Intelligent-Commerce Research in China

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With the rapid development of Web-based applications, the demand has been quickly growing for intelligent automation of e-commerce activities. Applying AI techniques to e-commerce applications leads to the intelligent-commerce paradigm. In this paradigm, commerce processes and systems employ intelligent software systems to increase automation, facilitate coordination and resource utilization, and assist human-machine interaction. The goal is to increase productivity, efficiency, and customer satisfaction.

Chinese AI researchers have been pursuing intelligent-commerce research since the 1990s, often jointly with information systems, marketing, and operations management researchers. Here, we survey several representative research streams.

Multiagent Decision Making

The centerpiece of the agent-mediated e-commerce platform is multiagent decision making, which has been studied extensively by economics, computer science, marketing, and behavioral researchers. One key perspective that AI researchers have brought to this research is that you can exploit machine learning and computational-intelligence techniques to facilitate these decision-making processes.

The most commonly used market mechanisms in e-commerce applications are negotiation and auction. D. Zeng and K. Sycara proposed a sequential decision-making model of negotiation.[1] This negotiation framework models the learning of negotiating agents as a Bayesian belief update process. Computational-experiment results indicated that learning can be beneficial in this model.

Y. Yuan and Y.Q. Liang investigated a coevolutionary genetic algorithm for multiagent negotiation.[2] This algorithm extracts each negotiating party's strategy space and encodes it as a strategy population. It simulates the coevolution process of multiple strategy populations among which a host-parasite interspecies relationship exists. After the coevolution stage, each strategy population will converge to an optimal population if an optimal strategy exists. This approach lets negotiating agents generate optimal strategies adaptively and automatically. Yuan's later research also studied multiagent negotiation from the perspective of evolutionary game theory and proved that coevolution can lead to optimal strategies (in a game-theoretic sense).

W. Han, Y. Wang, and C.D. Wang introduced a self-adaptive fuzzy-reasoning algorithm for e-commerce negotiation.[3] Buyer and seller agents can use this algorithm to participate in continuous negotiations. E-commerce agents can also change these fuzzy rules on the fly on the basis of the current market situation and these agents' own characteristics.

Online-auction researchers have heavily used computational-intelligence and agent-modeling techniques to analyze the auction mechanism. J. Chen, X.L. Chen, and X.P. Song analyzed the seller's pricing strategy in the context of a group-buying auction (GBA).[4] GBAs, a popular form of online auction (especially in China), aggregate bidder demands to gain volume discounts. On the basis of the bidders' stochastic arrival and their optimal strategies under the independent private-value assumption, these researchers analyzed the sellers' optimal price curve. They found that the best discount is zero, which implies the optimal GBA is equivalent to the optimal fixed-pricing mechanism (FPM). They then compared the GBA with the FPM in two special cases: economy of scale and the risk-seeking seller. In both cases, GBA outperformed FPM.

J. Fu, P.J. Shao, and X.P. Yang constructed the Bayesian Nash equilibrium of incomplete-information games in online double auctions from the viewpoint of experimental economics.[5] Through computer simulations, they analyzed their model's characteristics and found that it's resource efficient and can help improve online auction efficiency.

Keyword Advertising

In recent years, keyword advertising or sponsored search has become the most successful and rapidly growing sector of the online-advertising industry. In this new business

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model, advertisers purchase Web-search-related advertisement positions through keyword auctions. This mechanism has generated a significant portion of many Web search engine companies' revenues, and related research issues have attracted keen interest from computer scientists and economists. Much research in this area focuses on four issues: auction mechanism design, bidding-strategy optimization, game-theoretic equilibrium analysis, and keyword generation and recommendation.

