Hidden Market Design (Extended Abstract)

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ABSTRACT

The next decade will see an abundance of new intelligent systems, many of which will be market-based. Soon, users will indirectly interact with many markets without knowing it: when driving their car, when listening to a song, when talking on the phone, when backing up their files, or even when surfing the web. I argue that these new systems can only be successful if a new approach is chosen towards designing them. In particular, the complexities of the market must be hidden and the interaction for the user must be seamless. In this paper I introduce the general problem of "Hidden Market Design." An important goal of this research agenda is to understand the trade-off between increasing market efficiency on the one side, and decreasing interaction complexity for the user on the other side. To illustrate the main paradigm, I give a series of examples where hidden markets could be applied. I hope that the problem of hidden market design will inspire other researchers and lead to new research in this direction, paving the way for more successful market-based systems in the future.

Categories and Subject Descriptors

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

Keywords

Market Design, UI Design, Economics, AI

1. OVERVIEW

Most people primarily think of Amazon or eBay when they hear about *electronic markets*. They know they can buy goods on Amazon for a fixed price, or on eBay via an auction. In these systems, monetary transactions are natural and the markets are conceptually simple such that even non-expert users can effectively interact with them. However, in recent years, we have seen the emergence of more and more non-traditional electronic markets. For example, some toll roads adjust their prices dynamically as traffic changes. Digital content like music files is sometimes priced variably based on demand. Resource allocation decisions are often made based on market-based algorithms. In general, users will soon interact with many markets without even knowing it. While these new, non-traditional markets often provide large benefits to the users, they can also be unnatural or complex such that individuals may not have an easy time interacting with them. I argue that for these new systems to be successful, a new market design approach is necessary. In particular, the complexities of the market must be hidden and the interaction for the user must be seamless, calling for a new research agenda on what I term "Hidden Market Design".

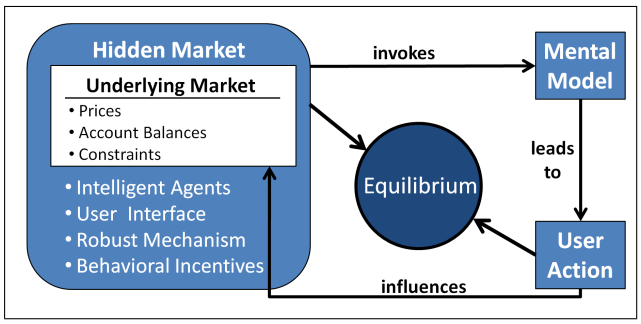

Figure 1: The hidden market wraps around the complex underlying market, hiding some aspects of the market, while still enabling a feedback loop between the users and the market.

Economists already have a deep understanding of how existing markets work and recently are applying this knowledge towards the design of new markets, giving rise to a new field called *market design* [1]. However, a fundamental assumption most economic designers of electronic markets make is that participants are sophisticated users, fully rational, and able to fully specify their preferences in complex interfaces. While this assumption might be valid for sourcing auctions, energy markets or grid networks, it is certainly far from reality for these new non-traditional "markets for the masses". Designing these markets and applications calls for a multi-disciplinary approach. We need AI technology to elicit and learn users' preferences. We need user interface design to provide users with simple ways to interact with these markets. We need behavioral decision making research to provide proper incentives and invoke the right mental models. We need economics/market design to make the system robust against strategic agents and design the market such that in equilibrium social welfare is maximized.

The primary goal of hidden market design is to hide some components of the market from the user, e.g., prices, account balances, trading constraints, etc., while still achieving high market efficiency. Finding the right trade-off between these desiderata is the challenge. Figure 1 illustrates the general paradigm: a "hidden market UI" is wrapped around the actual underlying market and exposes a simplified user interface. Because the market equilibrium depends on all individual users' actions, it is crucial that the interaction for the users is seamless while a true feedback loop between the users and the market is maintained.

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2. APPLICATIONS OF HIDDEN MARKETS

In this section I give a few sample applications of hidden market design. In [3], I have already explored the role of UI design for this research agenda and introduced a principled way of thinking about the "hidden markets" paradigm for UI design. I argue that the interface is of particular importance for the overall market because different UIs induce different mental models which in turn determine how users understand and interact with a market, which ultimately determines the market equilibrium (see Figure 1).

