The Atomic Market: Enabling Component-Based Agent Marketplaces

By Jim Youll

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Thesis Advisor
Pattie Maes
Associate Professor of Media Arts and Sciences
MIT Media Laboratory

Reader
Chrysanthos Dellarocas
Douglas Drane Career Development Assistant Professor of Management
MIT Sloan School of Management

Reader
Benjamin Grosof
Assistant Professor of Information Technology
MIT Sloan School of Management
Abstract

Today’s electronic marketplaces are closed, centralized and inflexible. This thesis proposes a new type of electronic marketplace, which we refer to as an “atomic market”. Atomic markets differ from today’s electronic marketplaces in that they are (1) open-ended, (2) decentralized and (3) component-based. The atomic market supports short-lived markets created around the individual components of everyday transactions. The traders in an atomic market are agents, software that acts as a proxy for the actual buyer and seller. The atomic marketplace allows expressive interactions among such trading agents, leading to productive, automated agent-based transactions. The focus of the thesis is on the technical infrastructure for atomic marketplaces, specifically the use of logic as a basis for the decomposition of transactions and the negotiations between the different agents.

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1.0 Introduction

1.1 The Problem

Today’s electronic markets enforce rules, conventions and norms that elicit desirable behavior from all involved, creating nominally stable and predictable environments for trading. These characteristics are important: markets gain and hold prominence only by the consent of traders, consent granted as a measure of confidence in a market and its mechanisms. Yet a trader’s ultimate interest is not the market itself, but the offers and desires of other traders met through the market. Although Internet-driven markets will dominate future business and consumer transactions, few of today’s electronic markets present truly novel capabilities. Despite their roles as matchmakers and deal facilitators, markets may actually interfere with satisfactory completion of trades, as discussed next.

Constraints and complications of current electronic markets

- **Segregation:** Traders in a particular market cannot see potential trading partners in other markets, thus their access to truly comprehensive product and price information is limited. For example, Chemdex, PlasticsNet, e-Chemicals [FAI00] and ChemConnect [BENSON00] are all online marketplaces for buyers and sellers of chemicals, gases and similar industrial goods. But Chemdex traders cannot interact with traders in the other markets – to do so, they must become traders in those markets, and manually toggle between them.

- **Inflexibility:** Markets determine how and when traders may trade. Competing for-profit electronic markets distinguish themselves through proprietary, incompatible trading mechanisms. Priceline.com invites customers to “Name Your Own Price℠,” Mercata.com and Mobshop.com are aggregators, lining up many customers in advance for a small range of goods, then selling in bulk at a discount [TESSLER00]. But several buyers could not, for example, consolidate a large order for plane tickets at Mercata.com, then enter a bid for the tickets at Priceline.com.

- **Monolithic transaction models:** E-commerce systems, and the latest e-commerce standards, generally presume that all transactions are sales involving only two parties: a “buyer” and a “seller.” For example, the recent Internet Open Trading Protocol defines transactions between one “merchant” and one “consumer” [RFC2801].

- **Weak automation:** Current electronic markets simply transfer offline human-run trading to online forums and do not support automation of nontrival strategies. For example, FreeMarkets [COLEMAN00] and CommerceOne [STEWART00] facilitate human-managed trading through the Internet, but not automated trading by software agents. Bidders’ proxies at eBay can raise a bid price monolithically, but cannot make strategic decisions such as comparing current bids to the prices of similar items in other auctions.

- **Reliance on price-based matching:** Despite empirical findings in [BRYNOLFSSON99] that customer awareness, branding and trust, not price, drive Internet purchase decisions, the predominant auction mechanisms use price as the key deciding factor in awarding sales. Automated price-shopping services abound, but few services attempt the more difficult task of integrating a customer’s true preferences with buyers’ offers.
1.2 Proposed Solution

I am interested in the opportunity to construct new models for e-commerce, models that make use of the possibilities of automation without forcing traders into conventional roles. That means:

- **Open marketplaces:** “Search cost” is the expense of meeting a new trading partner or learning the price of a good or service. In an electronic marketplace, price comparison agents can reduce search costs to nearly zero. However, today’s proprietary models preclude trading across markets, leading to high search costs. The proposed system demonstrates a new role for the central market as *facilitator* rather than *order executive* and *rulemaker*. We hypothesize that this approach will provide low search costs, even with traders dispersed across many marketplaces.