An auction mechanism's specification typically comprises allocation rules, payment rules, and resource-packaging rules. Most studies focus on the design, evaluation, and validation of auction mechanisms, applying mechanism design theory (a branch of game theory) and various computational approaches. For example, through computational simulations, J. Feng, K.B. Hemant, and M.P. David compared four mechanisms for allocating sponsored slots in keyword advertising, including two stylized versions of real-world mechanisms: Yahoo!/Overture's v ranking mechanism and Google's $v \times a$ ranking mechanism.[6] Their simulation results indicated that Google's mechanism performs as well as or better than other mechanisms in almost all cases.

J.Q. Chen and D. Liu studied the resource-packaging problem, aiming to determine an optimal design of share structures in unit-price auctions with independent private valuation.[7] They modeled advertising exposure as discrete resources measured by shares. Their discussion focused on two aspects. First, in a model with homogeneous resources, they found that no equal-sized shares can exist in the optimal share structures and that multishare structures arise as the optimal share structure when bidders' valuation for exposure is concave. Second, in a model with heterogeneous resources, it's optimal to auction shares separately if bidders strongly prefer one resource over the other. Otherwise, the auctioneer might be better off by pooling different resources for auction, which might increase competition among bidders.

Strategy optimization aims at generating optimal or near-optimal bidding strategies for advertisers. To develop such strategies, researchers have widely applied machine learning methods. L.W. Hou, L.P. Wang, and K. Li identified a set of relevant variables affecting keyword auction strategies and developed two predictive models based on Bayesian networks.[8] These variables are modeled in connection with historical data to simulate observed bidding behavior. The authors validated these predictions' effectiveness using empirical auction data and showed that the predictions with Bayesian networks produce close-to-reality results.

D. Zeng, C.C. James, and D. Moshe proposed analytical models to make effective bidding decisions in multiple auctions that consider combinatorial interdependency across markets.[9] These models focus on coordinating bidding activities across multiple auctions. In certain simplified scenarios, optimal bidding strategies can be derived.

Equilibrium analysis research usually models a keyword auction as a formal game and investigates solution concepts such as the Nash equilibrium or its refinements (usually a Bayesian Nash equilibrium). T.M. Bu, X.T. Deng, and Q. Qi proposed a forward-looking Nash equilibrium for the generalized second-price (GSP) auction, which is a widely studied sponsored-search auction protocol.[10] The authors proved that the proposed equilibrium concept is a unique solution for the GSP auction, and more importantly, will result in the same payoff for both bidders and auctioneers as in the theoretically optimal Vickrey-Clarke-Groves auction.

J. Feng and X.Q. Zhang studied the bidding strategy in a real-time environment with a dynamic model, and identified the Markov-perfect-equilibrium bidding strategy.[11] They found that in dynamic environments, the equilibrium price trajectory will follow a cyclical pattern—"escalating" phases interrupted by "collapsing" phases—similar to the Edgeworth cycle. They verified these theoretical predictions through an empirical framework based on Markov switching regression.

As to keyword generation and recommendation research, semantic techniques have played an important role. Y.F. Chen, G.R. Xue, and Y. Yu proposed a keyword suggestion method that fully exploits the semantic knowledge captured in the concept hierarchy.[12] Given a keyword, they first match it with some relevant concepts, which they use to substantiate the target keyword's meanings. Their approach then recommends new keywords based on this semantic hierarchy. Experimental results show that these recommended keywords can provide effective operational help to advertisers.

Most online social-networking sites, actively supported by e-commerce companies, let users express their preferences and share their recommendations and opinions.

Social Networks in Commerce

In the past few years, online social-networking sites in China have been driving an increasing volume of traffic to e-tailers. Most of these sites, actively supported by e-commerce companies, let users express their preferences and share their recommendations and opinions. These sites also feature product reviews contributed by the early adopters and ratings on the reviews given by the community. In this virtual space, members of these online social groups can significantly influence consumers' purchasing decisions. There's a critical need to study qualitatively and quantitatively, from an e-commerce perspective, the organizing principles governing the evolutionary paths of, and influence patterns on, these e-commerce social communities.

