Hidden Market Design

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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 interact with many new markets, perhaps without even knowing it: when driving their car, when listening to a song, when backing up their files, or when surfing the web. We argue that these new systems can only be successful if a new approach is chosen towards designing them. In this paper we introduce the general problem of "Hidden Market Design." The design of a "weakly hidden" market involves reducing some of the market complexities and providing a user interface (UI) that makes the interaction seamless for the user. A "strongly hidden market" is one where some semantic aspect of a market is hidden altogether (e.g., budgets, prices, combinatorial constraints). We show that the intersection of UI design and market design is of particular importance for this research agenda. To illustrate hidden market design, we give a series of potential applications. We 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.

1 Introduction

The Internet has allowed market-based systems to become increasingly pervasive. Many people think of Amazon or eBay when they hear about *electronic markets* and they feel comfortable interacting with these markets. However, we are now seeing more and more non-traditional markets emerging. For example, users can pay money for questions answered on the web (Hsieh and Counts 2009). Some toll roads adjust their prices dynamically as traffic changes. Digital content like music files is sometimes priced variably based on demand. Recent progress on micropayment systems might soon pave the way for many new electronic markets by significantly reducing transaction costs. These new markets can be quite complex, with users having limited budgets, dynamically changing prices, lots of commodities being traded, and potentially complex combinatorial constraints imposed on any of these trades. At the same time, the users of these markets will generally be non-sophisticated as these systems are designed for "the masses."

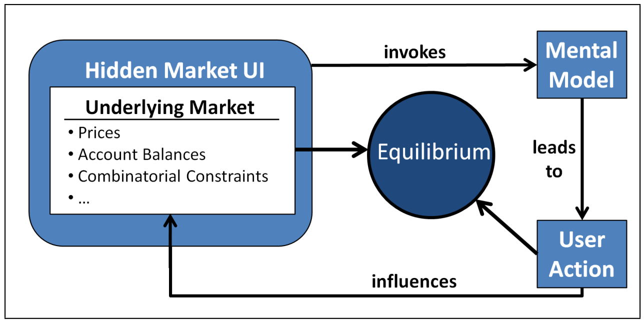

Figure 1: The Hidden Market UI wraps around the complex underlying market. The choice of the market design and the agents' actions together determine the equilibrium.

The users might find monetary transactions unnatural in some domains or they might not expect a market at all. Thus, while these new 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.

For these new market-based systems to be successful, unsophisticated users need simple methods to interact with them. We must help users make optimal decisions, in particular when they are reasoning about small amounts of value, or need to make many small decisions repeatedly. In many environments, this will require automatically eliciting users' preferences. Designing these markets, given all of these constraints, is the problem we introduce in this paper and which we call *Hidden Market Design*. We argue that many of these new market-based systems require a design that masks some complex market concepts such as prices, account balances, trading constraints, etc. from the user, i.e., that hides the underlying market to a certain degree. We propose the design of a "Hidden Market UI" wrapped around the actual market, which shall expose a simplified interface, assist the user with intelligent agent technology and potentially aggregate the decision making process for the user. A general model is illustrated in Figure 1.

When designing hidden markets, we must help users build appropriate mental models that allow them to take optimal actions on the market. For a market to work, we need a constant feedback loop between the user and the market. If we hide the market too much, for example if we don't display prices in a multi-commodity market, users might not realize that different commodities have different values, and the effect of the market would be lost. Thus, hidden market design will always involve making a trade-off between hiding certain market complexities on the one side, and maximizing economic efficiency of the market on the other side. Successful markets will require making the interaction for the user as easy as possible while still maintaining a true feedback loop between the user and the market.

2 The Hidden Market Design Challenge

The "Hidden Market Design" challenge is to find new techniques and approaches towards designing and building "hidden markets" for non-sophisticated users. The primary goal for the design of "weakly hidden markets" is to find the right trade-off between hiding or reducing some of the market complexities while maximizing economic efficiency attained in equilibrium. The design of smart user interfaces shall enable users to seamlessly interact with the market. A "strongly hidden market" is one where some semantic aspect of a market is hidden altogether (e.g., budgets, prices, trading constraints, etc.).