- **Flexible trading rules:** Direct trader-to-trader transactions benefit from rules tailored to individual traders, and individual trades. Present markets set global rules for all traders and all transactions, such as limits on the hours for trading, the currencies supported, or the increments by which prices change in an auction. In the proposed Atomic Market, traders forge transactions around deal- and partner-specific rules by deriving those rules from their own strategies, and then making those rules a part of the transaction itself.

- **Component-based trades:** When a traditional transaction is divided into small components, then reassembled and extended by methods described later, the complex new transaction may link many parties, not simply “buyer” and “seller.” That same transaction may also contain terms of the deal, as discussed above. And it may invoke external authorities to provide the controls found in a traditional “market,” but only when needed. For example, traders may consult an external authority to confirm that an insurer is licensed, or to verify that a quoted price is within a few percentage points of the “market price” of similar goods.

- **Automation with software agents:** Software agents [GUTTMAN98] provide an obvious means of implementing a flexible trading system in a component-based market. In the Atomic Market, agents will share a common functional design. A unique *strategy module* that is part of the design allows each agent to pursue an individual strategy. In a full implementation, Atomic Market agents may possess varied degrees of complexity and would not necessarily share a common internal design – the common approach is taken here to simplify agent construction.

- **Allowing differentiation:** Perfect information about prices, possible when search costs are low, could drive prices to the marginal production cost – at which manufacturers just cover expenses and earn no profits [BERTRAND83]. However, *differentiation* can address this risk. Sales can be profitable when buyers’ individual preferences are made a part of the decision process [CHAMBERLIN33], even when the search costs are very low [DIAMOND71]. In the component model proposed here, the transaction is richly descriptive, carrying both financial details and the preferences and unique needs or offers of each participant. Traders use this information to create responses that are tightly tailored to their counterparts’ expectations. As buyers distinguish themselves through preferences, sellers may differentiate by combining indistinct goods into “bundles” to make new, unique offers [VULKAN98]. Recent findings that customer awareness, branding and trust, not price, may drive Internet purchases [BRYNJOLFSSON99] suggest that agent marketplaces will need to express features analogous to “brand” if they are to fully model trader preferences. Potential analogues to “branding” in the proposed marketplace will be discussed.
1.3 Contributions
The contributions of this thesis will be:

• A new component-based model for commerce, permitting market interactions within every transaction. These market interactions will create flexibility for all traders, allowing transaction policies to conform to the specific needs of the traders rather than the general rules of a market authority.

• The actual infrastructure that will make it possible to build atomic markets. Specifically, the research focus will be on the use of logic to enable complex intra-trader negotiations.

• An implemented example of an atomic market, involving several buyers and sellers, and a multi-component transaction.

2.0 The Atomic Market

2.1 Introduction
The Atomic Market system supports direct negotiation between software trading agents that exchange component-based descriptions of their needs and wants. The main functional parts of the Atomic Market system are:

Registry – A directory and event service supporting the discovery of trading partners
Trading agent – Software that processes transactions in accordance with built-in goals, strategies and needs
Market message – A collection of atoms, tied together with logical bonds, that describes the features of an under-construction transaction in fine detail
Atom – The basic component that describes one feature of a market message

2.2 The Registry

In the Atomic Market, the role of a central “marketplace” is significantly diminished compared to other markets. It is simply an event-driven directory service (Fig. 1) for discovery of trading partners who then interact directly. Events (“notify me when a compatible trader arrives”) and queries (“are compatible traders present?”) will be supported. This approach is compatible with the proposed Universal Description, Discovery, and Integration specification, an enhanced Yellow Page service [UDDI]. The registry could potentially be eliminated by peer-to-peer methods; that problem and its solutions are outside the scope of this project.
2.3 Trading Agents

Trading agents (Fig. 2) create, receive and process market messages with an overall goal of converting market messages to completed transactions. The Market Virtual Machine within an agent works with the Strategy and Compliance component to apply the agent’s built-in goals, strategies and needs to ongoing negotiations.

2.4 Agent-to-Agent Messages

Agents in the Atomic Market first meet through the registry service, but then negotiate directly, outside a “market”, by exchanging market messages. They collaboratively build transactions by answering other agents’ needs with offers, or by adding their own requirements to the transaction. Market messages are assembled from two-part atoms. Half of each atom contains a required item or “need”, the other half, a complementary offer that attempts to satisfy the need. Agents try to fill other agents’ needs while expressing their own. For example, a CD-selling agent may answer a “need CD” atom with “offer CD AND need Payment”.

