The Impact of InfoCenters on E-Marketplaces

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ABSTRACT

Information marketplaces enable entities to buy and sell information; these buying and selling entities can be humans, or automated agents that represent them. In this paper, we introduce a new type of participant into electronic information marketplaces, namely the InfoCenter agent, which can not only buy and sell information, but can also procure and sell manipulated (i.e., processed) information. We explore the effects that InfoCenters have on the marketplace and on the other agents that participate in it. We show that the benefits of extending an information e-marketplace with InfoCenter agents are twofold. First, InfoCenters can help buyers obtain better information; second, InfoCenter agents can help sellers gain higher profits. Furthermore, we empirically test the influence of different pricing algorithms and payment methods on the buyers', sellers', and InfoCenters' behaviors.

1. INTRODUCTION

Electronic marketplaces (e-markets) broaden opportunities for humans to buy and sell, for example by allowing buyers to patronize stores that would not be physically accessible to them. But e-markets have the potential of expanding commercially traded commodities in other ways — for example, by enabling the buying and selling of pieces of information. Users can buy articles without being obliged to buy a whole journal, or obtain news adapted to their personal interests without buying the whole newspaper.

The possibility of treating information as a truly tradable commodity generates new questions that need to be examined. Pricing policies could be standardized to quantify basic units of information. New kinds of transactions can be developed that are not common for classical (physical) commodities. Eventually, operators can be applied to these pieces of information, creating new products based upon the buyers' requests or as new suggestions to those buyers.

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This paper focuses on information as a commodity traded in e-markets. In particular, we have developed the notion of InfoCenters, automated agents that have wide accessibility to information products, as well as to manipulated data. The basic idea of information markets is not new; pieces of information are already being traded in existing systems (e.g., [6]). Thus, automated tools to handle these pieces of information, such as we propose, are becoming more necessary.

Information management and commerce must deal with questions such as how different pieces of information will be handled, and how their prices will be calculated. Shall we enable the customer to have full information about available information products before carrying out a transaction? How can a software agent assist a user in building new information products out of the basic information building blocks existing in his data storage?

An InfoCenter is a software agent that interacts with information suppliers (i.e., sellers), information consumers (i.e., buyers), and Information Service Providers (InfoSPs) that can be automated agents or humans. Therefore, an InfoCenter agent can buy and sell information products. Moreover, it can obtain manipulated information from the InfoSPs. The InfoSP agent enables services such as changing the encoding of information (e.g., JPEG to GIF), adapting the presentation to different platforms (e.g., desktop or palmtop), updating information, summarizing it, or combining pieces of information. InfoCenters act as information intermediaries, and can reside, for example, in a library, at a portal Web site, or at a site that answers user questions.

The marketplace investigated in this paper contains InfoCenter agents, InfoSPs, information consumers (buyers), and information suppliers (sellers). Three models of trading interactions introduce the motivation for the creation of InfoCenter agents. Then, results from simulations run with different behaviors of InfoCenter agents are presented.

We focus on the impact that InfoCenters have on an e-market when they sell new information products resulting from applying operators on basic units of information. This study is part of a larger research project that aims at studying the effects of different AI techniques, such as planning and coordination, on the InfoCenter decision process.

2. RELATED WORK

Researchers at IBM have suggested the concept of an Information Economy as the context in which humans and automatic agents could find and trade information over the Web [5, 4]. These researchers focus on two kinds of agents: ShopBots and PriceBots. The ShopBot agent compares prices for the buyer and helps find the lowest price for the information the buyer needs. The PriceBot agent helps the seller set prices for the information commodities it offers. Our study is based on this model, but we have further expanded it by adding two new kinds of agents: InfoCenters and Information Service Providers (InfoSPs).

Ketchpel et al. [6] study how the Stanford Library can benefit from using electronic agents for managing its information. Another example of a digital library is UMDL [7]. These libraries behave like centers of information (i.e., an InfoCenter in our terms). The library interacts with information suppliers, like book and magazine publishers, to retrieve their information. The library has several payment options that it can use to obtain and supply information, like pay-per-view, subscription, sessions, shareware, and pre-paid vouchers. It offers its information to its customers, who pay for this service. The library can interact with other libraries to obtain information in their area of interest. In this paper, the InfoCenter agent has the capabilities of the Stanford Digital Library, with additional capabilities such as the ability to manipulate information.

