoming Xi *(Shandong Jianzhu University)*, Lei Zhu *(Shandong Normal University)*, Yilong Yin *(Shandong University)*
- **Loopless Semi-Stochastic Gradient Descent with Less Hard Thresholding for Sparse Learning** ... 881
  Xiangyang Liu, Bingkun Wei, Fanhua Shang, Hongying Liu *(Xidian University)*
- **EPA: Exoneration and Prominence based Age for Infection Source Identification** ... 891
  Syed Shafat Ali *(Jamia Millia Islamia)*, Tarique Anwar *(Indian Institute of Technology Ropar)*, Ajay Rastogi, Syed Afzal Murtaza Rizvi *(Jamia Millia Islamia)*

Session: Long - Mining in Emerging Applications I

- **Generating Persuasive Visual Storylines for Promotional Videos** 901
  Chang Liu, Yi Dong, Han Yu, Zhiqi Shen *(Nanyang Technological University)*,
  Zhanning Gao, Pan Wang, Changgong Zhang, Peiran Ren, Xuansong Xie *(Alibaba Group)*,
  Lizhen Cui *(Shandong University)*, Chunyan Miao *(Nanyang Technological University)*
- **Clustering Recurrent and Semantically Cohesive Program Statements in Introductory Programming Assignments** 911
  Victor J. Marin, Carlos R. Rivero *(Rochester Institute of Technology)*
- ***Going Beyond Content Richness:* Verified Information Aware Summarization of Crisis-Related Microblogs** 921
  Ashish Sharma *(University of Washington)*, Koustav Rudra *(Leibniz Universität Hannover)*,
  Niloy Ganguly *(Indian Institute of Technology Kharagpur)*
- **Declarative User Selection with Soft Constraints** 931
  Yael Amsterdamer *(Bar-Ilan University)*, Tova Milo, Amit Somech, Brit Youngmann *(Tel Aviv University)*
- **#suicidal - A Multipronged Approach to Identify and Explore Suicidal Ideation in Twitter** ... 941
  Pradyumna Prakhar Sinha, Rohan Mishra *(Delhi Technological University)*,
  Ramit Sawhney *(Netaji Subhash Insitute of Technology)*, Debanjan Mahata *(Bloomberg & IIIT-Delhi)*,
  Rajiv Ratn Shah *(IIIT-Delhi)*, Huan Liu *(Arizona State University)*

Session: Long - Mining in Emerging Applications II

- **MusicBot: Evaluating Critiquing-Based Music Recommenders with Conversational Interaction** 951
  Yucheng Jin *(Lenovo Research)*, Wanling Cai *(Hong Kong Baptist University)*,
  Li Chen *(Hong Kong Baptist University)*, Nyi Nyi Htun, Katrien Verbert *(KU Leuven)*
- **Discovering Polarized Communities in Signed Networks** 961
  Francesco Bonchi *(ISI Foundation & Eurecat)*, Edoardo Galimberti *(University of Turin & ISI Foundation)*,
  Aristides Gionis, Bruno Ordozgoiti *(Aalto University)*, Giancarlo Ruffo *(University of Turin)*
- **Model-based Constrained MDP for Budget Allocation in Sequential Incentive Marketing** 971
  Shuai Xiao, Le Guo, Zaifan Jiang, Lei Lv, Yuanbo Chen, Jun Zhu, Shuang Yang *(Ant Financial Services Group)*
- **Wide-Ranging Review Manipulation Attacks& Model, Empirical Study, and Countermeasures** 981
  Parisa Kaghazgaran, Majid Alfifi, James Caverlee *(Texas A&M University)*
- **Augment to Prevent: Short-Text Data Augmentation in Deep Learning for Hate-Speech Classification** 991
  Georgios Rizos, Konstantin Hemker *(Imperial College London)*,
  Björn Schuller *(Imperial College London & University of Augsburg)*

Session: Long - Natural Language Processing I

- **Nested Relation Extraction with Iterative Neural Network** 1001
  Yixuan Cao, Dian Chen, Hongwei Li, Ping Luo *(Institute of Computing Technology, Chinese Academy of Sciences & University of Chinese Academy of Sciences)*
- **Learning Chinese Word Embeddings from Stroke, Structure and Pinyin of Characters** 1011
  Yun Zhang, Yongguo Liu, Jiajing Zhu, Ziqiang Zheng *(University of Electronic Science and Technology of China)*,
  Xiaofeng Liu, Weiguang Wang, Zijie Chen, Shuangqing Zhai *(Beijing University of Chinese Medicine)*
- **Sentiment Commonsense Induced Sequential Neural Networks for Sentiment Classification** 1021
  Chen Shiyun, Lin Xin *(East China Normal University)*, Xiao Yanghua *(Fudan University)*,
  He Liang *(East China Normal University)*
- **Interactive Multi-Grained Joint Model for Targeted Sentiment Analysis** 1031
  Da Yin, Xiao Liu, Xiaojun Wan *(Peking University)*
- **Beyond word2vec: Distance-graph Tensor Factorization for Word and Document Embeddings** 1041
  Suhang Wang *(The Pennsylvania State University)*, Charu Aggarwal *(IBM T.J. Watson Research Center)*,
  Huan Liu *(Arizona State University)*

Session: Long - Natural Language Processing II

- **Hierarchical Multi-label Text Classification: An Attention-based Recurrent Network Approach** 1051
  Wei Huang, Enhong Chen, Qi Liu *(University of Science and Technology of China)*,
  Yuying Chen *(University of Science and Technology of China & Ant Financial Services Group)*,
  Zai Huang, Yang Liu *(University of Science and Technology of China)*, Zhou Zhao *(Zhejiang University)*,
  Dan Zhang *(iFLYTEK Research)*, Shijin Wang *(iFLYTEK Research)*
- **A Semantics Aware Random Forest for Text Classification** 1061
  Md Zahidul Islam, Jixue Liu, Jiuyong Li, Lin Liu *(University of South Australia)*, Wei Kang *(Data61, CSIRO)*
- **Federated Topic Modeling** 1071
  Di Jiang, Yuanfeng Song *(WeBank Co., Ltd)*, Yongxin Tong *(Beihang University)*,
  Xueyang Wu *(The Hong Kong University of Science and Technology)*,
  Weiwei Zhao, Qian Xu, Qiang Yang *(WeBank Co., Ltd)*
- **Multi-Turn Response Selection in Retrieval-Based Chatbots with Iterated Attentive Convolution Matching Network** 1081
  Heyuan Wang, Ziyi Wu, Junyu Chen *(Peking University)*
- **Sentiment Lexicon Enhanced Neural Sentiment Classification** 1091
  Chuhan Wu *(Tsinghua University)*, Fangzhao Wu *(Microsoft Research Asia)*,
  Junxin Liu, Yongfeng Huang *(Tsinghua University)*, Xing Xie *(Microsoft Research Asia)*

Session: Long - Deep Nerual Network I

- **ResumeGAN: An Optimized Deep Representation Learning Framework for Talent-Job Fit via Adversarial Learning** 1101
  Yong Luo, Huaizheng Zhang, Yonggang Wen *(Nanyang Technological University)*, Xinwen Zhang *(Hiretual)*
- **Regularizing Deep Neural Networks by Ensemble-based Low-Level Sample-Variances Method** 1111
  Shuai Yao, Yuexian Hou, Liangzhu Ge, Zeting Hu *(Tianjin University)*
- **Attention-Residual Network with CNN for Rumor Detection** 1121
  Yixuan Chen, Jie Sui, Liang Hu, Wei Gong *(University of Chinese Academy of Sciences)*
- **Imbalance Rectification in Deep Logistic Regression for Multi-Label Image Classification Using Random Noise Samples** 1131
  Wenjin Yan, Ruixuan Li *(Huazhong University of Science and Technology)*,
  Jun Wang *(Fujitsu Laboratories of America)*,
  Yuhua Li, Jinyang Wang, Pan Zhou, Xiwu Gu *(Huazhong University of Science and Technology)*
- **CamDrop: A New Explanation of Dropout and A Guided Regularization Method for Deep Neural Networks** 1141
  Hongjun Wang, Guangrun Wang, Guanbin Li, Liang Lin *(Sun Yat-sen University)*

Session: Long - Deep Nerual Network II

- **Dynamic Collaborative Recurrent Learning** 1151
  Teng Xiao *(Sun Yat-sen University Sun Yat-sen University & Guangdong Key Laboratory of Big Data Analysis and Processing)*, Shangsong Liang *(Sun Yat-sen University & Guangdong Key Laboratory of Big Data Analysis and Processing)*, Zaiqiao Meng *(University of Glasgow)*
- **AutoInt: Automatic Feature Interaction Learning via Self-Attentive Neural Networks** 1161
  Weiping Song, Chence Shi *(Peking University)*, Zhiping Xiao *(University of California, Los Angeles)*,
  Zhijian Duan, Yewen Xu, Ming Zhang *(Peking University)*,
  Jian Tang *(Mila-Quebec AI Institute, HEC Montreal & CIFAR AI Chair)*
- **Automatic Construction of Multi-layer Perceptron Network from Streaming Examples** 1171
  Mahardhika Pratama *(Nanyang Technological University)*, Choiru Za'in *(La Trobe University)*,
  Andri Ashfahani, Yew Soon Ong *(Nanyang Technological University)*,
  Weiping Ding *(Nantong University)*
- **Robust Embedded Deep K-means Clustering** 1181
  Rui Zhang *(Arizona State University)*, Hanghang Tong *(University of Illinois at Urbana-Champaign & Arizona State University)*, Yinglong Xia *(Facebook)*, Yada Zhu *(IBM T.J. Watson Research)*

Session: Long - Network Science

- **Discovering Interesting Cycles in Directed Graphs** 1191
  Florian Adriaens *(Ghent University)*, Cigdem Aslay *(Aalto University)*,
  Tijl De Bie *(Ghent University)*, Aristides Gionis *(Aalto University)*, Jefrey Lijffijt *(Ghent University)*
- **FLEET: Butterfly Estimation from a Bipartite Graph Stream** 1201
  Seyed-Vahid Sanei-Mehri, Yu Zhang *(Iowa State University)*, Ahmet Erdem Sariyüce *(University at Buffalo)*,
  Srikanta Tirthapura *(Iowa State University)*
- **Selecting the Optimal Groups: Efficiently Computing Skyline k-Cliques** 1211
  Chen Zhang, Wenjie Zhang *(University of New South Wales)*,
  Ying Zhang *(University of Technology, Sydney)*, Lu Qin *(University of Technology, Sydney)*,
  Fan Zhang *(Guangzhou University)*, Xuemin Lin *(University of New South Wales)*
- **Balance in Signed Bipartite Networks** 1221
  Tyler Derr *(Michigan State University)*, Cassidy Johnson *(University of the Pacific)*,
  Yi Chang *(Jilin University)*, Jiliang Tang *(Michigan State University)*
- **Adaptive Algorithms for Estimating Betweenness and *k*-path Centralities** 1231
  Mostafa Haghir Chehreghani *(Amirkabir University of Technology (Tehran Polytechnic) & Télécom-Paris, Institut Polytechnique de Paris (IP-Paris))*, Albert Bifet, Talel Abdessalem *(Télécom-Paris, IP-Paris)*