2.5 The Components of Transactions

A component or composite transaction [CHAN00] is a collection of individual offers or needs that represents a complete real-world transaction. For example, a vacation may require rental of a car, reservation of a hotel room, and purchase of an airline ticket. Each requirement is a component of the greater transaction, “vacation.”

In the Atomic Market we decompose transactions into separable goods, preferences and instructions called atoms. Atoms are assembled with propositional logic into market messages that precisely define the items, capabilities and preferences under negotiation. Atoms represent small but still separable parts – smaller than those in most agent trading systems. Because they stand only for single needs, offers or states, atoms may easily draw external conditions into a transaction. For example, the fair market price for an item according to a price-monitoring service may be checked before a bid is finalized. Agents attempt to satisfy unmet needs within the growing market message, subject to their own strategies, needs and abilities. Traders may extend a transaction by adding new requirements. Through this process, a market message is built collaboratively, forming a transaction when all traders’ needs have been met.
Fig. 4 shows three approaches to the task of vacation scheduling. “No coordination” is a manual approach – the buyer negotiates for three items in three markets, with the risk that not all negotiations will succeed. “Distributed locking” adapts principles of database systems to transactions in agent markets [GINIS00] but at the level of a traditional “transaction.” Finally, using the approach outlined in this thesis, the discrete requirements of vacation are distributed into many components, including connections to outside parties (the clearing banks) and features such as AAA discounts and item-specific preferences (e.g. “VW Beetle”, “Morning flight”).

2.6 Logic and Decision Support
Atoms in the proposed system are chained together using straightforward propositional logic. For example, the initial advertisement for a vacation may look like this:

\[
(\text{need Hotel,}) \land (\text{need Car Rental,}) \land (\text{need Flight,})
\]

As agents handle the transaction, it expands to reflect all participants’ needs:

\[
((\text{need Hotel, offer Hilton}) \land (\text{need Payment,})) \land ((\text{need Car Rental, offer Honda}) \land (\text{need Payment,})) \land ((\text{need Flight, offer BA2232}) \land (\text{need Payment,}))
\]

Finally, a completely satisfied proposition may evolve. This example is simplified:

\[
((\text{need Hotel, offer Hilton}) \land (\text{need Payment, offer MasterCard})) \land ((\text{need Car Rental, offer Honda}) \land (\text{need Payment, offer MasterCard})) \land ((\text{need Flight, offer BA2232}) \land (\text{need Payment, offer MasterCard}))
\]

Grosos’ work with Courteous Logic Programs [GROSO99] will inform the design of the Market Virtual Machine (MVM) component of the agents’ decision-support systems. The Prolog-driven Market Virtual Machine will use IBM CommonRules software and execute through the XSB Logic Programming and Deductive Database [XSB]. Methods to manage commitment in distributed transactions will inform our approach to transaction commitment [TYGAR96] [TYGAR98] [GINIS00].

3.0 Deliverables
- The Atomic Market system consisting of the agent messaging protocol, trading agents, and the registry with event notification service
- Written thesis, approved by my thesis committee
- Source code for all Atomic Market modules mentioned above
- Instructions for configuring and running an Atomic Market
- An instantiated Atomic Market for testing and demonstration
- Presentation covering the research and contributions described by the thesis
- PDF version of thesis

4.0 Related Work
- Commercenet and the eCo Framework [COMMERCENET] [TENENBAUM97] [GLUSHKO00]. CommerceNet is a global non-profit collaborative effort to builds and publishes standards for e-commerce. The eCo Framework was an attempted business-to-business (B2B) XML standard connecting at least twenty other standards in an e-commerce wrapper. The eCo Framework was officially released in 1999, but news reports say eCo has “lost steam” [MARKOFF00]. The eCo web site is down; the initiative is apparently not proceeding. Nonetheless, the lessons learned from the eCo Framework, and its approach, will inform the design of the agent trading language.
• **SRI Open Agent Architecture (OAA):** allows software services to be provided through the cooperative efforts of distributed collections of autonomous agents, via facilitator agents [MARTIN99]. In this architecture, facilitators match requests from agents or users with the capabilities of other agents. Users and agents do not need to know the identities, locations, or number of other agents involved in satisfying a request. The OAA facilitator is a model for the *market* or *directory service* agent in the proposed project.