Middle-agents were studied as a means to organizing information in multiagnet systems. However, work in this area (e.g., [2]) did not analyze the economic impact of these middle-agents as we do here. Bialey and Bakos [1] studied the roles of intermediaries in information e-marketplaces, which is relevant to our own study of automated intermediaries. They explored thirteen firms that participated in e-commerce activities. New roles for electronic intermediaries were found, including aggregating and disaggregating information (e.g., aggregating several magazines into one information product, or disaggregating magazines into separate articles), providing trust, and providing inter-organizational market information. In this paper we explore how manipulation of information (e.g., information aggregation) influences the information marketplace.

3. INFOCENTER AGENTS AND INFOSPS

In this section, we motivate the placement of InfoCenter agents into information e-markets. Even though accessibility to information on the internet is not constrained by physical distance, information intermediaries nevertheless appear to be beneficial. An InfoCenter agent is useful in three scenarios as described below:

- *When the InfoCenter agent already exists* — There are infrastructures that already exist and that contain "information centers", where InfoCenter agents' role as intermediaries is natural and direct — for example, in classical and digital libraries (e.g., the Stanford Digital Library Project [6]). The library buys information such as books, magazines and articles, and it serves its audience which pays for that information. Libraries already exist, and their services can be extended by adding InfoCenter agents that will interact with different information suppliers and consumers.
- *When buyers benefit from interacting with an InfoCenter agent* — E-marketplaces may be interested in extending the services they provide to their buyers, by adding assistance services. For example, an InfoCenter agent can help buyers by aggregating information (from different sources) that answers requests submitted by those buyers. In this case, the InfoCenter may need to interact with other software agents (e.g., agents who provide information services) to understand the question and to manipulate the different information elements so as to prepare the answer. The InfoCenter agent provides an obvious service to the buyer. The existence of such an InfoCenter agent "middleman" can also benefit sellers, because the InfoCenter agent can help them sell their information to buyers by customizing it. In other words, the InfoCenter is a "value-added" reseller of information. Of course, pricing strategies are needed to establish the relation between InfoCenter agents and the original sellers.
  Another example is when a buyer is only interested in one piece of information and is not interested in a surrounding set of information (e.g., a buyer may be interested in acquiring an article but not the complete journal). InfoCenter agents can handle subscriptions to information suppliers and provide buyers with the specific information.
- *When sellers benefit from interacting with an InfoCenter agent* — Sellers may have various pieces of information that they want to sell, but not want to handle the task of finding buyers. In that case, they can use an InfoCenter that will buy information from them and find potential buyers. In that way, the InfoCenter provides a way to match (for example) experts, and buyers that are interested in the experts' knowledge. A similar approach was taken by Kamoon [3].

Figure 1 depicts an e-marketplace that includes buyers and sellers interacting with InfoCenter agents that can obtain manipulated information from InfoSP agents.

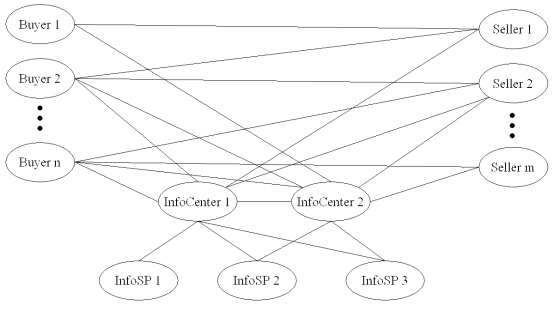

Figure 1: A basic e-marketplace including InfoCenter and InfoSP agents

4. THE MODEL

Our study is based on the same marketplace model proposed by Kephart et al. [5, 4]. This marketplace contains commodities that are offered by S sellers, and which may be bought by any of the B buyers, assuming $B >> S$. Each

buyer generates purchase orders at random times, at a rate of ρ_b, while each seller resets his price at random times, at a rate of ρ_s. The worth of a good to a buyer b is represented by the value V_b. The cost of production for a seller s is C_s.

Our framework extends the basic model [5] by including InfoCenter agents and Information Service Provider (i.e., InfoSP) agents. InfoCenters are added to the basic market as intermediaries of information. These agents interact with information suppliers and consumers by buying and selling information. We will use the terms sellers and buyers only for the original information suppliers and end consumers. Though InfoCenter agents also buy and sell, we will refer to these agents solely as InfoCenters to avoid confusion.

The InfoSP agents are responsible for manipulating basic pieces of information. New commodities will eventually be built out of the existing commodities in the market. InfoCenter agents can approach InfoSPs to obtain new information after the InfoSPs have manipulated it. It is important to approach the InfoSP services in a wise manner. First of all, the same manipulated information can be created using different information commodities and different InfoSPs' services. Choosing the best set of information commodities and InfoSPs' services may be a complicated job that requires planning. Second, new information commodities may decrease profit. That can occur when buyers prefer the new information commodity, but are not willing to pay more for it. In that way, the cost is higher since additional service was needed to produce it, but the price is the same.