Session: Long - Online and Real-Time

- **Interactive Variance Attention based Online Spoiler Detection for Time-Sync Comments** 1241
  Wenmian Yang *(Shanghai Jiao Tong University)*, Weijia Jia *(University of Macau)*,
  Wenyuan Gao, Xiaojie Zhou, Yutao Luo *(Shanghai Jiao Tong University)*
- **Detecting Malicious Accounts in Online Developer Communities Using Deep Learning** 1251
  Qingyuan Gong, Jiayun Zhang, Yang Chen *(Fudan University)*,
  Qi Li *(Tsinghua University)*, Yu Xiao *(Aalto University)*, Xin Wang *(Fudan University)*,
  Pan Hui *(University of Helsinki & Hong Kong University of Science and Technology)*
- **Exploring Multi-Objective Exercise Recommendations in Online Education Systems** 1261
  Zhenya Huang, Qi Liu *(University of Science and Technology of China)*,
  Chengxiang Zhai *(University of Illinois at Urbana-Champaign)*,
  Yu Yin *(University of Science and Technology of China)*,
  Enhong Chen, Weibo Gao *(University of Science and Technology of China)*, Guoping Hu *(iFLYTEK Co., LTD)*
- **Into the Battlefield: Quantifying and Modeling Intra-community Conflicts in Online Discussion** 1271
  Subhabrata Dutta *(Jadavpur University)*,
  Gunkirat Kaur, Shreyans Mogia, Arpan Mukherjee *(Indraprastha Institute of Information Technology)*,
  Dipankar Das *(Jadavpur University)*, Tanmoy Chakraborty *(Indraprastha Institute of Information Technology)*
- **Offline and Online Satisfaction Prediction in Open-Domain Conversational Systems** 1281
  Jason Ingyu Choi, Ali Ahmadvand, Eugene Agichtein *(Emory University)*

Session: Long - Privacy

- **Privacy-Preserving Tensor Factorization for Collaborative Health Data Analysis** 1291
  Jing Ma, Qiuchen Zhang, Jian Lou, Joyce C. Ho, Li Xiong *(Emory University)*,
  Xiaoqian Jiang *(UT Health Science Center at Houston)*
- **Achieve Privacy-Preserving Truth Discovery in Crowdsensing Systems** 1301
  Jianchao Tang *(National University of Defense Technology)*,
  ShaoJing Fu *(National University of Defense Technology & Sate Key Laboratory of Cryptology)*,
  Ming Xu, Yuchuan Luo, Kai Huang *(National University of Defense Technology)*
- **Privacy-preserving Crowd-guided AI Decision-making in Ethical Dilemmas** 1311
  Teng Wang *(Xi'an Jiaotong University)*, Jun Zhao, Han Yu *(Nanyang Technological University)*,
  Jinyan Liu *(The University of Hong Kong)*, Xinyu Yang, Xuebin Ren *(Xi'an Jiaotong University)*,
  Shuyu Shi *(Nanjing University)*

- **Privacy Preserving Approximate K-means Clustering** 1321
  Chandan Biswas *(Indian Statistical Institute)*, Debasis Ganguly *(IBM Research Lab)*,
  Dwaipayan Roy *(GESIS - Leibniz Institute for the Social Sciences & Indian Statistical Institute)*,
  Ujjwal Bhattacharya *(Indian Statistical Institute)*
- **Practical Access Pattern Privacy by Combining PIR and Oblivious Shuffle** 1331
  Zhilin Zhang *(Simon Fraser University & Amazon)*, Ke Wang, Weipeng Lin *(Simon Fraser University)*,
  Ada Wai-Chee Fu *(Chinese University of Hong Kong)*,
  Raymond Chi-Wing Wong *(Hong Kong University of Science and Technology)*

Session: Long - Question Answering and Dialogue Systems I

- **A Hybrid Retrieval-Generation Neural Conversation Model** 1341
  Liu Yang *(University of Massachusetts, Amherst)*, Junjie Hu *(Carnegie Mellon University)*,
  Minghui Qiu *(Alibaba Group)*, Chen Qu *(University of Massachusetts, Amherst)*,
  Jianfeng Gao *(Microsoft Research Redmond)*, W. Bruce Croft *(University of Massachusetts, Amherst)*,
  Xiaodong Liu *(Microsoft Research Redmond)*, Yelong Shen *(Tencent AI Lab)*,
  Jingjing Liu *(Microsoft Research Redmond)*
- **A Latent-Constrained Variational Neural Dialogue Model for Information-Rich Responses** 1351
  Yanan Zheng, Yan Wang *(Central University of Finance and Economics)*,
  Lijie Wen, Jianmin Wang *(Tsinghua University)*
- **Legal Summarization for Multi-role Debate Dialogue via Controversy Focus Mining and Multi-task Learning** 1361
  Xinyu Duan *(Zhejiang University)*, Yating Zhang *(Alibaba Group)*, Lin Yuan *(Zhejiang University)*,
  Xin Zhou *(Alibaba Group)*, Xiaozhong Liu *(Indiana University Bloomington)*,
  Tianyi Wang *(Alibaba Group)*, Ruocheng Wang *(Zhejiang University)*,
  Qiong Zhang, Changlong Sun *(Alibaba Group)*, Fei Wu *(Zhejiang University)*
- **ConCET: Entity-Aware Topic Classification for Open-Domain Conversational Agents** 1371
  Ali Ahmadvand, Harshita Sahijwani, Jason Ingyu Choi, Eugene Agichtein *(Emory University)*
- **An Interactive Mechanism to Improve Question Answering Systems via Feedback** 1381
  Xinbo Zhang, Lei Zou, Sen Hu *(Peking University)*

Session: Long - Question Answering and Dialogue Systems II

- **Attentive History Selection for Conversational Question Answering** 1391
  Chen Qu, Liu Yang *(University of Massachusetts, Amherst)*, Minghui Qiu *(Alibaba Group)*,
  Yongfeng Zhang *(Rutgers University)*, Cen Chen *(Ant Financial Services Group)*,
  W. Bruce Croft, Mohit Iyyer *(University of Massachusetts, Amherst)*
- **Emotion-aware Chat Machine: Automatic Emotional Response Generation for Human-like Emotional Interaction** 1401
  Wei Wei, Jiayi Liu *(Huazhong University of Science and Technology)*,
  Xianling Mao *(Beijing Institute of Technology)*, Guibing Guo *(Northeastern University)*,
  Feida Zhu *(Singapore Management University)*,
  Pan Zhou, Yuchong Hu *(Huazhong University of Science and Technology)*
- **Commonsense Properties from Query Logs and Question Answering Forums** 1411
  Julien Romero *(Télécom Paris)*, Simon Razniewski, Koninika Pal *(Max Planck Institute for Informatics)*,
  Jeff Z. Pan *(University of Aberdeen)*, Archit Sakhadeo, Gerhard Weikum *(Max Planck Institute for Informatics)*
- **Adapting Visual Question Answering Models for Enhancing Multimodal Community Q&A Platforms** 1421
  Avikalp Srivastava *(Carnegie Mellon University)*, Hsin-Wen Liu *(Waseda University)*,
  Sumio Fujita *(Yahoo! Japan)*
- **Message Passing for Complex Question Answering over Knowledge Graphs** 1431
  Svitlana Vakulenko, Javier David Fernandez Garcia, Axel Polleres *(Vienna University of Economics and Business)*,
  Maarten de Rijke *(University of Amsterdam)*, Michael Cochez *(Fraunhofer FIT)*

Session: Long - Recommendation System I

- **BERT4Rec: Sequential Recommendation with Bidirectional Encoder Representations from Transformer** 1441
  Fei Sun, Jun Liu, Jian Wu, Changhua Pei, Xiao Lin, Wenwu Ou, Peng Jiang *(Alibaba Group)*
- **Adaptive Feature Sampling for Recommendation with Missing Content Feature Values** 1451
  Shaoyun Shi, Min Zhang *(Tsinghua University)*, Xinxing Yu *(Zhihu)*, Yongfeng Zhang *(Rutgers University)*, Bin Hao, Yiqun Liu, Shaoping Ma *(Tsinghua University)*
- **A Dynamic Co-attention Network for Session-based Recommendation** 1461
  Wanyu Chen *(National University of Defense Technology & University of Amsterdam)*, Fei Cai, Honghui Chen *(National University of Defense Technology)*, Maarten de Rijke *(University of Amsterdam)*
- **Attributed Multi-Relational Attention Network for Fact-checking URL Recommendation** 1471
  Di You, Nguyen Vo, Kyumin Lee *(Worcester Polytechnic Institute)*, Qiang LIU *(Alibaba Group)*
- **A Hierarchical Self-Attentive Model for Recommending User-Generated Item Lists**..... 1481
  Yun He, Jianling Wang, Wei Niu, James Caverlee *(Texas A&M University)*

Session: Long - Recommendation System II

- **HAES: A New Hybrid Approach for Movie Recommendation with Elastic Serendipity** 1503
  Xueqi Li, Wenjun Jiang, Weiguang Chen *(Hunan University)*, Jie Wu *(Temple University)*, Guojun Wang *(Guangzhou University)*
- **DBRec: Dual-Bridging Recommendation via Discovering Latent Groups** 1513
  Jingwei Ma *(University of Queensland)*, Jiahui Wen *(National University of Defense Technology)*, Mingyang Zhong *(Central Queensland University & Chongqing Meiqi Industry Co.)*, Liangchen Liu *(University of Queensland)*, Chaojie Li *(Alibaba Group)*, Weitong Chen *(University of Queensland)*, Yin Yang *(Hamad Bin Khalifa University)*, Hongkui Tu *(National University of Defense Technology)*, Xue Li *(University of Queensland)*
- **Candidate Generation with Binary Codes for Large-Scale Top-N Recommendation** 1523
  Wang-Cheng Kang, Julian McAuley *(University of California, San Diego)*
- **DTCDR: A Framework for Dual-Target Cross-Domain Recommendation**..... 1533
  Feng Zhu *(Macquarie University)*, Chaochao Chen *(Ant Financial Services Group)*, Yan Wang, Guanfeng Liu *(Macquarie University)*, Xiaolin Zheng *(Zhejiang University)*
- **Recommender System Using Sequential and Global Preference via Attention Mechanism and Topic Modeling** 1543
  Kyeongpil Kang *(Korea University & SKT AI Center)*, Junwoo Park *(SK Planet)*, Wooyoung Kim *(Korea University & SKT AI Center)*, Hojung Choe *(NICE Information Service)*, Jaegul Choo *(Korea University)*

Session: Long - Recommendation System III

- **A Spatio-temporal Recommender System for On-demand Cinemas**..... 1553
  Taofeng Xue, Beihong Jin, Beibei Li *(Institute of Software, Chinese Academy of Sciences & University of Chinese Academy of Sciences)*, Weiqing Wang *(Monash University)*, Qi Zhang, Sihua Tian *(Beijing iQIYI Cinema Management Co., Ltd.)*
- **Semi-Supervised Learning for Cross-Domain Recommendation to Cold-Start Users** 1563
  SeongKu Kang, Junyoung Hwang, Dongha Lee, Hwanjo Yu *(POSTECH)*
- **Leveraging Ratings and Reviews with Gating Mechanism for Recommendation**..... 1573
  Haifeng Xia, Zengmao Wang, Bo Du, Lefei Zhang *(Wuhan University)*, Shuai Chen, Gang Chun *(Xiaomi Inc.)*
- **Instagrammers, Fashionistas, and Me: Recurrent Fashion Recommendation with Implicit Visual Influence** 1583
  Yin Zhang, James Caverlee *(Texas A&M University)*
- **What Can History Tell Us? Identifying Relevant Sessions for Next-Item Recommendation** 1593
  Ke Sun, Tieyun Qian *(Wuhan University)*, Hongzhi Yin, Tong Chen *(University of Queensland)*, Yiqi Chen *(Wuhan University)*, Ling Chen *(University of Technology Sydney)*