In [2], I have taken the problem of a market-based P2P backup application and carried it through market design, to implementation, to theoretical and experimental analysis. The main idea of P2P backup is that users provide some of their resources (storage space, upload bandwidth, download bandwidth, and online time) in exchange for using the backup service. I implemented a hidden market as part of a Microsoft research project on P2P backup systems and an alpha version of the software has been successfully tested. At all times, the design and analysis was done for the actual implemented system. Our approach is novel and different from related work in that we hide the market as much as possible. In particular, we use an indirect market model where users do not continuously specify demand and supply vectors but instead only periodically choose bounds on their maximum supply and demand. We show that for economic efficiency, it is sufficient to focus on these bounds. We define a *safety property* that shall guarantee that the system can always satisfy new incoming demand and define an equilibrium based on the supply and demand bounds. Our main result is to demonstrate that this equilibrium exists and is unique. Moreover, it satisfies the safety property and, somewhat surprisingly, cannot be easily controlled by the market designer.

In parallel to the economic market design, we also designed the UI for millions of non-sophisticated users to interact with the market underlying the P2P backup system. It is important to consider the market and UI design in parallel, because a simplified user interface restricts the market design space. Our final UI, described in detail in [3], allows the users to interact with the market without specifying bid/ask prices. Instead, the users only have to move three sliders to place bounds on how much of each resource they want to maximally supply. While the resource prices are hidden from the users, they can infer them indirectly by observing how much of each resource they have to supply to get more online backup space. Via a usability study, I found that most users intuitively understand the give & take principle as well as the bundle constraints of the market. However, while the pricing aspect worked well for some users, it was difficult to discover for others and thus needs further investigation. Overall, the results were encouraging and show promise for the hidden market paradigm.

Note that in the P2P backup application, we used a virtual currency market. This was particularly nice, because it allowed us to hide many aspects of the underlying market from the user, to such a degree even, that some users did not realize that there was a market at all. In general, this is not always possible because some markets must involve the use of real money. However, even there we can explore how to hide some of the market complexities. Consider, for example, the design of a market for pricing a toll bridge: imagine a bridge with two lanes, a toll lane and a free lane. Users crossing the bridge experience a delay that is a function of the lane they use and the total traffic on that lane. The designer of the bridge wants to price the toll lane adaptively so as to shape the traffic to achieve a certain objective function. The users decide which lane to use according to certain rules that depend on the price of the toll lane and the users' preferences. I argue that a user's decision of whether to take the toll lane or not depends to a large extent on the market design and the UI design of the system and choosing the right design is far from obvious.

The straw man solution is to simply show the current price of the toll lane to the users at the entry point of the bridge. However, this certainly does not provide the users with enough information to make an optimal decision because they cannot see how much time they can expect to save by using the toll lane. We can imagine increasingly complex UIs, with more and more information provided to the users. However, we have to consider, at the same time, that the more information we display, i.e., the more complex a UI we provide to the users, the more difficult it is for them to optimally interact with this market. Ideally, we want to reduce the complexity of the market interaction and hide as many aspects as possible. Thus, imagine now an artificial agent that automatically learns users' important appointments from their calendars and then makes decisions regarding which roads/bridges to take automatically. In this model, of course, there would still be a dynamic market that underlies the pricing of the bridge. But the design of the market rules and the interface might be very different depending on whether we expect humans and/or artificial agents to make the decisions.

So far, we have discussed markets with more or less traditional resources like storage space, bandwidth or street space. But in particular on the Internet, much less tangible commodities like "attention", "time", or "access rights" become more and more valuable. Every time users watch an ad, their attention is sold to someone. When users wait for a service to load because of slow servers, they might be willing to pay someone for saving some time. Every time users find some restricted content on the web (e.g., a NY Times article), they face the question how to get access to that content. I argue that for these domains, the application of hidden market design is particularly suitable. These are domains where users don't expect traditional market interfaces and where users are making many small decisions repeatedly. This calls for some kind of automation of the users' decision processes and the design of simpler overall market interfaces.

3. FUTURE RESEARCH

For the future development of hidden markets, I believe the following three research questions will be most important:

1. What are the consequences from hiding different semantic aspects of a market (e.g., prices, budgets, etc.) on achievable market equilibria and economic efficiency.
2. What are suitable UI design principles for the design of hidden market interfaces.
3. Which metrics can be applied for the evaluation of hidden market designs.

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