Buyers can buy information products directly from regular sellers, and they can also buy them from the InfoCenters, taking advantage of the more sophisticated features of the latter. Regular sellers can sell information to the InfoCenters as well, regarding them as other interested buyers.

The goal of the InfoCenter is to profit, as a middleman, by using the marketplace entities in a smart way. Unlike a seller, the InfoCenter can selectively choose which commodities it wants to offer, and can use the InfoSPs to create new commodities that are not available in the market. Choosing which niche it wants to support can influence its profits. For example, if a certain commodity has a low profit margin, the InfoCenter can stop offering it. InfoCenters can also track the history of buyers' requests, and adapt their list of products accordingly (i.e., continue selling a newly created product that buyers keep demanding, or stop selling it).

Sellers are the basic information sources (i.e., we assume that sellers already hold information products). InfoCenters are agents that can buy information products from sellers and can sell it, potentially in a different form. In the more general model, InfoCenter agents can also buy information products from other InfoCenters. The InfoCenter agent can use any one of the following payment systems to pay for information sold by sellers:

- Full Price (FP) — The InfoCenter agent pays the list price for information it buys from sellers. This model of payment is reasonable if the InfoCenters can sell manipulated information. Otherwise, the InfoCenter will not have any incentive to buy and resell the same information, because then they will not have any added value from which to profit.
- Wholesale Price (WP) — The InfoCenter agent pays a reduced price if it buys a large quantity of information. In this case, the seller has to decide which discount method to use. We suggest three discount methods:
  - Discount Price — The seller gives a discount (e.g. 10%) of the current market price.
  - Average Price — The seller uses the average price of the information commodity. In that way, it guarantees generating some average profit.
  - Minimum Price — The seller offers the information at cost, plus a selling fee. Thus, although the average profit will be low (i.e., it will be the selling fee), sellers will have more opportunities to sell more information commodities, by offering them at a low price.
- Subscription Payment (SP) — The InfoCenter agent pays a subscription payment for the right to sell a certain quantity of information, and royalties on each information unit that it sells. If the royalties are equal to zero, then we get the WP payment as described above. The seller can use one of the discount methods described above, and in addition will have to determine the ratio between the subscription payment and the royalty payments (e.g., 80% of the price will be paid as subscription payment, and the remaining 20% will include royalty payments).

We tested two criteria for evaluating the effectiveness of the different configurations and algorithms. The first is **profit**. This criterion compares the profit obtained by InfoCenter agents, information suppliers, and consumers in all settings tested. Applying this criterion, we can learn whether sellers and buyers benefit from the existence of InfoCenters in e-markets where they exist. The second criterion is **stability of the marketplace**. A marketplace with frequent price changes can create unstable environments for buyers. The reason is that a commodity bought now may cost, for example, half the price or twice the price if the buyer waits. A marketplace with (relatively) stable prices is desirable, although care should be taken to avoid a monopolistic marketplace, in which prices will be set to their highest point. The desired marketplace is one with stable prices that are competitive.

5. INFOCENTER BEHAVIORS

We have currently implemented InfoCenter agents with three capabilities that give them advantages over classical sellers. First, InfoCenters can offer new information products after having approached an InfoSP, who manipulates a given piece of information. Second, InfoCenters may switch among the commodities they offer for sale. Since InfoCenters do not "hold in stock" the information they sell, these agents can flexibly decide upon the area in which to specialize. Third, we have implemented a mechanism for sharing information among InfoCenters, so that information remains distributed and its price is not necessarily handled by a monopolistic agent. In this paper, we focus on the InfoCenters' basic capability, which is manipulation of information. Experiments run on InfoCenters with additional capabilities will be reported separately.

5.1 Manipulated Information

InfoCenters can approach InfoSP agents so as to provide buyers and sellers with new information products. The information manipulation methods that the InfoSP can offer include:

- Different presentation formats and resolutions — Resolution may depend on the connection speed available to the consumer. The buyer may wish to match the format of the information to the device he is using (e.g., the device can be a PC, a handheld, a cellular phone, a fax-machine, or a printer). Currently, we have implemented a unary operator that, for example, enables the presentation of information to be either in PS or PDF formats.
- Information updates — The InfoSP can offer updates to existing pieces of information. This is relevant when the information in question may change over time, for example, information that refers to cost rates, stock values, news, and reviews. This operator was left for future implementation.
- Combining and summarization — The information requested by a consumer may require the combination of several information pieces. In addition, the resulting information may consist of non-relevant information that should be removed. Currently, we have implemented a binary operator called *collector* that enables the combination of two pieces of information into a single unit.