Session: Long - Reinforcement Learning

- **Context-Aware Ranking by Constructing a Virtual Environment for Reinforcement Learning** 1603
  Junqi Zhang, Jiaxin Mao, Yiqun Liu, Ruizhe Zhang, Min Zhang, Shaoping Ma *(Tsinghua University)*, Jun Xu *(Renmin University of China)*, Qi Tian *(Huawei Noah's Ark Lab)*
- **A Multi-Scale Temporal Feature Aggregation Convolutional Neural Network for Portfolio Management** 1613
  Si Shi, Jianjun Li, Guohui Li, Peng Pan *(Huazhong University of Science and Technology)*
- **Order-free Medicine Combination Prediction with Graph Convolutional Reinforcement Learning** 1623
  Shanshan Wang *(Shandong University)*, Pengjie Ren *(University of Amsterdam)*, Zhumin Chen, Zhaochun Ren, Jun Ma *(Shandong University)*, Maarten de Rijke *(University of Amsterdam)*
- **Reinforcement Learning with Sequential Information Clustering in Real-Time Bidding** 1633
  Junwei Lu, Chaoqi Yang, Xiaofeng Gao *(Shanghai Jiao Tong University)*, Liubin Wang, Changcheng Li *(Tencent)*, Guihai Chen *(Shanghai Jiao Tong University)*
- **Generative Question Refinement with Deep Reinforcement Learning in Retrieval-based QA System** 1643
  Ye Liu *(University of Illinois at Chicago)*, Chenwei Zhang *(Amazon)*, Xiaohui Yan *(Poisson Lab, Huawei Technologies)*, Yi Chang *(Jilin University)*, Philip S. Yu *(University of Illinois at Chicago)*

Session: Long - Search & Retrieval

- **Analyzing the Effects of Document's Opinion and Credibility on Search Behaviors and Belief Dynamics** 1653
  Suppanut Pothirattanachaikul *(Kyoto University)*, Takehiro Yamamoto *(University of Hyogo)*, Yusuke Yamamoto *(Shizuoka University)*, Masatoshi Yoshikawa *(Kyoto University)*
- **Identifying Facet Mismatches In Search Via Micrographs** 1663
  Sriram Srinivasan *(University of California, Santa Cruz)*, Nikhil S. Rao, Karthik Subbian *(Amazon Inc.)*, Lise Getoor *(University of California, Santa Cruz)*
- **GRIP: Multi-Store Capacity-Optimized High-Performance Nearest Neighbor Search for Vector Search Engine** 1673
  Minjia Zhang, Yuxiong He *(Microsoft AI and Research)*
- **Improving Web Image Search with Contextual Information** 1683
  Xiaohui Xie, Jiaxin Mao, Yiqun Liu *(Tsinghua University)*, Maarten de Rijke *(University of Amsterdam)*, Qingyao Ai *(University of Utah)*, Yufei Huang, Min Zhang, Shaoping Ma *(Tsinghua Unviersity)*
- **Dynamic Bayesian Metric Learning for Personalized Product Search** 1693
  Teng Xiao, Jiaxin Ren *(Sun Yat-sen University)*, Zaiqiao Meng *(University of Glasgow)*, Huan Sun *(The Ohio State University)*, Shangsong Liang *(Sun Yat-sen University)*

Session: Long - Sequential Data Analysis

- **Towards Accurate and Interpretable Sequential Prediction: A CNN & Attention-Based Feature Extractor** 1703
  Jingyi Wang *(University of Electronic Science and Technology of China & RealAI)*, Qiang Liu *(RealAI and Tsinghua University)*, Zhaocheng Liu *(RealAI)*, Shu Wu *(Chinese Academy of Sciences)*
- **Locally Slope-based Dynamic Time Warping for Time Series Classification** 1713
  Jidong Yuan, Qianhong Lin, Wei Zhang, Zhihai Wang *(Beijing Jiaotong University)*
- **HiCAN: Hierarchical Convolutional Attention Network for Sequence Modeling** 1723
  Yi Cao, Weifeng Zhang, Bo Song, Congfu Xu *(Zhejiang University)*
- **Automatic Sequential Pattern Mining in Data Streams** 1733
  Koki Kawabata, Yasuko Matsubara, Yasushi Sakurai *(ISIR, Osaka University)*
- **Efficient Sequential and Parallel Algorithms for Estimating Higher Order Spectra** 1743
  Zigeng Wang *(University of Connecticut)*, Abdullah-Al Mamun *(University of Connecticut & Google LLC)*, Xingyu Cai, Nalini Ravishanker, Sanguthevar Rajasekaran *(University of Connecticut)*

Session: Long - Social Network

- **A Modular Adversarial Approach to Social Recommendation** 1753
  Adit Krishnan, Hari Cheruvu, Cheng Tao, Hari Sundaram *(University of Illinois at Urbana-Champaign)*
- **Emotional Contagion-Based Social Sentiment Mining in Social Networks by Introducing Network Communities** 1763
  Xiaobao Wang, Di Jin, Mengquan Liu, Dongxiao He *(Tianjin University)*,
  Katarzyna Musial *(University of Technology Sydney)*,
  Jianwu Dang *(Japan Advanced Institute of Science and Technology)*
- **Social-Aware VR Configuration Recommendation via Multi-Feedback Coupled Tensor Factorization** 1773
  Hsu-Chao Lai *(National Chiao Tung University & Academia Sinica)*,
  Hong-Han Shuai *(National Chiao Tung University)*, De-Nian Yang *(Academia Sinica)*,
  Jiun-Long Huang *(National Chiao Tung University)*, Wang-Chien Lee *(The Pennsylvania State University)*,
  Philip S. Yu *(University of Illinois at Chicago & Fudan University)*
- **Tracking Top-k Influential Users with Relative Errors** 1783
  Yu Yang *(City University of Hong Kong)*, Zhefeng Wang *(Huawei Tech.)*,
  Tianyuan Jin *(University of Science and Technology of China)*, Jian Pei *(Simon Fraser University)*,
  Enhong Chen *(University of Science and Technology of China)*
- ***NActSeer:* Predicting User Actions in Social Network using Graph Augmented Neural Network** 1793
  Mohammad Raihanul Islam, Sathappan Muthiah, Naren Ramakrishnan *(Virginia Tech)*

Session: Long - Understanding and Interpretability I

- **In2Rec: Influence-based Interpretable Recommendation** 1803
  Huafeng Liu, Jingxuan Wen, Liping Jing, Jian Yu *(Beijing Jiaotong University)*,
  Xiangliang Zhang *(King Abdullah University of Science and Technology)*, Min Zhang *(Tsinghua University)*
- **Accounting for Temporal Dynamics in Document Streams** 1813
  Zhendong Chu *(Fudan University)*, Renqin Cai, Hongning Wang *(University of Virginia)*
- **How Does BERT Answer Questions? A Layer-Wise Analysis of Transformer Representations** 1823
  Betty van Aken, Benjamin Winter, Alexander Löser, Felix A. Gers *(Beuth University of Applied Sciences)*
- **Patterns of Search Result Examination: Query to First Action** 1833
  Mustafa Abualsaud, Mark D. Smucker *(University of Waterloo)*
- **A Dynamic Product-aware Learning Model for E-commerce Query Intent Understanding** . 1843
  Jiashu Zhao *(Wilfrid Laurier University)*, Hongshen Chen, Dawei Yin *(JD.COM)*

Session: Long - Understanding and Interpretability II

- **Scalable Causal Graph Learning through a Deep Neural Network** 1853
  Chenxiao Xu *(Stony Brook University)*, Hao Huang *(GE Global Research)*,
  Shinjae Yoo *(Stony Brook University)*
- **Interpretable Multiple-Kernel Prototype Learning for Discriminative Representation and Feature Selection** 1863
  Babak Hosseini, Barbara Hammer *(CITEC Cluster of Excellence, Bielefeld University)*
- **BePT: A Behavior-based Process Translator for Interpreting and Understanding Process Models** 1873
  Chen Qian, Lijie Wen *(Tsinghua University)*, Akhil Kumar *(Penn State University)*
- **Towards Effective and Interpretable Person-Job Fitting** 1883
  Ran Le, Wenpeng Hu *(Peking University)*, Yang Song *(BOSS Zhipin NLP Center)*, Tao Zhang *(BOSS Zhipin)*,
  Dongyan Zhao, Rui Yan *(Peking University)*
- **Leveraging Graph Neighborhoods for Efficient Inference** 1893
  Melisachew Wudage Chekol, Heiner Stuckenschmidt *(University of Mannheim)*

Session: Long - Urban Computing I

- **STAR: Spatio-Temporal Taxonomy-Aware Tag Recommendation for Citizen Complaints**... 1903
  Jingyue Gao, Yuanduo He, Yasha Wang *(Peking Univeristy)*,
  Xiting Wang *(Microsoft Research Asia)*, Jiangtao Wang *(Lancaster University)*,
  Guangju Peng, Xu Chu *(Peking Univeristy)*
- **CoLight: Learning Network-level Cooperation for Traffic Signal Control**..... 1913
  Hua Wei *(The Pennsylvania State University)*, Nan Xu, Huichu Zhang *(Shanghai Jiao Tong University)*,
  Guanjie Zheng *(The Pennsylvania State University)*,
  Xinshi Zang, Chacha Chen, Weinan Zhang, Yanmin Zhu *(Shanghai Jiao Tong University)*,
  Kai Xu *(Shanghai Tianrang Intelligent Technology Co., Ltd)*, Zhenhui Li *(The Pennsylvania State University)*
- **Learning to Effectively Estimate the Travel Time for Fastest Route Recommendation** 1923
  Ning Wu, Jingyuan Wang *(Beihang University)*, Wayne Xin Zhao *(Renmin University of China)*,
  Yang Jin *(Beihang University)*
- **PRNet: Outdoor Position Recovery for Heterogenous Telco Data by Deep Neural Network**..... 1933
  Yige Zhang, Weixiong Rao *(Tongji University)*, Kun Zhang *(Carnegie Mellon University)*,
  Mingxuan Yuan, Jia Zeng *(Huawei Noah's Ark Lab)*
- **Active Collaborative Sensing for Energy Breakdown** 1943
  Yiling Jia *(University of Virginia)*, Nipun Batra *(IIT Gandhinagar)*,
  Hongning Wang, Kamin Whitehouse *(University of Virginia)*