• **Micro-Options:** The Micro-Option addresses the coordination of a complex transaction (such as a vacation) across multiple unrelated vendors, through an approach based on options markets. [GINIS00] The authors distinguish “consumer” and “resource” – no such distinction is made in the Atomic Market. The micro-option system considers transactions in which the smallest components are complete interactions with vendors. Much smaller component parts of such transactions will be employed in our system. The authors’ treatment of optimality and planning provide constructive examples that will inform the design of agents for the Atomic Market.

• **Modeling Supply Chain Formation in Multiagent Systems:** Supply chain formation is “the process of bottom-up assembly of complex production and exchange relationships.” The authors discuss issues in supply chain formation, existing multiagent models, and difficulties that arise from resource contention [WALSH99]. The Atomic Market’s transaction-building process may be viewed as supply-chain assembly.

• **MAGNET: A Testbed for Multiagent Negotiation Involving Intermediaries:** This system supports transaction types from simple sales to multiagent negotiations, through an active market that tracks requests, commitments, and progress toward goals [COLLINS98, 99, 00]. In contrast, the proposed Atomic Market diminishes the role of the central market, leaving only a directory service. MAGNET also has a strong focus on “buyer” and “seller” roles; the proposed Atomic Market explicitly avoids the creation of rigid roles for traders.

• **Internet Open Trading Protocol (IOTP) RFC 2801:** This April, 2000 RFC attempts to define a framework for Internet commerce that is payment system independent. IOTP defines rigid roles for commerce actors including “Consumer”, "Merchant", "Payment Handler" and "Delivery Handler". It illustrates of the current design ethic for electronic markets [RFC2801]. The authors’ compilation of current standards and needs will be useful, though the approach taken in the Atomic Market is unlike the trading environment discussed in RFC2801.

• **Existing agent and cross-system languages:** The role in e-commerce for agent languages such as KQML [FININ94], KIF and others is not immediately clear [ONG98]. Regarding XML, analysts have advised businesses to adopt the technology immediately, but to maintain compatibility with many standards [DEMERS00] until a “clear winner” is found.

### 5.0 Resources

The greatest resource will be the time required to design and code the prototype open trading environment. The system will be written in Java 2, and should run on Windows, Linux and Solaris platforms. The free XSB Logic Programming and Deductive Database [XSB] will facilitate inferencing in the agents. IBM CommonRules, also freely downloadable, will convert Courteous Logic Programs to a form suitable for the XSB execution environment.
6.0 Schedule

Dec 11: Submit thesis proposal to DCGS
Dec 1- Feb 15: Develop message structure, logic processor, agents
Feb 9: Apply for SM degree
Feb 15-Apr 3: Draft thesis

Feb 15-28: Run experiment, analyze results
Mar. 9: Thesis outline, draft to committee
Apr. 13: First draft to committee
Apr. 27: Final draft to committee
May 4-10: Committee signoff
May 11: Submit thesis
7.0 References


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8.0 Thesis Committee

Pattie Maes
Associate Professor, Media Laboratory, MIT
pattie@media.mit.edu

Pattie Maes is an Associate Professor at MIT's Media Laboratory, where she founded and directs the Software Agents Group, and is principal investigator of the e-markets Special Interest Group. Her areas of expertise are Artificial Intelligence, Human Computer Interaction, Computer Supported Collaborative Work, Information Filtering and Electronic Commerce.

Chrysanthos Dellarocas
Douglas Drane Career Development Assistant Professor of Management
MIT Sloan School of Management
dell@mit.edu
http://ccs.mit.edu/dell/

Chrysanthos Dellarocas develops the next generation of open marketplaces for electronic commerce. In such marketplaces, software agents meet to trade products and services through the Internet. He draws upon concepts from sociology, law, and artificial intelligence in order to address technical, legal, and management issues in agent-mediated electronic markets. Dellarocas is also developing novel computer-based methodologies and tools for helping dynamic companies systematically analyze and manage the risks of their rapidly changing business processes. His areas of expertise are electronic commerce, software agents, business process management, and operational risk management.

Benjamin Grosof
Assistant Professor of Information Technology
MIT Sloan School of Management
bgrosof@mit.edu
http://www.mit.edu/~bgrosof/home.html

Benjamin Grosof recently joined MIT Sloan after 12 years at IBM Research. He creates and study information technologies for electronic commerce applications. His primary research concerns web and XML languages for contracts, trust, and business rules/policies in B2B agent communication and negotiation; and in marketplaces and virtual organizations. His research rests upon fundamental techniques for knowledge representation and inferencing and software engineering. He is informally associated with the Center for eBusiness@MIT.