For simplicity, the price paid by InfoCenters to InfoSPs for services provided was fixed, and did not change according to marketplace demands.[1]

We assume that the time needed by the InfoSP to apply any of the operators is very small. Therefore, InfoCenters can offer information that was manipulated by various InfoSPs. If buyers are interested in some new information that is not offered by any seller, then the InfoCenter will contact relevant InfoSPs and will produce the information. Only then will the InfoCenter pay the InfoSPs. In that way, InfoCenters and InfoSPs can check the demand for different information commodities.

The InfoCenter agent can respond to a market request for an information commodity, and plan a way to make it available, using the information sources and the InfoSP services that are available. It can replace information commodities with more profitable ones. The InfoCenter's ability to introduce new information commodities using the InfoSP should be used 'wisely'. Un-wise use of InfoSP services can lead to lower profits. More details are given in the extended version of this paper [8].

6. SIMULATION SETTINGS

In this section, we present the simulations performed to test the impact of adding InfoCenter agents and Information Service Providers to an e-market. One simulation consists of a series of repeated encounters between finite sets of buyers, sellers, and InfoCenters. A finite set of basic commodities is offered for sale by the sellers. New commodities can be created by InfoSPs and can be sold by InfoCenters.

Sellers and InfoCenters offer the information products that can be bought. Each product is initialized with a fixed price. Each seller holds an infinite amount of the products offered. The cost of producing a basic commodity was set to 0.[2] During one simulation, the price is updated according to the sellers' strategies at a given rate ρ_s. The buyers choose a seller, based on the products they are interested in and based on their strategy (as explained below).[3] The buyers approach the sellers at a rate ρ_b. Once a buyer approaches a seller, the transaction is necessarily performed between the two.

The utility of a seller S at time t, after he has sold r products at a price P, is given by $U(S,t) = (\Sigma_{i=1}^{r} P(t))/r$. The utility of a buyer B at time t, after he has bought r products at a price P is $U(B,t) = v - (\Sigma_{i=1}^{r} P(t))/r$.[4] The utility of an InfoCenter I at time t is given by $U(I,t) = (\Sigma_{i=1}^{r} P(t) - C_{f_j}(t))/r$, where $C_{f_j}(t)$ expresses the costs incurred by the InfoCenter from following each one of its behaviors given by its features. For example, C_{f_1} is the cost of approaching an InfoSP. C_{f_2} is the cost incurred from paying a seller for its information product.

Kephart et al. [5] implemented a market with buyers and sellers solely. The sellers have different pricing algorithms. The authors tested the dynamics of the prices and the dynamics of the agents' behaviors in the given market. Here, we show the added value of implementing InfoCenter agents in the market, by enriching the information products that can be offered to buyers.

6.1 Buyers' and Sellers' Strategies

Buyers need to choose from which seller they will buy the commodity of interest. We have examined three algorithms that were implemented by information consumers (these same algorithms were implemented by Kephart et al. [5]). The numbers in parentheses represent the percentage of such buyers in our tested market:

1. Compare-All (70%) — Buyers compare all of the prices requested for the commodity of interest. Then, buyers will choose the seller that asks for the lowest price. This algorithm is similar to the implementation of the ShopBot in [5].
2. Compare-None (10%) — Each buyer chooses, randomly, an information source that offers the requested commodity.

[1] We plan on adapting the cost of manipulated information to market demands, since this cost is affected by the prices of information commodities of which it consists, and these prices change according to market demand.

[2] A commodity created after applying an operator by the InfoSP incurs an additional cost.

[3] There is a central agent that responds to each buyer's request with a list of all the sellers that sell the requested items. Each buyer applies the corresponding algorithm to choose which seller to approach from this list.

[4] v denotes the value of one commodity for the buyer. In our implementation we assume all basic commodities have the same value: 1. The new information has a value depending on what it contains (e.g., combined information of two basic information pieces will have a value of 2).

3. Compare-two (20%) — Each buyer chooses two information sources randomly and then buys from the cheaper one.

The information suppliers in the marketplace apply three algorithms for changing the price of their commodity (following Kephart et al.'s model [5, 4]):

1. GT (Game Theory) — Kephart et al. have shown that there is not a single pure strategy that is in Nash equilibrium for sellers to establish the price of a commodity. There is, instead, a mixed strategy that is in Nash equilibrium. This mixed strategy instructs each seller to choose prices randomly using the following function $p(F)$, where F is a random value between the cost c of the commodity and its value v (in our case $F \in [0,1]$). S denotes the number of sellers in the market, and w_i is the fraction of buyers that compare i prices. $p(F) = c + \frac{w_1 * (v-c)}{\Sigma_{i=1}^{S} i * w_i * (1-F)^{i-1}}$.
2. MY (Myoptimal) — The seller sets the price of the commodity in the market to maximize its short-term profit (i.e., it assumes that current known market conditions do not change, which is true in the short-term). This method requires knowledge about the buyer population W, the number of competing sellers S, and all of the sellers' prices.
3. DF (Deviate Follower) — The seller keeps increasing the price of a commodity as long as its profit increases. The seller will decrease the price when the profit drops off a certain level. The seller will continue decreasing the price as long as its profit increases, and so forth.