Session: Long - Urban Computing II

- **Forecasting Pavement Performance with a Feature Fusion LSTM-BPNN Model**..... 1953
  Yushun Dong, Yingxia Shao, Xiaotong Li *(Beijing University of Posts and Telecommunications)*,
  Sili Li, Lei Quan *(Research Institute of Highway, Ministry of Transportation)*,
  Wei Zhang *(East China Normal University)*,
  Junping Du *(Beijing University of Posts and Telecommunications)*
- **Learning Phase Competition for Traffic Signal Control** 1963
  Guanjie Zheng *(The Pennsylvania State University)*, Yuanhao Xiong *(Zhejiang Univerisity)*,
  Xinshi Zang *(Shanghai Jiao Tong Univerisity)*, Jie Feng *(Tsinghua Univerisity)*,
  Hua Wei *(The Pennsylvania State University)*, Huichu Zhang *(Shanghai Jiao Tong Univerisity)*,
  Yong Li *(Tsinghua Univerisity)*, Kai Xu *(Shanghai Tianrang Intelligent Technology Co., Ltd)*,
  Zhenhui Li *(The Pennsylvania State University)*
- **Path Travel Time Estimation using Attribute-related Hybrid Trajectories Network** 1973
  Xi Lin *(Nanyang Technological University)*, Yequan Wang *(Tencent Inc.)*,
  Xiaokui Xiao *(National University of Singapore)*,
  Zengxiang Li *(Institute of High Performance Computing)*,
  Sourav S. Bhowmick *(Nanyang Technological University)*
- **CoRide: Joint Order Dispatching and Fleet Management for Multi-Scale Ride-Hailing Platforms**..... 1983
  Jiarui Jin, Ming Zhou, Weinan Zhang *(Shanghai Jiao Tong University)*,
  Minne Li *(University College London)*, Zilong Guo *(Shanghai Jiao Tong University)*,
  Zhiwei Qin, Yan Jiao, Xiaocheng Tang, Chenxi Wang *(DiDi AI Labs)*,
  Jun Wang *(University College London)*, Guobin Wu *(DiDi Research)*, Jieping Ye *(DiDi AI Labs)*
- **Unsupervised Representation Learning of Spatial Data via Multimodal Embedding**..... 1993
  Porter Jenkins *(The Pennsylvania State University)*, Ahmad Farag *(Georgia Tech University)*,
  Suhang Wang, Zhenhui Li *(The Pennsylvania State University)*

Session: Long - User Behavior

- **Rating Mechanisms for Sustainability of Crowdsourcing Platforms**..... 2003
  Chenxi Qiu *(Rowan University)*, Anna Squicciarini, Sarah Rajtmajer *(The Pennsylvania State University)*
- **Exploring The Interaction Effects for Temporal Spatial Behavior Prediction** 2013
  Huan Yang, Tianyuan Liu, Yuqing Sun *(Shandong University)*, Elisa Bertino *(Purdue University)*
- **Social Cards Probably Provide For Better Understanding Of Web Archive Collections**..... 2023
  Shawn M. Jones, Michele C. Weigle, Michael L. Nelson *(Old Dominion University)*

- **Learning from Dynamic User Interaction Graphs to Forecast Diverse Social Behavior** 2033
  Prasha Shrestha, Suraj Maharjan, Dustin Arendt, Svitlana Volkova *(Pacific Northwest National Laboratory)*
- **Understanding Default Behavior in Online Lending** 2043
  Yang Yang *(Zhejiang University)*, Yuhong Xu *(Netease Inc.)*, Chunping Wang *(PPDAI Group Inc.)*, Yizhou Sun *(University of California, Los Angeles)*, Fei Wu, Yueting Zhuang *(Zhejiang University)*, Ming Gu *(PPDAI Group Inc.)*

Session: Short - Interpretability & Reasoning

- **Interpretable MTL from Heterogeneous Domains using Boosted Tree** 2053
  Ya-Lin Zhang, Longfei Li *(Ant Financial Services Group)*
- **Machine Reading Comprehension: Matching and Orders** 2057
  Ao Liu *(University of Electronic Science and Technology of China)*, Lizhen Qu *(Monash University)*, Junyu Lu, Chenbin Zhang, Zenglin Xu *(University of Electronic Science and Technology of China)*
- **Aspect and Opinion Aware Abstractive Review Summarization with Reinforced Hard Typed Decoder** 2061
  Yufei Tian *(Tsinghua University)*, Jianfei Yu, Jing Jiang *(Singapore Management University)*
- **Datalog Reasoning over Compressed RDF Knowledge Bases** 2065
  Pan Hu *(University of Oxford)*, Jacopo Urbani *(Vrije Universiteit Amsterdam)*, Boris Motik, Ian Horrocks *(University of Oxford)*
- **An Explainable Deep Fusion Network for Affect Recognition Using Physiological Signals** 2069
  Jionghao Lin, Shirui Pan, Cheng Siong Lee, Sharon Oviatt *(Monash University)*

Session: Short - Machine Learning

- **MarlRank: Multi-agent Reinforced Learning to Rank** 2073
  Shihao Zou *(University of Alberta & University of College London & Huawei)*, Zhonghua Li *(Huawei)*, Mohammad Akbari, Jun Wang *(University College London)*, Peng Zhang *(Tianjin University)*
- **LinkRadar: Assisting the Analysis of Inter-app Page Links via Transfer Learning** 2077
  Diandian Gu *(Peking University)*, Ziniu Hu *(University of California, Los Angeles)*, Shangchen Du *(Peking University)*, Yun Ma *(Tsinghua University)*
- **NAD: Neural Network Aided Design for Textile Pattern Generation** 2081
  Zhifei Pang, Sai Wu, Dongxiang Zhang, Yunjun Gao, Gang Chen *(Zhejiang University)*
- **Feature Selection for Facebook Feed Ranking System via a Group-Sparsity-Regularized Training Algorithm** 2085
  Xiuyan Ni *(City University of New York)*, Yang Yu, Peng Wu, Youlin Li *(Facebook Inc.)*, Shaoliang Nie *(North Carolina State University)*, Qichao Que *(Facebook Inc.)*, Chao Chen *(Stony Brook University)*
- **Fine-Grained Geolocalization of User-Generated Short Text based on Weight Probability Model** 2089
  Congjie Gao, Yongjnu Li, Jiaqi Yang *(Northwestern Polytechnical University)*
- **A Compare-Aggregate Model with Latent Clustering for Answer Selection** 2093
  Seunghyun Yoon *(Seoul National University)*, Franck Dernoncourt, Doo Soon Kim, Trung Bui *(Adobe Research)*, Kyomin Jung *(Seoul National University)*

Session: Short - Embeddings

- **Spotting Terrorists by Learning Behavior-aware Heterogeneous Network Embedding** 2097
  Pei-Chi Wang, Cheng-Te Li *(National Cheng Kung University)*
- **Scalable Manifold-Regularized Attributed Network Embedding via Maximum Mean Discrepancy** 2101
  Jun Wu, Jingrui He *(University of Illinois at Urbana-Champaign)*
- **Tensor Decomposition-based Node Embedding** 2105
  Shah Muhammad Hamdi, Soukaïna Filali Boubrahimi, Rafal Angryk *(Georgia State University)*

- **Geometric Estimation of Specificity within Embedding Spaces** 2109
  Negar Arabzadeh, Fattaneh Zarrinkalam *(Ryerson University)*, Jelena Jovanovic *(University of Belgrade)*, Ebrahim Bagheri *(Ryerson University)*
- **Similarity-Aware Network Embedding with Self-Paced Learning** 2113
  Chao Huang *(University of Notre Dame)*, Baoxu Shi *(LinkedIn)*, Xuchao Zhang *(Virginia Tech)*, Xian Wu *(University of Notre Dame)*, Nitesh V. Chawla *(University of Notre Dame)*
- **Integrating Multi-Network Topology via Deep Semi-supervised Node Embedding** 2117
  Hansheng Xue, Jiajie Peng *(Northwestern Polytechnical University)*, Jiying Li *(Microsoft Corporation)*, Xuequn Shang *(Northwestern Polytechnical University)*

Session: Short - Time Sequences & Dynamics

- **Query-Specific Knowledge Summarization with Entity Evolutionary Networks** 2121
  Carl Yang, Lingrui Gan, Zongyi Wang, Jiaming Shen, Jinfeng Xiao, Jiawei Han *(University of Illinois at Urbana Champaign)*
- **Real-time Edge Repartitioning for Dynamic Graph** 2125
  He Li, Hang Yuan, Jianbin Huang *(Xidian University)*
- **DSANet: Dual Self-Attention Network for Multivariate Time Series Forecasting** 2129
  Siteng Huang, Donglin Wang *(Westlake University)*, Xuehan Wu *(Huawei Technologies Co., Ltd.)*, Ao Tang *(WeCar Technology Co., Ltd.)*
- **Time Series Prediction with Interpretable Data Reconstruction** 2133
  Qiangxing Tian *(Zhejiang University & Westlake University)*, Jinxin Liu, Donglin Wang *(Westlake University)*, Ao Tang *(WeCar (Shenzhen) Technology Co., Ltd.)*
- **Towards Explainable Representation of Time-Evolving Graphs via Spatial-Temporal Graph Attention Networks** 2137
  Zhining Liu *(University of Electronic Science and Technology of China)*, Dawei Zhou, Jingrui He *(University of Illinois at Urbana-Champaign)*
- **Deep Prototypical Networks for Imbalanced Time Series Classification under Data Scarcity** 2141
  Chao Huang, Xian Wu *(University of Notre Dame)*, Xuchao Zhang *(Virginia Tech)*, Suwen Lin, Nitesh V. Chawla *(University of Notre Dame)*

Session: Short - Graph Neural Networks

- **Knowledge-aware Textual Entailment with Graph Attention Network** 2145
  Daoyuan Chen *(Peking University Shenzhen Graduate School)*, Yaliang Li *(Alibaba Group)*, Min Yang *(Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences)*, Hai-Tao Zheng *(Tsinghua University)*, Ying Shen *(Peking University Shenzhen Graduate School)*
- **Fast Approximations of Betweenness Centrality with Graph Neural Networks** 2149
  Sunil Kumar Maurya *(Tokyo Institute of Technology)*, Xin Liu *(AIRC, AIST)*, Tsuyoshi Murata *(Tokyo Institute of Technology)*
- **Neighborhood Interaction Attention Network for Link Prediction** 2153
  Zhitao Wang, Yu Lei, Wenjie Li *(The Hong Kong Polytechnic University)*
- **Long-short Distance Aggregation Networks for Positive Unlabeled Graph Learning** 2157
  Man Wu *(Florida Atlantic University)*, Shirui Pan, Lan Du *(Monash University)*, Ivor Tsang *(University of Technology Sydney)*, Xingquan Zhu *(Florida Atlantic University)*, Bo Du *(Wuhan University)*
- **Using External Knowledge for Financial Event Prediction Based on Graph Neural Networks** 2161
  Yiying Yang *(Fudan University & Pingan Life Insurance)*, Zhongyu Wei, Qin Chen, Libo Wu *(Fudan University)*
- **Cross-Domain Recommendation via Preference Propagation GraphNet** 2165
  Cheng Zhao, Chenliang Li *(Wuhan University)*, Cong Fu *(Zhejiang University)*

Session: Short - Recommendation

- **ARP: Aspect-aware Neural Review Rating Prediction** 2169
  Chuhan Wu *(Tsinghua University)*, Fangzhao Wu *(Microsoft Research Asia)*,
  Junxin Liu, Yongfeng Huang *(Tsinghua University)*, Xing Xie *(Microsoft Research Asia)*
- **CosRec: 2D Convolutional Neural Networks for Sequential Recommendation** 2173
  An Yan, Shuo Cheng, Wang-Cheng Kang, Mengting Wan, Julian McAuley *(University of California, San Diego)*
- **Data Poisoning Attacks on Cross-domain Recommendation** 2177
  Huiyuan Chen, Jing Li *(Case Western Reserve University)*
- **Session-based Recommendation with Hierarchical Memory Networks** 2181
  Bo Song, Yi Cao, Weifeng Zhang, Congfu Xu *(Zhejiang University)*
- **Correcting for Recency Bias in Job Recommendation** 2185
  Ruey-Cheng Chen *(RMIT University)*, Qingyao Ai *(University of Utah)*, Gaya Jayasinghe *(GO1)*,
  W. Bruce Croft *(RMIT University)*
- **Motif Enhanced Recommendation over Heterogeneous Information Network** 2189
  Huan Zhao, Yingqi Zhou, Yangqiu Song, Dik Lun Lee *(Hong Kong University of Science and Technology)*