This area has been receiving increased attention from Chinese researchers. Y. Zhao and colleagues studied actual social networks in the Maze peer-to-peer file-sharing network, which includes a network of users' friends and a download network.[13] Through empirical analysis, they observed that these two networks as well as the combined network exhibit the same "small-world" property as in many real-world complex networks.

Y.L. Cai and colleagues discussed how to effectively establish and evaluate trust between a seller and a buyer in a mobile e-commerce system.[14] They argued that irrespective of whether trust can be developed from a buyer's side, a seller often strongly influences purchasing decisions, especially in customer-to-customer e-commerce. On the basis of this finding, they proposed

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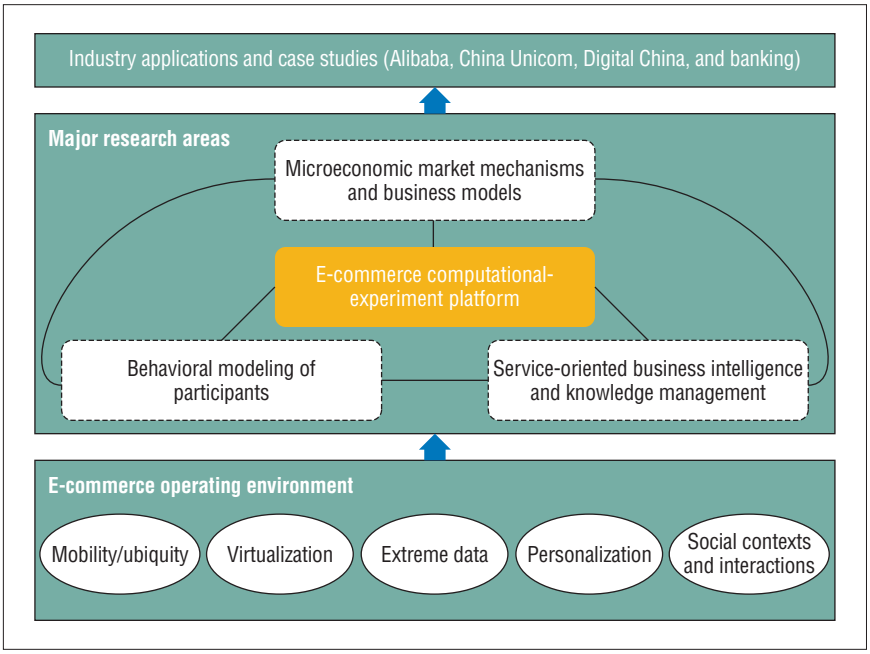

Figure 1. The National Natural Science Foundation of China e-commerce research project. This project aims at investigating a range of core scientific challenges facing e-commerce practice in environments with ubiquity, virtualization, abundance of extreme data, needs for personalization, and increasingly broadened social contexts and interactions.

a social-network-based recommendation model for mobile e-commerce. This model is based on social relationships, actual geographical distances, and various connections mined from historical transaction data records between buyers and sellers.

Studies of social networks in real-world offline communities typically focus on purely topological characteristics, largely ignoring semantic information associated with the network nodes and links. D. Zhou and colleagues proposed two general Bayesian models for semantics-based community discovery in social networks.[15] They introduced a sampling algorithm to address traditional methods' efficiency and performance problems. Their results show that their approach successfully detects the communities of individuals and can provide semantic descriptions of these communities.

J. Jiang and N. Yang studied how financial news and online postings frequently lead to emergence and evolution of certain types of sentiments among investors.[16] They proposed and tested a conceptual model that considers several key factors (most of which are semantically driven) of financial news and postings that can influence investor sentiments.