7. EXPERIMENTS

In the simulations described below, we examined whether the addition of InfoCenter agents to e-markets is beneficial, i.e., they gain a positive profit. In all of the markets studied, there were two basic commodities, three sellers, and one hundred buyers. The number of InfoCenters in each scenario varies as described below:

1. No InfoCenters — In this case there will be only sellers implementing the same pricing algorithm. We will use this as a control group so we can evaluate the effect of the existence of InfoCenters in the marketplace.
2. A single InfoCenter Agent — In this case, there is one InfoCenter that interacts with several information suppliers and with InfoSPs in order to obtain manipulated information.
3. Homogeneous InfoCenter Agents — In this case, there are three InfoCenters that implement the same pricing and payment algorithms.
4. Heterogeneous InfoCenter Agents — In this case, we have simulated markets with two sets of InfoCenters, where each set followed different pricing and payment algorithms.

Furthermore, we check the effects that the different discount methods (as stated in section 4) have. All of the following discount methods were tested in all of the marketplace configurations with one InfoCenter and with homogeneous and heterogeneous sets of InfoCenters:

1. Discount price of 10%.
2. Discount price of 20%.
3. Discount price of 50%.
4. Average price.
5. Minimum price.

Moreover, we have tested the influence of the ratio between the subscription payment and the royalty payments as described in Section 4. We tested all of the following ratios in all of the marketplace configurations with one InfoCenter, and with homogeneous and heterogeneous sets of InfoCenters.

1. 80% of the price will be paid in the subscription payment and the remaining 20% will include royalty payments.
2. 50% of the price will be paid in the subscription payment and the remaining 50% will include royalty payments.
3. 20% of the price will be paid in the subscription payment and the remaining 80% will include royalty payments.

The results obtained from running simulations implementing the algorithms described are summarized below in Section 8.

8. RESULTS

8.1 Seller and InfoCenter Behavior

We consider a marketplace as a game, when each player represents a group of sellers or InfoCenters. We assume that all of the sellers are homogeneous in all the marketplace configurations, and therefore they will all choose the same pricing algorithm (i.e., MY, GT or DF) and will be represented by a single player. The InfoCenters will be represented by players depending on the market configuration: 1) the single InfoCenter will be represented by a single player, 2) the homogeneous InfoCenters, like the homogeneous sellers, will be represented by a single player, and 3) the heterogeneous marketplace include two groups of InfoCenters, the single InfoCenter that will be represented by one player, and the other homogeneous four InfoCenters that will be represented by an additional player. Each player chooses a pricing strategy (i.e., MY, GT or DF) and a payment method (i.e., FP, WP or SP) in case it represents an InfoCenter. The profit of each player in the game is the average profit of the agents it represents.

We would like to find out if there is an equilibrium for this game in each market configuration. If there is such an equilibrium, we call it the strategic equilibrium of the marketplace. From now on we will refer to an InfoCenter that applies the pricing algorithm MY and the payment method WP as an InfoCenter that uses MY with WP.

IC Algorithm	IC payment	IC Profit	Sellers Profit
MY	FP	0.97	0.52
MY	WP	0.68	0.47
MY	SP	0.64	0.53
GT	FP	1.45	0.50
GT	WP	0.75	0.47
GT	SP	0.71	0.47
DF	FP	0.52	0.51
DF	WP	0.28	0.50
DF	SP	0.32	0.49

Table 1: The profits of the InfoCenter and the sellers in a marketplace with a single InfoCenter, when all sellers use the DF algorithm for pricing

IC Algorithm	IC payment	IC Profit	Sellers Profit
MY	FP	0.70	0.48
MY	WP	0.50	0.50
MY	SP	0.57	0.51
GT	FP	0.69	0.46
GT	WP	0.34	0.50
GT	SP	0.45	0.47
DF	FP	0.34	0.49
DF	WP	0.15	0.52
DF	SP	0.22	0.51

Table 2: The profits of InfoCenters and sellers in a marketplace with three homogeneous InfoCenters when all sellers use the DF algorithm for pricing

The sellers' profit is higher when they implemented the DF pricing algorithm over the MY and GT pricing algorithms in all market configurations (as will be shown later in Table 5). Due to space limitations, we present the profits of the sellers and the InfoCenters in the Tables [1, 2, 3, 4] when sellers apply the DF algorithm only. Complete information can be found in the extended version of this paper [8].