Session: Short - Algorithm

- **GPU-Accelerated Decoding of Integer Lists** 2193
  Antonio Mallia, Michał Siedlaczek, Torsten Suel, Mohamed Zahran *(New York University)*
- **Synergizing Local and Global Models for Matrix Approximation** 2197
  Chao Chen *(Shanghai Jiao Tong University & IBM Research China)*, Hao Zhang *(Shanghai Jiao Tong University)*,
  Dongsheng Li *(IBM Research China)*, Junchi Yan, Xiaokang Yang *(Shanghai Jiao Tong University)*
- **Deep Colorization by Variation** 2201
  Zineng Tang *(University of North Carolina at Chapel Hill)*
- **Fast Random Forest Algorithm via Incremental Upper Bound** 2205
  Yasuhiro Fujiwara *(NTT Communication Science Laboratories)*,
  Yasutoshi Ida, Sekitoshi Kanai, Atsutoshi Kumagai, Junya Arai *(NTT Software Innovation Center)*,
  Naonori Ueda *(NTT Communication Science Laboratories)*
- **Convolution-Consistent Collective Matrix Completion** 2209
  Xu Liu *(Arizona State University)*, Jingrui He *(University of Illinois at Urbana-Champaign)*,
  Sam Duddy, Liz O'Sullivan *(Allstate Northern Ireland)*
- **Faster Algorithms for *k*-Regret Minimizing Sets via Monotonicity and Sampling** 2213
  Qi Dong, Jiping Zheng *(Nanjing University of Aeronautics and Astronautics)*
- **Towards Stochastic Simulations of Relevance Profiles** 2217
  Kevin Roitero, Andrea Brunello *(University of Udine)*,
  Julián Urbano *(Delft University of Technology)*, Stefano Mizzaro *(University of Udine)*

Session: Short - Anomaly Detection

- **SpecAE: Spectral AutoEncoder for Anomaly Detection in Attributed Networks** 2233
  Yuening Li, Xiao Huang *(Texas A&M University)*, Jundong Li *(University of Virginia)*,
  Mengnan Du, Na Zou *(Texas A&M University)*
- **On Continuously Matching of Evolving Graph Patterns** 2237
  Qianzhen Zhang, Deke Guo, Xiang Zhao, Aibo Guo *(National University of Defense Technology)*
- **Time-Series Aware Precision and Recall for Anomaly Detection: Considering Variety of Detection Result and Addressing Ambiguous Labeling** 2241
  Won-Seok Hwang, Jeong-Han Yun, Jonguk Kim, Hyoung Chun Kim *(The Affiliated Institute of ETRI)*
- **Additive Explanations for Anomalies Detected from Multivariate Temporal Data** 2245
  Ioana Giurgiu, Anika Schumann *(IBM Research - Zurich)*

- **ED2: A Case for Active Learning in Error Detection** 2249
  Felix Neutatz *(DFKI GmbH)*, Mohammad Mahdavi *(TU Berlin)*,
  Ziawasch Abedjan *(TU Berlin & DFKI GmbH)*
- **Multi-scale Trajectory Clustering to Identify Corridors in Mobile Networks** 2253
  Li Li, Sarah Erfani, Chien Aun Chan, Christopher Leckie *(University of Melbourne)*

Session: Short - Recognition

- **Multi-view Moments Embedding Network for 3D Shape Recognition** 2257
  Jun Xiao, Yuanxing Zhang, Pengyu Zhao, Kecheng Xiao, Kaigui Bian, Chunli Zhang,
  Wei Yan *(Peking University)*
- **Active Entity Recognition in Low Resource Settings** 2261
  Ning Gao, Nikos Karampatziakis, Rahul Potharaju *(Microsoft)*, Silviu Cucerzan *(Microsoft Research)*
- **On Novel Object Recognition: A Unified Framework for Discriminability and Adaptability** 2265
  Kai Li *(Northeastern University)*, Martin Renqiang Min *(NEC Labs America - Princeton)*,
  Bing Bai *(NEC Labs America - Princeton)*, Yun Fu *(Northeastern University)*,
  Hans Peter Graf *(NEC Labs America - Princeton)*
- **Exploiting Multiple Embeddings for Chinese Named Entity Recognition** 2269
  Canwen Xu, Feiyang Wang *(Wuhan University)*, Jialong Han *(Tencent AI Lab)*,
  Chenliang Li *(Wuhan University)*
- **Gate-based Bidirectional Interactive Decoding Network for Scene Text Recognition** 2273
  Yunze Gao, Yingying Chen, Jinqiao Wang, Hanqing Lu *(Institute of Automation, Chinese Academy of Sciences)*
- **Modeling Long-Range Context for Concurrent Dialogue Acts Recognition** 2277
  Yue Yu, Siyao Peng, Grace Hui Yang *(Georgetown University)*

Session: Short - Urbanism and Mobility

- **Labelling for Venue Visit Detection by Matching Wi-Fi Hotspots with Businesses** 2281
  Denis Shaposhnikov, Anastasia Bezzubtseva, Ekaterina Gladkikh, Alexey Drutsa *(Yandex)*
- **Heterogeneous Components Fusion Network for Load Forecasting of Charging Stations** ... 2285
  Kai Li *(independent)*, Fei Yu *(Harbin Institute of Technology)*,
  Cheng Feng *(Northeast Forestry University)*, Tian Xia *(Harbin University of Science and Technology)*
- **Learning Traffic Signal Control from Demonstrations** 2289
  Yuanhao Xiong *(Zhejiang University)*, Guanjie Zheng *(The Pennsylvania State University)*,
  Kai Xu *(Shanghai Tianrang Intelligent Technology Co., Ltd)*, Zhenhui Li *(The Pennsylvania State University)*
- **Spatio-Temporal Graph Convolutional and Recurrent Networks for Citywide Passenger Demand Prediction** 2293
  Lei Bai, Lina Yao, Salil S. Kanhere *(University of New South Wales)*,
  Xianzhi Wang *(University of Technology Sydney)*, Wei Liu *(University of New South Wales)*,
  Zheng Yang *(Tsinghua University)*
- **Collaborative Analysis for Computational Risk in Urban Water Supply Systems** 2297
  Di Wu, Hao Wang, Razak Seidu *(Norwegian University of Science and Technology)*
- **Long- and Short-term Preference Learning for Next POI Recommendation** 2301
  Yuxia Wu, Ke Li, Guoshuai Zhao, Xueming Qian *(Xi'an Jiaotong University)*

Session: Short - Information Retrieval

- **Cluster-Based Focused Retrieval** 2305
  Eilon Sheetrit, Oren Kurland *(Technion – Israel Institute of Technology)*
- **Cross-modal Image-Text Retrieval with Multitask Learning** 2309
  Junyu Luo *(SIAT, Chinese Academy of Sciences & Sichuan University)*, Ying Shen *(Peking University)*,
  Xiang Ao *(ICT, Chinese Academy of Sciences)*, Zhou Zhao *(Zhejiang University)*,
  Min Yang *(SIAT, Chinese Academy of Sciences)*

- **A Unified Generation-Retrieval Framework for Image Captioning** 2313
  Chunpu Xu *(Huazhong University of Science and Technology)*,
  Wei Zhao *(Technische Universität Darmstadt)*, Min Yang *(SIAT, Chinese Academy of Sciences)*,
  Xiang Ao *(ICT, Chinese Academy of Sciences)*,
  Wangrong Cheng, Jinwen Tian *(Huazhong University of Science and Technology)*
- **A Lossy Compression Method on Positional Index for Efficient and Effective Retrieval** 2317
  Shuni Gao, Jipeng Liu, Xiaoguang Liu, Gang Wang *(Nankai University)*
- **Interactive Matching Network for Multi-Turn Response Selection in Retrieval-Based Chatbots** 2321
  Jia-Chen Gu, Zhen-Hua Ling *(University of Science and Technology of China)*,
  Quan Liu *(University of Science and Technology of China & iFLYTEK Research)*
- **Analysis of Adaptive Training for Learning to Rank in Information Retrieval** 2325
  Saar Kuzi, Sahiti Labhishetty *(University of Illinois at Urbana-Champaign)*,
  Shubhra Kanti Karmaker Santu *(Massachusetts Institute of Technology)*,
  Prasad Pradip Joshi *(Unbxd)*, ChengXiang Zhai *(University of Illinois at Urbana-Champaign)*

Session: Short - E-commerce & Production

- **QPIN: A Quantum-inspired Preference Interactive Network for E-commerce Recommendation** 2329
  Panpan Wang *(Tianjin University)*, Zhao Li *(Alibaba Group)*,
  Yazhou Zhang, Yuexian Hou, Liangzhu Ge *(Tianjin University)*
- **A Study of Context Dependencies in Multi-page Product Search** 2333
  Keping Bi *(University of Massachusetts, Amherst)*,
  Choon Hui Teo, Yesh Dattatreya, Vijai Mohan *(Search Labs, Amazon)*,
  W. Bruce Croft *(University of Massachusetts, Amherst)*
- **Query-bag Matching with Mutual Coverage for Information-seeking Conversations in E-commerce** 2337
  Zhenxin Fu *(Peking University & Alibaba Group)*, Feng Ji *(Alibaba Group)*, Wenpeng Hu *(Peking University)*,
  Wei Zhou *(Alibaba Group)*, Dongyan Zhao *(Peking University)*, Haiqing Chen *(Alibaba Group)*,
  Rui Yan *(Peking University)*
- **Neural Review Rating Prediction with User and Product Memory** 2341
  Zhigang Yuan *(Tsinghua University)*, Fangzhao Wu *(Microsoft Research Asia)*,
  Junxin Liu, Chuhan Wu, Yongfeng Huang *(Tsinghua University)*,
  Xing Xie *(Microsoft Research Asia)*
- **Intent Term Weighting in E-commerce Queries** 2345
  Saurav Manchanda *(University of Minnesota)*, Mohit Sharma *(WalmartLabs)*,
  George Karypis *(University of Minnesota)*
- **Fine-Grained Product Categorization in E-commerce** 2349
  Hongshen Chen *(JD.COM)*, Jiashu Zhao *(Wilfrid Laurier University)*, Dawei Yin *(JD.COM)*

Session: Short - Classification

- **Large Margin Prototypical Network for Few-shot Relation Classification with Fine-grained Features** 2353
  Miao Fan, Yeqi Bai, Mingming Sun, Ping Li *(Baidu Research)*
- **Meta-GNN: On Few-shot Node Classification in Graph Meta-learning** 2357
  Fan Zhou, Chengtai Cao *(University of Electronic Science and Technology of China)*,
  Kunpeng Zhang *(University of Maryland)*, Goce Trajcevski *(Iowa State University)*,
  Ting Zhong, Ji Geng *(University of Electronic Science and Technology of China)*
- **Enriching Pre-trained Language Model with Entity Information for Relation Classification** 2361
  Shanchan Wu, Yifan He *(Alibaba Group (U.S.) Inc.)*
- **Unsupervised Concept Drift Detection with a Discriminative Classifier** 2365
  Ömer Gözüaçık, Alican Büyükçakır *(Bilkent University)*, Hamed Bonab *(University of Massachusetts, Amherst)*,
  Fazli Can *(Bilkent University)*

