Do Experts Help in Two-Sided Search?

(Extended Abstract)

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Categories and Subject Descriptors

J.4 [**Social and Behavioral Sciences**]: Economics

General Terms

Algorithms, Economics

Keywords

Sequential Search, Two-Sided Search, Social Welfare

1. INTRODUCTION

We study agents matching to form teams in a distributed multi-agent environment. Each agent receives information about the potential value of teaming with others. This information signal may be noisy. If all candidate agents agree to the matching the team is formed and each agent receives the true unknown utility of the matching, and leaves the market. We consider the effect of the presence of information brokers, or experts, on the outcomes of such matching processes. Experts can, upon payment of a fee, perform the service of finding and revealing the true value of a match to any agent. We analyze the equilibrium formed in the two-sided search setting, given the fee set by a monopolist expert. We then derive the revenue maximizing strategy for the expert as the first mover in a Stackelberg game. We find that better information can hurt: the presence of the expert, even if the use of its services is optional, can degrade individual agents' utilities and overall social welfare. While in one-sided search the presence of the expert can only help, in two-sided search the externality imposed by the fact that others are consulting the expert can lead to a situation where the equilibrium outcome is that everyone consults the expert, even though all agents would be better off if the expert were not present. As an antidote, we show how market designers can enhance welfare by subsidizing the expert to make her services more expensive, instead of providing conventional subsidies which reduce consumer costs.

2. MODEL

Our model is based on a standard two-sided distributed search model [1, 2], augmented to include uncertain signals. The model assumes fully rational self-interested agents, searching for appropriate partners to form mutually acceptable pair-wise partnerships.

The number of agents may be either infinite or finite and all agents are ex ante identical, in that there are no individuals who are "naturally" better than others. However, when a potential match is formed, each agent gets some idiosyncratic utility from the particular qualities of that partnership. This utility is drawn anew each time a partnership with the same agent is evaluated in later stages of the search (as the number of agents in the population grows large, this becomes increasingly unlikely, since potential partnerships are drawn at random from the population; however, even with a relatively small number of agents, it models cases where the utility of a partnership is dependent on the circumstances in which it is formed).

At any period, the matching technology arranges a meeting between two agents, each of whom pays a search cost c_s and receives a different, independent noisy signal, denoted s, indicating the estimated value of the match to it. We assume that agents are acquainted with the distribution of signals $f_s(s)$ and the conditional probability density of values given signals, $f_v(v|s)$. Upon receiving a signal, an agent can either accept the partnership, decline it, or pay a cost c_e to consult an expert who then reveals to that agent the (noiseless) true value of the partnership to that agent. If the agent does consult the expert, it must decide whether to accept or decline the partnership once it receives the true value. If both agents decide to accept the partnership, a match takes place and the agents leave the market. If either one of the agents declines the partnership, the agents go back into the searching population and continue their search by sampling another partnering opportunity at search cost c_s, and so on.

Agents are rational and self-interested; they maximize expected utility (the value they receive from the partnership they eventually form minus the accumulated costs of querying the expert and interacting with other agents along the search path). In addition, the expert is a rational, self-interested monopolist; her goal is to maximize her own expected utility: the accumulated payment she receives from the agents minus her expenses, denoted d_e, which are a function of the cost of producing the information required to inform agents of the exact values of matches.

3. ANALYSIS

Any searcher can query an expert at cost c_e to find out

Appears in: *Proceedings of the 11th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2012)*, Conitzer, Winikoff, Padgham, and van der Hoek (eds.), 4-8 June 2012, Valencia, Spain.

the true value (to her) of a potential partner. The searcher has 3 alternatives. She can (1) reject the current potential partnership without querying the expert, paying search cost c_s to reveal the signal for the next potential partnership; (2) query the expert to obtain the true value v, paying a cost c_e, and then decide whether to accept the partnership; or (3) accept the current partnership without querying the expert. If both potential partners accept then the search terminates. Case (2) termination provides the searcher with the true value v. Case (3) termination provides the searcher with the (unknown) true value of the partnership. With no mutual acceptance, the search resumes.

A solution for a general density function $f_v(v|s)$ dictates an optimal strategy with a complex structure of the form of (S', S'', V), where: (a) S' is a set of signal intervals for which the searcher should resume her search without querying the expert; (b) S'' is a set of signal intervals for which the searcher should accept the partnership without querying the expert; and (c) for any signal that is not in S' or S'' the searcher should query the expert, and accept the partnership if the value obtained is above a threshold V, and resume otherwise. The value V is the expected utility from resuming the search given that the other agents use strategy $(S'_{\text{others}}, S''_{\text{others}}, V_{\text{others}})$and is given by:

$$V(S', S'', V) = -c_s - c_e \int_{s \notin \{S', S''\}} f_s(s)\, ds + (1 - A \cdot B) \cdot V(S', S'', V) + B \cdot C \qquad (1)$$