In the marketplace with a single InfoCenter (see Table 1), the InfoCenter benefits more from implementing the full price (FP) payment method no matter what pricing method the sellers have implemented. As seen in this table, the single InfoCenter will benefit most by applying the GT pricing algorithm when sellers implement the DF algorithm. The same result is obtained when sellers apply the MY algorithm. However, the single InfoCenter will prefer the MY pricing algorithm when sellers follow the GT algorithm. Since sellers prefer to use the DF pricing algorithm as mentioned before, the InfoCenter will then prefer to use GT with FP, and this is the market strategic equilibrium. The InfoCenter will obtain an average profit of 1.45 and the seller will obtain an average profit of 0.5, as can be seen in Table 1.

In the homogeneous marketplace (see Table 2), the InfoCenters gained the highest profit using MY with FP, no matter what pricing method sellers have implemented. Sellers will prefer the DF pricing algorithm no matter what pricing and payment method the homogeneous InfoCenters have implemented. Therefore, the equilibrium found will be when InfoCenters use MY with FP and sellers use the DF algorithm. InfoCenters will obtain an average profit of 0.7 and sellers will obtain an average profit of 0.48, as can be seen

Payment Used		InfoCenter and Seller Profits		
1 IC	4 IC	1 IC	4 IC	Sellers
FP	FP	0.68	0.84	0.47
FP	WP	0.56	0.49	0.49
FP	SP	0.50	0.03	0.49
WP	FP	0.63	0.68	0.49
WP	WP	0.45	0.41	0.54
WP	SP	0.51	0.32	0.51
SP	FP	0.39	0.93	0.49
SP	WP	0.43	0.38	0.48
SP	SP	0.48	0.54	0.50

Table 3: The profits of InfoCenters and sellers in a marketplace with five heterogeneous InfoCenters when all sellers use the DF algorithm and InfoCenters use the GT algorithm

Configuration	Profit	Different discount methods				
		10%	20%	50%	Avg	Min
Single IC	IC	0.79	0.71	0.78	0.68	0.68
	Sellers	0.47	0.49	0.47	0.49	0.49
Homogeneous	IC	0.69	0.58	0.56	0.66	0.67
	Sellers	0.49	0.48	0.51	0.45	0.50
Heterogeneous	1 IC	0.59	0.75	0.63	0.61	0.65
	4 IC	0.51	0.42	0.41	0.52	0.41
	Sellers	0.49	0.49	0.51	0.51	0.50

Table 4: The profits of InfoCenters and sellers when they use different discount methods in marketplace where the sellers use the DF algorithm and the InfoCenters use the MY algorithm

in Table 2. The single InfoCenter (results shown in table 1) obtained an average profit of 1.45 in the equilibrium case because then it was a monopolistic agent. In the homogeneous market, InfoCenters applied the same algorithm, but they also compete with one another.

The influence of the different payment methods in a marketplace with heterogeneous InfoCenters can be seen in Table 3. Due to space limitations, we present data only for the case where sellers use the DF algorithm and InfoCenters use the GT algorithm. Complete information can be found in the extended version of the paper [8]. The single InfoCenter gains the highest profit when applying the FP payment method at about 90% of the configurations, and the four InfoCenters at about 66% of the tested configurations. We could not found any equilibrium in this marketplace configuration.

8.2 Different Sellers' Discount

The InfoCenters do not behave as usual buyers because they buy more information than regular buyers. Therefore, sellers may benefit from giving them discounts. The seller can offer discounts with the Wholesale Price (WP) and with the Subscription Price (SP). In this section, we compare the different discount methods mentioned in Section 7.

We expected that sellers would gain the highest profits with the lowest discount, while the InfoCenters would gain the highest profit with the highest discount. But the simulation actually showed the opposite (see Table 4). The reason

	Sellers Algorithm		
Market configuration	DF	GT	MY
No InfoCenter	0.49	0.09	0.47
Single InfoCenter	0.50	0.10	0.47
Homogeneous InfoCenters	0.49	0.10	0.46
Heterogeneous InfoCenters	0.49	0.10	0.47

Table 5: The sellers' average profit in different market configurations

is that InfoCenters can benefit from higher prices, because then the prices they set are higher, too. Sellers benefit from higher discounts, because it enables them to offer attractive prices for InfoCenters, and in that way to sell more information and increase their profit. No preferred discount method was found. It depended on the seller and InfoCenter algorithms, as can be seen in Table 4.