- **Hybrid Deep Pairwise Classification for Author Name Disambiguation** 2369
  Kunho Kim, Shaurya Rohatgi, C. Lee Giles *(The Pennsylvania State University)*
- **Approximate Definitional Constructs as Lightweight Evidence for Detecting Classes Among Wikipedia Articles** 2373
  Marius Pasca *(Google)*

Session: Short - Knowledge Extraction & Generation

- **Towards the Gradient Vanishing, Divergence Mismatching and Mode Collapse of Generative Adversarial Nets** 2377
  Zhaoyu Zhang, Changwei Luo, Jun Yu *(University of Science and Technology of China)*
- **Generating Paraphrase with Topic as Prior Knowledge** 2381
  Yuanxin Liu *(Institute of Information Engineering, Chinese Academy of Sciences & University of Chinese Academy of Sciences)*, Zheng Lin *(Institute of Information Engineering, Chinese Academy of Sciences)*, Fenglin Liu *(Peking University)*, Qinyun Dai *(Shanghai Branch, CNCERT/CC)*, Weiping Wang *(Institute of Information Engineering, Chinese Academy of Sciences)*
- **Sexual Harassment Story Classification and Key Information Identification** 2385
  Yingchi Liu, Quanzhi Li *(Alibaba Group US)*, Xiaozhong Liu *(Indiana University Bloomington)*, Qiong Zhang, Luo Si *(Alibaba Group US)*
- **Neural Review Summarization Leveraging User and Product Information** 2389
  Hui Liu, Xiaojun Wan *(Peking University)*
- **Incorporating Relation Knowledge into Commonsense Reading Comprehension with Multi-task Learning** 2393
  Jiangnan Xia, Chen Wu, Ming Yan *(Alibaba DAMO Academy)*

Session: Short - Health & Sentiment

- **DIRT: Deep Learning Enhanced Item Response Theory for Cognitive Diagnosis** 2397
  Song Cheng, Qi Liu, Enhong Chen, Zai Huang, Zhenya Huang *(University of Science and Technology of China)*, Yiying Chen *(Ant Financial Services Group & University of Science and Technology of China)*, Haiping Ma, Guoping Hu *(IFLYTEK Co.,Ltd.)*
- **Neural Gender Prediction in Microblogging with Emotion-aware User Representation** 2401
  Chuhan Wu *(Tsinghua University)*, Fangzhao Wu *(Microsoft Research Asia)*, Tao Qi, Junxin Liu, Yongfeng Huang *(Tsinghua University)*, Xing Xie *(Microsoft Research Asia)*
- **Health Card Retrieval for Consumer Health Search: An Empirical Investigation of Methods** 2405
  Jimmy *(University of Queensland & University of Surabaya)*, Guido Zuccon *(University of Queensland)*, Bevan Koopman *(CSIRO)*, Gianluca Demartini *(University of Queensland)*
- **NICE: Neural In-Hospital Cost Estimation from Medical Records** 2409
  Chuhan Wu *(Tsinghua University)*, Fangzhao Wu *(Microsoft Research Asia)*, Yongfeng Huang *(Tsinghua University)*, Xing Xie *(Microsoft Research Asia)*
- **Modeling Sentiment Evolution for Social Incidents** 2413
  Yunjie Wang, Hui Li, Chen Lin *(Xiamen University)*

Session: Short - Theory

- **Adaptive Feature Redundancy Minimization** 2417
  Rui Zhang *(Arizona State University)*, Hanghang Tong *(University of Illinois at Urbana-Champaign)*, Yifan Hu *(Yahoo! Research)*
- **Finding a Maximum Clique in Dense Graphs via χ^2 Statistics** 2421
  Sourav Dutta *(Eaton Corp.)*, Juho Lauri *(Nokia Bell Labs)*
- **On Heavy-user Bias in A/B Testing** 2425
  Yu Wang *(University of California, Berkeley)*, Somit Gupta, Jiannan Lu, Ali Mahmoudzadeh, Sophia Liu *(Microsoft)*

- **Adversarial Training of Gradient-Boosted Decision Trees** 2429
  Stefano Calzavara, Claudio Lucchese *(Università Ca' Foscari Venezia)*,
  Gabriele Tolomei *(Sapienza Università di Roma)*
- **Adversarial Structured Neural Network Pruning** 2433
  Xingyu Cai *(University of Connecticut)*, Jinfeng Yi *(JD AI Research)*,
  Fan Zhang *(Zhejiang University)*, Sanguthevar Rajasekaran *(University of Connecticut)*
- **Ontology-Mediated Queries over Probabilistic Data via Probabilistic Logic Programming** 2437
  Timothy van Bremen, Anton Dries *(KU Leuven)*, Jean Christoph Jung *(Universität Bremen)*

Session: Short - Search

- **Query Embedding Learning for Context-based Social Search** 2441
  Yi-Chun Chen, Yu-Che Tsai , Cheng-Te Li *(National Cheng Kung University)*
- **Towards More Usable Dataset Search: From Query Characterization to Snippet Generation** 2445
  Jinchi Chen, Xiaxia Wang, Gong Cheng *(Nanjing University)*,
  Evgeny Kharlamov *(Bosch Center for AI & University of Oslo)*, Yuzhong Qu *(Nanjing University)*
- **Session-based Search Behavior in Naturalistic Settings for Learning-related Tasks** 2449
  Souvick Ghosh *(Rutgers University)*, Chirag Shah *(University of Washington)*
- **Best Co-Located Community Search in Attributed Networks** 2453
  Jiehuan Luo *(Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences)*,
  Xin Cao *(University of New South Wales)*, Xike Xie *(University of Science and Technology of China)*,
  Qiang Qu *(Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences)*
- **Caching Scores for Faster Query Processing with Dynamic Pruning in Search Engines** 2457
  Erman Yafay, Ismail Sengor Altingovde *(Middle East Technical University)*
- **Investigating the Learning Process in Job Search: A Longitudinal Study** 2461
  Jiaxin Mao *(Tsinghua University)*, Damiano Spina *(RMIT University)*,
  Sargol Sadeghi *(SEEK Ltd.)*, Falk Scholer, Mark Sanderson *(RMIT University)*

Session: Short - System & Database

- **Set Reconciliation with Cuckoo Filters** 2465
  Lailong Luo, Deke Guo *(National University of Defense Technology)*,
  Ori Rottenstreich *(Technion – Israel Institute of Technology)*, Richard T.B Ma *(National University of Singapore)*,
  Xueshan Luo *(National University of Defense Technology)*
- **Shared-Nothing Distributed Enumeration of 2-Plexes** 2469
  Alessio Conte *(University of Pisa)*,
  Donatella Firmani, Maurizio Patrignani, Riccardo Torlone *(Roma Tre University)*
- **Estimating the Number of Distinct Items in a Database by Sampling** 2473
  Roel Apfelbaum *(Yahoo Research)*
- **Cost-effective Resource Provisioning for Spark Workloads** 2477
  Yuxing Chen, Jiaheng Lu *(University of Helsinki)*, Chen Chen *(Huawei Canada Research Centre)*,
  Mohammad Hoque, Sasu Tarkoma *(University of Helsinki)*
- **A Sampling-Based System for Approximate Big Data Analysis on Computing Clusters** 2481
  Salman Salloum *(Shenzhen University)*,
  Yinxu Wu *(Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences & University of Chinese Academy of Sciences)*, Joshua Zhexue Huang *(Shenzhen University)*
- **TianGong-ST: A New Dataset with Large-scale Refined Real-world Web Search Sessions** ... 2485
  Jia Chen, Jiaxin Mao, Yiqun Liu, Min Zhang, Shaoping Ma *(Tsinghua University)*

Session: Applied - E-commerce

- **Virtual ID Discovery from E-commerce Media at Alibaba: Exploiting Richness of User Click Behavior for Visual Search Relevance** 2489
  Yanhao Zhang, Pan Pan, Yun Zheng, Kang Zhao, Jianmin Wu, Yinghui Xu, Rong Jin *(Alibaba Group)*

- **Autor^3: *A*utomated *R*eal-time *R*anking with *R*einforcement Learning in E-commerce Sponsored Search Advertising** 2499
  Yusi Zhang, Zhi Yang *(Peking University)*, Liang Wang, Li He *(Alibaba Group)*
- **Cross-domain Attention Network with Wasserstein Regularizers for E-commerce Search** .. 2509
  Minghui Qiu *(Alibaba Group & Zheijiang University)*,
  Bo Wang, Cen Chen, Xiaoyi Zeng, Jun Huang, Deng Cai, Jingren Zhou *(Alibaba)*,
  Forrest Sheng Bao *(Iowa State University)*
- **Conceptualize and Infer User Needs in E-commerce** 2517
  Xusheng Luo, Yonghua Yang *(Alibaba Group)*, Kenny Qili Zhu *(Shanghai Jiao Tong University)*,
  Yu Gong, Keping Yang *(Alibaba Group)*
- **Learning to Advertise for Organic Traffic Maximization in E-Commerce Product Feeds** 2527
  Dagui Chen, Junqi Jin *(Alibaba Group)*, Weinan Zhang *(Shanghai Jiao Tong University)*,
  Fei Pan, Lvyin Niu, Chuan Yu *(Alibaba Group)*, Jun Wang *(University College London)*,
  Han Li, Jian Xu, Kun Gai *(Alibaba Group)*

Session: Applied - Graph Applications

- **System Deterioration Detection and Root Cause Learning on Time Series Graphs** 2537
  Hao Huang *(GE Global Research)*, Shinjae Yoo *(Brookhaven National Laboratory)*, Yunwen Xu *(Amazon)*
- **A Dynamic Default Prediction Framework for Networked-guarantee Loans** 2547
  Dawei Cheng, Yiyi Zhang *(Shanghai Jiao Tong University)*, Fangzhou Yang *(Seek Data Inc.)*,
  Yi Tu *(Shanghai Jiao Tong University)*, Zhibin Niu *(Tianjin University)*,
  Liqing Zhang *(Shanghai Jiao Tong University)*
- **Feature Enhancement via User Similarities Networks for Improved Click Prediction in Yahoo Gemini Native** 2557
  Morelle Arian *(University of Washington)*,
  Eliran Abutbul, Michal Aharon, Yair Koren, Oren Somekh, Rotem Stram *(Yahoo Research)*
- **Large-Scale Visual Search with Binary Distributed Graph at Alibaba** 2567
  Kang Zhao, Pan Pan, Yun Zheng, Yanhao Zhang, Changxu Wang, Yingya Zhang,
  Yinghui Xu, Rong Jin *(Alibaba Group)*
- **Graph Representation Learning for Merchant Incentive Optimization in Mobile Payment Marketing** 2577
  Ziqi Liu, Dong Wang, Qianyu Yu, Zhiqiang Zhang, Yue Shen, Jian Ma, Wenliang Zhong,
  Jinjie Gu, Jun Zhou, Shuang Yang, Yuan Qi *(Ant Financial)*