where A is the probability that the searcher accepts the partnership eventually (either directly or after querying the expert), B is the probability that the potential partner accepts the match, and C is the searcher's expected utility if both sides accept the partnership; these are given by:

$$A = \int_{s \in S''} f_s(s)\, ds + \int_{s \notin \{S', S''\}} f_s(s) \Big(1 - F_v(V|s)\Big)\, ds$$

$$B = \int_{s \in S''_{\text{others}}} f_s(s)\, ds + \int_{s \notin \{S'_{\text{others}}, S''_{\text{others}}\}} f_s(s) \Big(1 - F_v(V_{\text{others}}|s)\Big)\, ds$$

$$C = \int_{s \in S''} f_s(s) E[v|s]\, ds + \int_{s \notin \{S', S''\}} \left(f_s(s) \int_{y=V}^{\infty} y f_v(y|s)\, dy \right) ds$$

The value of $V(S', S'', V)$ in Equation 1 is derived recursively, considering the next search iteration. The searcher pays c_s for receiving the noisy signal. The next element is the expected expert query cost, incurred whenever receiving a signal $s \notin \{S', S''\}$. The third element applies to the case of resuming search, when at least one of the sides rejects the partnership, in which case the searcher continues with an expected utility $V(S', S'', V)$. The last element applies to the case where the search is terminated, since both sides accepted the opportunity. Similarly, the first element in A and B applies to a case where the searcher accepted the match without querying the expert and the second applies to a case where the searcher accepted the match after querying the expert. The first element in C applies to a case where the searcher accepted the match without querying the expert, in which case the expected revenue is $E[v|s]$. The second element applies to the case where the searcher accepted the match after querying the expert.

Expected profit of the expert: The expected profit of the expert is: $\pi_e = \mathbb{E}(\text{Profit}) = (c_e - d_e)\eta_{c_e}$, where η_{c_e} is the expected number of expert queries a searcher performs. The expert can maximize the above expression with respect to c_e (η_{c_e} decreases as c_e increases) to find the profit maximizing price to charge searchers.

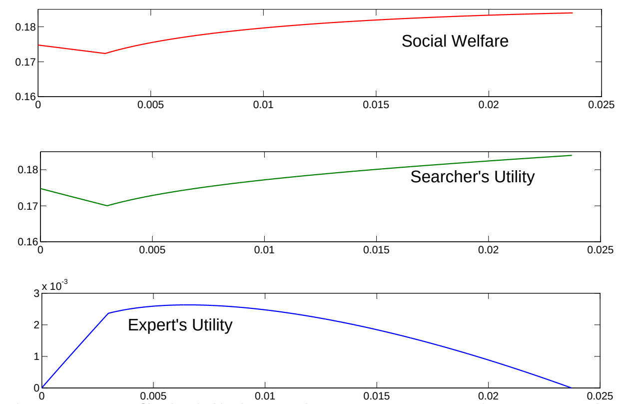

Figure 1: Subsidizing the expert to increase her query price from 0.0065 to 0.0237, thus maximizing social welfare. In this example $c_s = 0.1$.

4. ILLUSTRATIVE EVALUATION

As an example, we consider a synthetic environment where agents form pairwise partnerships. The signal is an upper bound on the true value (e.g., people tend to get a good first impression of others). Specifically, we assume signals s are uniformly distributed on $[0, 1]$ ($f_s(s) = 1$ if $0 < s < 1$ and zero otherwise) and the conditional density of true values is a monotonic increasing function in the interval $[0, s]$: $f_v(y|s) = \frac{3\sqrt{y}}{2\sqrt{s^3}}$.

A market designer can motivate the expert to modify her query price by changing the expert's incentives, in order to increase social welfare. The expert computes the profit-maximizing cost c_e to charge, given that individual agents play their optimal search strategies subject to c_s. For instance, for $c_s = 0.1$, the optimal expert query cost is $c_e = 0.0065$ (for example, see Figure 1, where the lower curve, which demonstrates the expert's profit as a function of query cost, peaks at 0.0065; note, however, that social welfare is not maximized at $c_e = 0.0065$).

In the case of one-sided search, social welfare maximization typically involves reducing the expert's query cost. However, in keeping with our finding that more information can hurt social welfare in two-sided search, in many settings a *reverse subsidy* can be optimal. That is, for increasing social welfare, it is necessary that the expert increase her query price. Figure 1 presents one example. In this case, social welfare (taking into account the subsidy) is maximized when the query price is 0.0237 (seen at the upper curve in the figure). The optimal subsidy is so high that the expert never gets used – in this case the mechanism is essentially paying the expert to leave the market.

Acknowledgments

This work was supported in part by ISF/BSF grants 1401/09 and 2008-404 and in part by NSF award IIS-0952918.

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