The Subscription Payment (SP) consists of two parts: a subscription fee that is paid in order to become a subscriber, and royalty payments that are paid for each unit of information that was purchased. We will denote a marketplace in which there exists a ratio of 80% subscription payments and 20% royalty payments as a ratio of (80%,20%).[5] In both the homogeneous and heterogeneous configurations, the highest profit was achieved with the ratio (50%,50%). The ratio that yielded the highest profit for the single InfoCenter scenario was (20%,80%). Further tests are needed to better understand these results.

8.3 General Discussion

One of the objectives of this work was to test whether the inclusion of InfoCenter agents in an information e-marketplace is beneficial to sellers that supply pieces of information in such a market. On one hand, the sellers are willing to sell the information to the InfoCenters with a discount when the InfoCenters buy large amounts of information from them. In that case, InfoCenters guarantee that they will buy large amounts of information from these sellers, and therefore these sellers know that they will continue to sell for a certain amount of time. This behavior will cause sellers to sell at higher prices. On the other hand, this kind of interaction (i.e., giving a discount) reduces the sellers' prices and therefore their average profit. The effect of the InfoCenters on the sellers' profit can be seen in Table 5. The sellers' average profit remains similar in all of the cases tested, but they sold more information which increased the total profit.

We expected that sellers and InfoCenters will get the highest profit by implementing the myoptimal (MY) or the game-theory (GT) pricing algorithm. This was due to the following reason: both the MY and the GT algorithms use information on buyers' demand and information about the prices set by other sellers. The MY algorithm sets the price optimally. In the case of GT, the price is set to one of the prices of the mixed equilibrium.

The Deviate-Follower (DF) pricing algorithm, on the contrary, does not have any information on buyers and sellers.

[5]This payment method is the most general because the WP payment and the FP payment methods can be represented by (100%,0%) and (0%,100%), respectively.

Our results show that the InfoCenters indeed gain the highest profit when implementing the MY and GT algorithms. However, *sellers* gain the highest profit when implementing the DF algorithm. The DF algorithm reacts to market conditions and does not assume any behavior of buyers and sellers in the marketplace. This is in contrast to MY and GT, that try to set the best price according to market demand. The seller does not consider the InfoCenter when it decides on the price. This gives an advantage to the DF algorithm over the MY and the GT algorithms, because it regards the InfoCenter as part of the general market conditions. Sellers are interested in setting prices for basic information products (i.e., they do not have to handle new products' prices as InfoCenters do). Therefore, they prefer the DF pricing algorithm which adapts better to market conditions.

Regarding the different discount methods, we expected that InfoCenters will benefit most from the discounts offered to them by the sellers. Our results do not support this conjecture. There are two cases in which discount payments are implemented: one is the Wholesale Price (WP), and the other is the Subscription Price (SP). When applying those payments, the InfoCenter guarantees to buy from one seller only. But, over time, there may be other sellers that will offer the information at lower prices. That is the reason that the InfoCenter does not necessarily benefit from those discounts.

When we evaluate market stability, we need to look at two distinct sets of information: the information that sellers sell and the new information that InfoCenters sell. This is because InfoCenters have no added value in re-selling the sellers information, while the sellers cannot offer the new information offered by the InfoCenters. The existence of the InfoCenters may increase the sellers' profit, but they will have to continue to be price competitive in order to sell information to InfoCenters and to regular buyers. Therefore, the behavior of the price of information that sellers offer will be similar to the case of a marketplace without InfoCenters. InfoCenters that offer new information behave like sellers in a marketplace with that information. In that way, the behavior of prices of new information is similar to the behavior of prices in a marketplace that does not contain sellers that offer the new information. In summary, we can say that the influence that the InfoCenters have on the marketplace is by adding new information to the market, but the InfoCenters do not change the price behavior of the information (that is, they do not increase the price of information and do not decrease the price of it).

9. SUMMARY AND CONCLUSIONS

In this paper, we have examined the role of InfoCenters, value-added information middle-men, in information marketplaces. In the simulations presented in this paper, we implemented the following algorithms for pricing: the MY algorithm sets the price to the myoptimal price, the GT algorithm sets the price to one of the mixed equilibria prices, and the DF algorithm increases or decreases the price depending on the profit levels.