Session: Applied - Recommendation and Advertising

- **Query-based Interactive Recommendation by Meta-Path and Adapted Attention-GRU** 2585
  Yu Zhu, Yu Gong, Qingwen Liu, Yingcai Ma, Wenwu Ou, Junxiong Zhu *(Alibaba Group)*,
  Beidou Wang *(State Key Laboratory of CAD&CG, Zhejiang University)*, Ziyu Guan *(Xidian University)*,
  Deng Cai *(State Key Laboratory of CAD&CG, Zhejiang University)*
- **Learning Adaptive Display Exposure for Real-Time Advertising** 2595
  Weixun Wang *(Tianjin University)*, Junqi Jin *(Alibaba Group)*, Jianye Hao *(Tianjin University)*,
  Chunjie Chen, Chuan Yu *(Alibaba Group)*, Weinan Zhang *(Shanghai Jiao Tong University)*,
  Jun Wang *(University College London)*, Xiaotian Hao, Yixi Wang *(Tianjin University)*,
  Han Li, Jian Xu, Kun Gai *(Alibaba Group)*
- **What You Look Matters? Offline Evaluation of Advertising Creatives for Cold-start Problem** 2605
  Zhichen Zhao, Lei Li, Bowen Zhang, Meng Wang, Yuning Jiang, Li Xu, Fengkun Wang,
  Wei-Ying Ma *(Bytedance Inc)*
- **Multi-Interest Network with Dynamic Routing for Recommendation at Tmall** 2615
  Chao Li, Zhiyuan Liu, Mengmeng Wu, Yuchi Xu, Huan Zhao, Pipei Huang *(Alibaba Group)*,
  Guoliang Kang *(University of Technology Sydney)*, Qiwei Chen, Wei Li *(Alibaba Group)*,
  Dik Lun Lee *(Hong Kong University of Science and Technology)*

- **Learning to be Relevant: Evolution of a Course Recommendation System** 2625
  Shivani Rao, Konstantin Salomatin, Gungor Polatkan, Mahesh Joshi,
  Sneha Chaudhari, Vladislav Tcheprasov, Jeffrey Gee, Deepak Kumar *(LinkedIn Corporation)*
- **SDM: Sequential Deep Matching Model for Online Large-scale Recommender System** 2635
  Fuyu Lv, Taiwei Jin *(Alibaba Group)*, Changlong Yu *(The Hong Kong University of Science and Technology)*,
  Fei Sun, Quan Lin, Keping Yang *(Alibaba Group)*,
  Wilfred Ng *(The Hong Kong University of Science and Technology)*

Session: Applied - Urbanism and Mobility

- **Multi-Agent Reinforcement Learning for Order-dispatching via Order-Vehicle Distribution Matching** 2645
  Ming Zhou, Jiarui Jin, Weinan Zhang *(Shanghai Jiao Tong University)*,
  Zhiwei Qin, Yan Jiao, Chenxi Wang *(DiDi AI Labs)*, Guobin Wu *(DiDi Research)*,
  Yong Yu *(Shanghai Jiao Tong University)*, Jieping Ye *(DiDi AI Labs)*
- **MONOPOLY: Learning to Price Public Facilities for Revaluing Private Properties with Large-Scale Urban Data** 2655
  Miao Fan, Jizhou Huang, An Zhuo, Ying Li, Ping Li , Haifeng Wang *(Baidu Inc.)*
- **CityTraffic: Modeling Citywide Traffic via Neural Memorization and Generalization Approach** 2665
  Xiuwen Yi *(JD Intelligent Cities Research, JD Intelligent Cities Business Unit, & Tsinghua University)*,
  Zhewen Duan *(Xidian University & JD Intelligent Cities Research, JD Intelligent Cities Business Unit)*,
  Ting Li *(JD Intelligent Cities Research & JD Intelligent Cities Business Unit)*,
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  Junbo Zhang *(JD Intelligent Cities Research, JD Intelligent Cities Business Unit & Southwest Jiaotong University)*,
  Yu Zheng *(JD Intelligent Cities Research, JD Intelligent Cities Business Unit & Southwest Jiaotong University)*
- **Deep Dynamic Fusion Network for Traffic Accident Forecasting** 2673
  Chao Huang *(JD Digits)*, Chuxu Zhang *(University of Notre Dame)*, Peng Dai, Liefeng Bo *(JD Digits)*
- **Matrix Factorization for Spatio-Temporal Neural Networks with Applications to Urban Flow Prediction** 2683
  Zheyi Pan, Zhaoyuan Wang, Weifeng Wang, Yong Yu *(Shanghai Jiao Tong University)*,
  Junbo Zhang *(JD Intelligent Cities Research, JD Intelligent Cities Business Unit & Southwest Jiaotong University)*,
  Yu Zheng *(JD Intelligent Cities Research, JD Intelligent Cities Business Unit & Xidian University)*

Session: Applied - Language Models

- **Semantically Driven Auto-completion** 2693
  Konstantine Arkoudas, Mohamed Yahya *(Bloomberg)*
- **Spam Review Detection with Graph Convolutional Networks** 2703
  Ao Li, Zhou Qin, Runshi Liu, Yiqun Yang, Dong Li *(Alibaba Group)*
- **Industry Specific Word Embedding and its Application in Log Classification** 2713
  Elham Khabiri, Wesley M. Gifford, Bhanukiran Vinzamuri, Dhaval Patel *(IBM Research)*,
  Pietro Mazzoleni *(IBM)*
- **Document-Level Multi-Aspect Sentiment Classification for Online Reviews of Medical Experts** 2723
  Tian Shi *(Virginia Tech)*, Vineeth Rakesh *(Interdigital)*, Suhang Wang *(The Pennsylvania State University)*,
  Chandan K. Reddy *(Virginia Tech)*

Session: Applied - Novel Applications

- **Deep Learning for Blast Furnaces: Skip-Dense Layers Deep Learning Model to Predict the Remaining Time to Close Tap-holes for Blast Furnaces** 2733
  Keeyoung Kim *(The State University of New York (SUNY), Korea)*, Byeongrak Seo *(IngenioAI)*,
  Sang-Hoon Rhee *(Linkgenesis)*, Seungmoon Lee *(Pohang Iron and Steel Company (POSCO))*,
  Simon S. Woo *(Sungkyunkwan University)*

- **Deep Graph Similarity Learning for Brain Data Analysis** 2743
  Guixiang Ma, Nesreen K. Ahmed, Theodore L. Willke, Dipanjan Sengupta *(Intel Labs)*,
  Michael W. Cole *(Rutgers University)*, Nicholas B. Turk-Browne *(Yale University)*,
  Philip S. Yu *(University of Illinois at Chicago)*
- **How to Find It Better? Cross-Learning for WeChat Mini Programs** 2753
  He Li *(Tencent Inc. & Peking University)*, Zhiqiang Liu, Sheng Xu, Zhiyuan Lin *(Tencent Inc.)*,
  Xiangqun Chen *(Peking University)*
- **Job2Vec: Job Title Benchmarking with Collective Multi-View Representation Learning** 2763
  Denghui Zhang *(Rutgers University)*, Junming Liu *(City University of Hong Kong)*,
  Hengshu Zhu *(Baidu Inc)*, Yanchi Liu *(Rutgers University)*, Lichen Wang *(Northeastern University)*,
  Pengyang Wang *(University of Central Florida)*, Hui Xiong *(Rutgers University & Baidu Inc.)*
- **Learning to Predict Human Stress Level with Incomplete Sensor Data from Wearable Devices** 2773
  Jyun-Yu Jiang, Zehan Chao, Andrea L. Bertozzi, Wei Wang, Sean D. Young,
  Deanna Needell *(University of California, Los Angeles)*
- **Fine-Grained Fuel Consumption Prediction** 2783
  Chenguang Fang, Shaoxu Song, Zhiwei Chen, Acan Gui *(Tsinghua University)*

Session: Applied - Online and User Behaviors

- **Soft Frequency Capping for Improved Ad Click Prediction in Yahoo Gemini Native** 2793
  Michal Aharon, Yohay Kaplan, Rina Levy, Oren Somekh *(Yahoo Research)*,
  Ayelet Blanc, Neetai Eshel, Avi Shahar, Assaf Singer, Alex Zlotnik *(Tech Yahoo)*
- **Adversarial Factorization Autoencoder for Look-alike Modeling** 2803
  Khoa D. Doan *(Virginia Tech)*, Pranjul Yadav *(Criteo AI Labs)*, Chandan K. Reddy *(Virginia Tech)*
- **Concept Drift Adaption for Online Anomaly Detection in Structural Health Monitoring** 2813
  Hongda Tian *(University of Technology Sydney)*, Nguyen Lu Dang Khoa *(Data61 | CSIRO)*,
  Ali Anaissi *(The University of Sydney)*, Yang Wang, Fang Chen *(University of Technology Sydney)*
- **Multi-task based Sales Predictions for Online Promotions** 2823
  Shen Xin *(Zhejiang University)*, Martin Ester *(Simon Fraser University)*,
  Jiajun Bu, Chengwei Yao *(Zhejiang University)*, Zhao Li *(Alibaba Group)*,
  Xun Zhou *(Zhejiang University)*, Yizhou Ye *(Alibaba Group)*, Can Wang *(Zhejiang University)*
- **Experimental Study of Multivariate Time Series Forecasting Models** 2833
  Jiaming Yin, Weixiong Rao *(Tongji University)*, Mingxuan Yuan, Jia Zeng *(Huawei Noah's Ark Lab)*,
  Kai Zhao *(Georgia State University)*, Chenxi Zhang, Jiangfeng Li, Qinpei Zhao *(Tongji University)*
- **GMTL: A GART Based Multi-task Learning Model for Multi-Social-Temporal Prediction in Online Games** 2841
  Jianrong Tao, Linxia Gong, Changjie Fan *(NetEase Inc.)*, Longbiao Chen *(Xiamen University)*,
  Dezhi Ye *(NetEase Inc.)*, Sha Zhao *(Zhejiang University)*
- **Learning Compositional, Visual and Relational Representations for CTR Prediction in Sponsored Search** 2851
  Xiao Yang, Tao Deng, Weihan Tan, Xutian Tao, Junwei Zhang, Shouke Qin, Zongyao Ding *(Baidu Inc.)*

Session: Demo - Demo Session 1

- **Inspect What Your Location History Reveals About You: Raising user awareness on privacy threats associated with disclosing his location data** 2861
  Antoine Boutet *(Insa-Lyon / Inria)*, Sébastien Gambs *(Uqam)*
- **PODIUM: Probabilistic Datalog Analysis via Contribution Maximization** 2865
  Tova Milo, Yuval Moskovitch, Brit Youngmann *(Tel Aviv University)*
- **Document in Context of its Time (DICT): Providing Temporal Context to Support Analysis of Past Documents** 2869
  Adam Jatowt *(Kyoto University & AIRC, AIST)*,
  Ricardo Campos *(Polytechnic Institute of Tomar, LIAAD–INESC TEC)*,
  Sourav S. Bhowmick *(Nanyang Technological University)*, Antoine Doucet *(University of La Rochelle)*