Discovering social interests shared by groups of users can help connect people with common interests and encourage them to contribute and share contents. Representing and detecting user interests in rich, dynamic environments, however, isn't easy. X. Li, L. Guo, and Y.E. Zhao presented a social-interest-discovery approach based on user-generated tags.[17] Their empirical analysis, based on a large data set collected from social-bookmarking Web sites, reveals that one generally can use patterns of frequent co-occurrences of user tags to characterize and capture topics of user interest.

Q. Mei and colleagues proposed a novel approach to tackle topic modeling with a network structure, integrating statistical topic detection methods with graph-based modeling and discrete regularization.[18] Their method bridges the gap between topic modeling and social-network analysis and can produce results such as text summaries of the topics, topic mapping on the network, and topically driven social communities.

Recommender Systems

These systems are among the most successful intelligent e-commerce technologies, and the related interdisciplinary academic research has been rapidly accumulating. L. Liu and X.L. Ren reviewed recent research on the theories, methods, techniques, and applications of personalized recommender systems.[19] The covered topics include data collection and modeling, recommendation algorithms, recommender system evaluation, and such systems' commercial and social impact. They also discussed specific applications of recommender systems in banking and insurance, knowledge management, and customer relationship management.

Collaborative filtering is at the core of many recommender systems and has met with wide success. Nonetheless, the effective application of collaborative-filtering techniques faces many technical challenges, owing to the high dimensionality and sparsity of user-item rating/transaction matrices. F.R. Gao and colleagues proposed a collaborative-filtering method based on matrix clustering to overcome some of these challenges.[20] Their matrix-clustering algorithm can partition the user-item rating matrices and operate on low-dimensional data matrices. An extensive performance study shows that their method can outperform traditional collaborative-filtering algorithms, reduce the neighbor search space, and improve recommendation accuracy.

To better understand consumer purchase behavior in e-commerce settings, Z. Huang, D. Zeng, and H. Chen applied random-graph theory to analyze bipartite consumer-product graphs representing sales transactions.[21] Using two real-world e-commerce data sets, they found that such graphs demonstrate topological features that significantly deviate from theoretical predictions based on standard random-graph models. These findings motivated them to develop a recommendation algorithm based on graph partitioning, aimed at achieving high clustering coefficients as observed in the real-world graphs. They showed empirically that this algorithm significantly outperforms representative collaborative-filtering algorithms when the consumer-product graphs' clustering coefficients are sufficiently larger than what can be accounted for by the standard algorithms.

Information Retrieval and the Semantic Web

Many e-commerce transactions start with consumers searching online for product

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or service information. Consequently, information-retrieval techniques and, more recently, Semantic Web technology have been an integral component of intelligent-commerce platforms.

X.H. Tang and G.Q. Chen explored equivalence and transformation properties of algebraic operators in the context of querying large-scale data sets with imprecise information (for example, using "young" for customer ages or "high" for sales performance).[22] With extended notions of data closeness and approximate match, Tang and Chen use these properties in query formulation and retrieval path optimization to support efficient data manipulation and search.

Z. Wang, Q. Wang, and D.W. Wang analyzed the problem of searching for business information in an e-commerce environment.[23] They proposed a search method using a Hopfield neural network with the Internet as an information source, integrating AI and information-retrieval techniques. Their approach represents business-information features as weights associated with links. The Hopfield neural network automatically generates a set of extended query terms in accordance with the user-provided query keywords. Searching general-purpose search engines with those extended query terms, this approach can expand the search scope and improve search precision to provide valuable business information for enterprise users.

The Semantic Web can provide interoperability from the syntactic level to the semantic level for intelligent agents that typically interact through Web services protocols. F.J. Zhong and B. Mu proposed a promising e-commerce model based on the Semantic Web; its implementation relies on Web services and intelligent agents.[24] This model has three main advantages. First, it uses Semantic Web techniques to process information extracted from various Web resources with explicit domain-specific semantics. Second, by integrating Semantic Web and Web services techniques, it can lead to loosely coupled applications with highly reliable systems properties. Finally, the combined intelligent-agent and Semantic Web techniques can deal with various service tasks automatically with less human interference, resulting in a framework that promises environmental independence, active integration, and automatic maintenance.