Sellers benefit from the existence of InfoCenters in the marketplace. Their average profit does not change, even though they sell information to InfoCenters at a discount. Info-

Centers are additional buyers, which enable sellers to sell more information and increase their total profit. Sellers gain highest profits when applying the DF algorithm in all marketplace configurations. The MY and GT algorithms have perfect knowledge of other sellers' prices and buyer demand. They use that knowledge in order to set the best price, when treating InfoCenters as regular buyers. The DF algorithm, on the other hand, does not have perfect knowledge of the market, and it reacts to market demand. In a marketplace where there is high demand, the DF algorithm will cause sellers to raise their prices. Therefore, sellers may not have the most competitive prices, but they will have higher profits, since they sell larger amounts of information.

Buyers benefit from the existence of InfoCenters, because InfoCenters can offer additional information that was not offered previously by sellers. That information may be more relevant, and in that way buyers get more for the money they pay.

InfoCenters in the e-marketplace gain positive profits. An InfoCenter will prefer to follow the MY and GT algorithms over the DF algorithm. Those algorithms have knowledge of the other seller and InfoCenter prices, and of buyer preferences. They can use that knowledge in order to set the best prices for the new information they offer.

There was no payment method that InfoCenters will prefer to use at all times in all configurations. But in most cases, they will benefit most by implementing the full price (FP) payment. In that case, the InfoCenter chooses the cheapest seller each time it buys information. Implementing any other payment method makes it guarantee to buy large amounts of information from a specific seller, and to get a discount in a return, but to lose out on possibly cheaper sellers in the future. In other words, an InfoCenter benefits more from the price war between sellers, than from the discount that the sellers offer.

The existence of InfoCenters in the marketplace did not affect price behavior. This is because InfoCenters bought the information offered by sellers and sold new information. Therefore, sellers had additional buyers (i.e., the InfoCenters), and the InfoCenters were the sellers of the new information.

When we compared the different discount methods that can be used when an InfoCenter buys a large amount of information from a seller, we found that the seller will gain the highest profit when the discount is higher. The InfoCenter will gain the highest profit when the discount is lower. Therefore, sellers gain more when selling their information with lower prices to selected customers, while those customers preferred higher prices. This is because a seller benefits from selling to an InfoCenter that buys a large amount of information, even if it sells it at a lower price. The InfoCenter, on the other hand, will prefer to buy the information at higher prices, because that will enable it to sell the new information with higher prices as well.

In summary, the existence of InfoCenters in a marketplace creates a win-win-win situation. Buyers benefit because they can get focused information for their needs. Sellers benefit because they have additional buyers (i.e., the InfoCenters), and the InfoCenters succeed at being profitable.

10. FUTURE WORK

One of the results obtained from our simulations was that InfoCenters could benefit more from paying the full price to avoid being committed to a certain seller. Therefore, it would be interesting to check whether InfoCenters will gain higher profits when they could subscribe to several sellers at the same time.

In this paper, all sellers offered the same information. They could cooperate in the sense that each of them could offer less information, and specialize in a niche. InfoCenters can cooperate in that way too. It would be interesting to check in which cases this cooperation does increase the profit of sellers or InfoCenters.

Furthermore, InfoCenters can approach buyers in order to understand what kind of information they are interested in and offer this information to them. In this paper, InfoCenters guess which information the buyers need. We would like to check what influence the InfoCenter will have on the marketplace, if they would be aware of buyers' needs.

11. REFERENCES

[1] J. P. Bialey and Y. Bakos. An exploratory study of the emerging role of electronic intermediaries. In *International Journal of Electronic Commerce*, March 1997.

[2] K. Decker, K. Sycara, and M. Williamson. Middle-agents for the internet. In *Proceedings of the 15th International Joint Conference on Artificial Intelligence*, Nagoya, Japan, 1997.

[3] Kamoon. http://www.Kamoon.com.

[4] J. O. Kephart and A. Greenwald. Shopbot economics. In *Proceedings of the Fifth European Conference on Symbolic and Quantitative Approaches to Reasoning with Uncertainty*, London, UK, July 1999.

[5] J. O. Kephart, J. E. Hanson, and A. R. Greenwald. Dynamic pricing by software agents. *Computer Networks*, 32(6):731–752, May 2000.

[6] S. Ketchpel, H. Garcia-Molina, and A. Paepcke. Shopping models: A flexible architecture for information commerce. In *Proceedings of Digital Libraries*, 1997.

[7] S. Park, E. H. Durfee, and W. P. Birmingham. Emergent prototypes of a marketplace digital library with strategic agents. In *Proceedings of the Third International Conference on Multi-Agent Systems*, pages 230–237, July 1998.

[8] I. Yarom, C. V. Goldman, and J. S. Rosenschein. The Behavior of InfoCenters in E-marketplaces. *In Preparation*, 2001.