- **ATENA: An Autonomous System for Data Exploration Based on Deep Reinforcement Learning** 2873
  Ori Bar El, Tova Milo, Amit Somech *(Tel Aviv University)*
- **ExplIQuE: Interactive Databases Exploration with SQL** 2877
  Marie Le Guilly, Jean-Marc Petit, Vasile-Marian Scuturici *(Univ Lyon, INSA Lyon, CNRS, LIRIS UMR 5205)*, Ihab F. Ilyas *(University of Waterloo)*
- **TraVis: An Interactive Visualization System for Mining Inbound Traveler Activities by Leveraging Mobile Ad Request Data** 2881
  Pei-Xun Wang, Hsuan Chiu, Wen-Qian Chen, Che-Chia Chang, Yu-Hsuan Huang, Tzu-Hao Huang, Yuchun Lai, Chia-Hu Chang *(Vpon Inc.)*
- **Understanding Data in the Blink of an Eye** 2885
  Matteo Paganelli *(DIEF-UNIMORE)*, Paolo Sottovia *(DISI-UNITN)*, Antonio Maccioni *(Collective[i])*, Matteo Interlandi *(Microsoft)*, Francesco Guerra *(DIEF - UNIMORE)*
- **SIMILANT: An Analytic Tool for Similarity Modeling** 2889
  David Bernhauer *(Czech Technical University in Prague & Charles University)*, Tomáš Skopal, Irena Holubová, Ladislav Peška, Martin Svoboda *(Charles University)*
- **MithraLabel: Flexible Dataset Nutritional Labels for Responsible Data Science** 2893
  Chenkai Sun *(University of Michigan)*, Abolfazl Asudeh *(University of Illinois at Chicago)*, H. V. Jagadish *(University of Michigan)*, Bill Howe *(University of Washington)*, Julia Stoyanovich *(New York University)*
- **PRIVATA: Differentially Private Data Market Framework using Negotiation-based Pricing Mechanism** 2897
  Kangsoo Jung, Junkyu Lee, Kunyoung Park, Seog Park *(Sogang University)*
- **MiCRon: Making Sense of News via Relationship Subgraphs** 2901
  Zixian Huang, Shuxin Li, Gong Cheng *(Nanjing University)*, Evgeny Kharlamov *(Bosch Center for AI)*, Yuzhong Qu *(Nanjing University)*
- **LuPe: A System for Personalized and Transparent Data-driven Decisions** 2905
  Sarah Oppold, Melanie Herschel *(University of Stuttgart)*
- **Insta-Search: Towards Effective Exploration of Knowledge Graphs** 2909
  Madhulika Mohanty, Maya Ramanath *(Indian Institute of Technology, Delhi)*

Session: Demo - Demo Session 2

- **SkyRec: Finding Pareto Optimal Groups** 2913
  Jinfei Liu *(Emory University & Georgia Institute of Technology)*, Li Xiong *(Emory University)*, Jian Pei *(Simon Fraser University)*, Jun Luo *(Machine Intelligence Center Lenovo Group Limited)*, Haoyu Zhang *(Indiana University Bloomington)*, Si Zhang *(Jianghan University)*
- **CurrentClean: Interactive Change Exploration and Cleaning of Stale Data** 2917
  Zheng Zheng, Tri Minh Quach, Ziyi Jin, Fei Chiang *(McMaster University)*, Mostafa Milani *(The University of British Columbia)*
- **PatMat: A Distributed Pattern Matching Engine with Cypher** 2921
  Kongzhang Hao, Zhengyi Yang, Longbin Lai *(University of New South Wales)*, Zhengmin Lai, Xin Jin *(ECNU)*, Xuemin Lin *(University of New South Wales)*
- **On a Chatbot Conducting Virtual Dialogues** 2925
  Boris Galitsky *(Oracle Inc.)*, Dmitry Ilvovsky *(National Research University Higher School of Economics)*
- ***Rehab-Path:* Recommending Alcohol and Drug-free Routes** 2929
  Yihong Zhang *(Osaka University)*, Panote Siriaraya, Yukiko Kawai *(Kyoto Sangyo University)*, Adam Jatowt *(Kyoto University)*
- **kBrowse: kNN Graph Browser** 2933
  Ramon Bespinyowong, Anthony K. H. Tung *(National University of Singapore)*

- **BIP! Finder: Facilitating Scientific Literature Search by Exploiting Impact-Based Ranking** 2937
  Thanasis Vergoulis *(IMSI, Athena RC)*,
  Serafeim Chatzopoulos *(University of the Peloponnese & IMSI, Athena RC)*,
  Ilias Kanellos *(IMSI, Athena RC)*,
  Panagiotis Deligiannis, Christos Tryfonopoulos *(University of the Peloponnese)*,
  Theodore Dalamagas *(IMSI, Athena RC)*
- **BeLink: Querying Networks of Facts, Statements and Beliefs** 2941
  Tien-Duc Cao *(Inria and LIX (UMR 7161, CNRS and Ecole polytechnique))*,
  Ludivine Duroyon, François Goasdoué *(Univ Rennes, CNRS, Inria, IRISA)*,
  Ioana Manolescu *(Inria and LIX (UMR 7161, CNRS and Ecole polytechnique))*,
  Xavier Tannier *(Sorbonne Université and Inria)*
- **TuneR: Fine Tuning of Rule-based Entity Matchers** 2945
  Matteo Paganelli *(DIEF-UNIMORE)*, Paolo Sottovia *(DISI-UNITN)*, Francesco Guerra *(DIEF-UNIMORE)*,
  Yannis Velegrakis *(Utrecht University)*
- **I-REX: A Lucene Plugin for EXplainable IR** 2949
  Dwaipayan Roy *(GESIS - Leibniz Institute for the Social Sciences)*,
  Sourav Saha, Mandar Mitra *(Indian Statistical Institute)*,
  Bihan Sen *(Microsoft, India)*, Debasis Ganguly *(IBM Research Lab)*
- **Model Asset eXchange: Path to Ubiquitous Deep Learning Deployment** 2953
  Alex Bozarth, Brendan Dwyer, Fei Hu, Daniel Jalova, Karthik Muthuraman, Nick Pentreath, Simon Plovyt,
  Gabriela de Queiroz, Saishruthi Swaminathan, Patrick Titzler, Xin Wu, Hong Xu, Frederick R. Reiss,
  Vijay Bommireddipalli *(IBM)*
- **ReducE-Comm: Effective Inventory Reduction System for E-Commerce** 2957
  Shay Gershtein, Tova Milo *(Tel Aviv University)*, Slava Novgorodov *(eBay Research)*
- **dEFEND: A System for Explainable Fake News Detection** 2961
  Limeng Cui *(Penn State University)*, Kai Shu *(Arizona State University)*,
  Suhang Wang, Dongwon Lee *(Penn State University)*, Huan Liu *(Arizona State University)*

Tutorials

- **Enterprise Knowledge Graph From Specific Business Task to Enterprise Knowledge Management** 2965
  Rong Duan *(Huawei Technology)*, Yanghua Xiao *(Fudan University)*
- **Taming Social Bots: Detection, Exploration and Measurement** 2967
  Abdullah Mueen *(University of New Mexico)*, Nikan Chavoshi *(Oracle Corporation)*,
  Amanda Minnich *(Lawrence Livermore National Laboratories)*
- **Learning-Based Methods with Human-in-the-Loop for Entity Resolution** 2969
  Sairam Gurajada, Lucian Popa, Kun Qian, Prithviraj Sen *(IBM Research - Almaden)*
- **Learning and Reasoning on Graph for Recommendation** 2971
  Xiang Wang *(National University of Singapore)*,
  Xiangnan He *(University of Science and Technology of China)*,
  Tat-Seng Chua *(National University of Singapore)*
- **Recent Developments of Deep Heterogeneous Information Network Analysis** 2973
  Chuan Shi *(Beijing University of Posts and Telecommunications)*,
  Philip S. Yu *(University of Illinois at Chicago)*
- **Synergy of Database Techniques and Machine Learning Models for String Similarity Search and Join** 2975
  Jiaheng Lu *(University of Helsinki)*, Chunbin Lin *(Amazon AWS)*,
  Jin Wang *(University of California, Los Angeles)*, Chen Li *(University of California Irvine)*
- **Realtime Object Detection via Deep Learning-based Pipelines** 2977
  James G. Shanahan *(Bryant University & University of California, Berkeley)*,
  Liang Dai *(Facebook & University of California, Santa Cruz)*

- **Recommendation for Multi-stakeholders and through Neural Review Mining** 2979
  Muthusamy Chelliah *(Flipkart)*, Yong Zheng *(Illinois Institute of Technology)*,
  Sudeshna Sarkar *(Indian Institute of Technology)*
- **Machine Learning on Graphs with Kernels** 2983
  Michalis Vazirgiannis *(École Polytechnique & AUEB)*, Giannis Nikolentzos *(École Polytechnique)*,
  Giannis Siglidis *(Sorbonne Université)*

Workshop Summaries

- **DTMBIO 2019: The Thirteenth International Workshop on Data and Text Mining in Biomedical Informatics** 2985
  Hyojung Paik *(KISTI)*, Ruibin Xi *(Peking University)*,
  Doheon Lee *(Korea Advanced Institute of Science & Technology)*
- **Knowledge-Driven Analytics and Systems Impacting Human Quality of Life** 2989
  Arijit Ukil *(Tata Consultancy Services)*, Leandro Marin *(University of Murcia)*,
  Antonio Jara *(University of Applied Sciences Western Switzerland (HES-SO))*,
  John Farserotu *(Centre Suisse d'Electronique et de Microtechnique (CSEM))*
- **HENA 2019: The 3rd Workshop of Heterogeneous Information Network Analysis and Applications** 2991
  Chuan Shi *(Beijing University of Posts and Telecommunications)*,
  Yanfang Ye *(Case Western Reserve University)*, Jiawei Zhang *(Florida State University)*
- **EYRE 2019: 2nd International Workshop on EntitY REtrieval** 2993
  Gong Cheng *(Nanjing University)*, Kalpa Gunaratna *(Samsung Research America)*,
  Jun Wang *(University College London)*
- **CIKM 2019 Workshop on Artificial Intelligence in Transportation (AI in transportation)** 2995
  Weinan Zhang, Haiming Jin *(Shanghai Jiao Tong University)*,
  Lingyu Zhang, Hongtu Zhu *(AI Labs, DiDi)*,
  Jessie Zhenhui Li *(The Pennsylvania State University)*, Jieping Ye *(AI Labs, DiDi)*
- **GRLA 2019: The first International Workshop on Graph Representation Learning and its Applications** 2997
  Huawei Shen *(CAS Key Laboratory of Network Data Science and Technology, Institute of Computing Technology, Chinese Academy of Sciences)*,
  Jian Tang *(HEC Montreal Montreal Institute for Learning Alogorithms)*,
  Peng Bao *(School of Software Engineering, Beijing Jiaotong University)*
- **International Workshop on Model Selection and Parameter Tuning in Recommender Systems** 2999
  Fikret Sivrikaya *(GT-ARC gemeinnützige GmbH)*, Sahin Albayrak *(Technische Universität Berlin)*,
  Defu Lian *(University of Science and Technology of China)*
- **2nd Workshop on Knowledge-aware and Conversational Recommender Systems - KaRS** .. 3001
  Vito Walter Anelli, Tommaso Di Noia *(Polytechnic University of Bari)*
- **BigScholar 2019: The 6th Workshop on Big Scholarly Data** 3003
  Feng Xia *(Dalian University of Technology)*, Huan Liu *(Arizona State University)*,
  Irwin King *(The Chinese University of Hong Kong)*, Kuansan Wang *(Microsoft Research)*

Author Index 3005

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