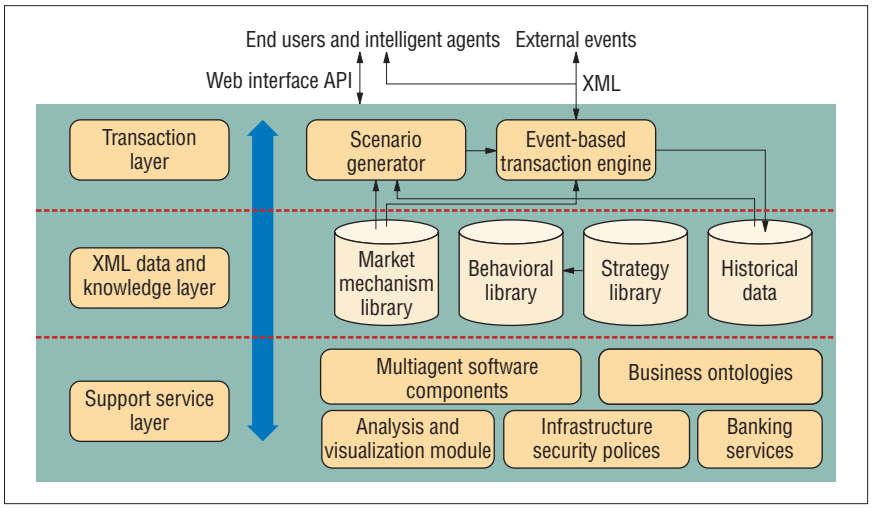

Figure 2. The architectural design of an e-commerce computational-experiment platform. This platform will play a central role in testing, validating, and evaluating theories, models, and algorithms developed from the National Natural Science Foundation of China project.

Computational Experiments

Social-computing research has been gaining significant momentum,[25,26] and one major application area of social computing is e-commerce. Many Chinese researchers have conducted related studies in this emerging field. In particular, they're extensively studying computational experiments as a major component of an established social-computing research framework.[25]

Researchers have argued that social studies traditionally rely on passive observations and statistical methods because repeatable experiments are difficult. Even when experiments are permissible, many intriguing human and societal factors might limit their use and make interpretation of findings difficult. Because analytical methods can solve only a handful of highly stylized and clean problems, finding an effective way to conduct meaningful experiments becomes critical.

Computational experiments are a natural extension of computer simulation techniques and are part of the ACP (artificial society, computational experiments, and parallel execution) framework.[27] Recognizing that e-commerce researchers face unique challenges such as ubiquity, virtualization, abundance of extreme data, needs for personalization, and the increasingly broadened social context associated with e-commerce practice, the National Natural Science Foundation of China recently initiated a large multidisciplinary e-commerce project.

Figure 1 illustrates this project's major components, covering microeconomic market mechanisms and business models, behavioral modeling of e-commerce participants, service-oriented business intelligence and knowledge management, and an e-commerce computational-experiment platform (see Figure 2). This platform will play a central role in the project, enabling integrated experimental research methods that weren't possible in previous e-commerce research. It aims to deliver an agent-based modeling, experimental, and integrative framework. Through this framework, researchers will be able to use real-world data sets and synthetic scenarios to test and validate theories, models, and algorithms developed from the study of market mechanisms, business models, and business intelligence and from behavioral and social studies of participants.

Considering the practical significance of e-commerce research and the strong footing AI already has in this application domain, AI research in this area will continue to flourish and have a real-world impact. From an academic standpoint, this provides fruitful ground for cross-fertilization between AI and many branches of economics, social sciences, and business disciplines. This multidisciplinary approach will not only generate innovative technical-research results but also open up paths

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for AI researchers to improve their research methods through interaction with partnering fields.

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