We find the distinction between *weakly hidden markets* and *strongly hidden markets* useful for defining the particular research challenge one wants to pursue:

Weakly hidden markets describe the more general paradigm where some of the market complexities are simply *reduced*. For example, imagine the price for some service is constantly changing (e.g., the true price of electricity) but for the hidden market design, you choose to only display two different price levels to the user, a "high" and a "low" level. This would qualify as a weakly hidden market. Another example would be if you designed a market where you combine the preferences and decisions from multiple users in a sensible way, such that the individual user only needs to interact with the market on a very infrequent basis. This would also qualify as a weakly hidden market.

Strongly hidden markets are those in which some semantic aspect of a market is completely hidden. For example, if users have account balances which constantly change, but if the market design does not require the users to ever think about their account balances, then this would qualify as a strongly hidden market. Another example is a domain where the value of resource bundles is combinatorial and requires non-linear pricing. If the market design hides this aspect from the user by only displaying linear prices, then this would also qualify as a strongly hidden market.

3 Required Research Approach

At this stage, hidden market design might still seem more like an art than a science. But with more research, the recurring problems in designing hidden markets will soon be isolated, formalized, and can then be addressed more scientifically. We believe, the main contributions will be made by combining two or more research areas. Certainly, economics and market design are central to this research, to make sure the system provides the right incentives and a desirable equilibrium with high welfare properties is reached over time.

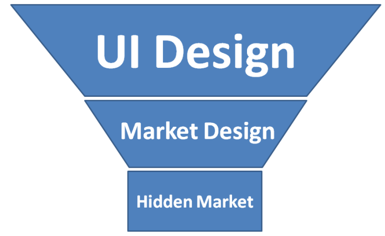

Figure 2: The UI Design/Market Design Funnel.

But almost as important is UI design and associated disciplines of cognitive psychology and behavioral economics. The UI plays a particularly important role for four reasons. First, the UI is the first point of contact between the user and the system/market. If the UI is not well-designed, it will fail to encourage user involvement, leading to very thin markets and potentially their total failure if a critical mass cannot be reached (Roth 2008). Second, the choice of the UI directly constrains the market design space like a funnel (see Figure 2). For example, if one chooses to hide certain semantic aspects of a market, this restricts the kinds of markets that can be designed. Third, the UI defines the way users express their preferences, the way users are informed about the current state of the market, and the way users can make decisions and take actions that influence the market. Thus, the UI defines what the feedback loop between the user and the market looks like. Finally, the UI design can address one aspect that is often neglected: the user's cognitive costs.

In standard economic models, users' cognitive costs often remain unmodelled. This includes the costs for evaluating an option, the costs for learning how to use a new interface, and the costs for decision making. A domain where these cognitive costs matter a lot is the Internet. For example, consider a user's decision about whether to buy a new MP3 for $0.99, or the decision about whether to pay $0.25 for an article on the web. How many users will be able to correctly evaluate whether the article is worth $0.25 cents to them? If we consider advertising on the web, we get down to an even smaller level of economic activity. Consider for example a 30 second video ad that users must watch before they can see the actual video they were interested in (e.g., on IMDB or on Hulu). Often times, the users could alternatively search for a different website that hosts the same video without ads, they could sign up for a monthly membership to some service, or they could pay a one-time fee to see the video. Which alternative is the optimal one for the user depends on the user's value for time. However, at this level of economic activity, standard rules of economic behavior become invalid and we have to use "atomic economics," a concept first introduced by Kamal Jain. Once the cognitive costs for making a decision become larger than the possible value lost or gained by making the decision itself, then optimal (economically rational) user behavior can no longer be assumed. This poses a significant challenge for UI and market design. To prevent users from repeatedly incurring these cognitive costs, we must learn their preferences over time and ultimately assist in making these small, atomic decisions. This is a point where UI design and sophisticated AI technology must go hand in hand to address this challenge.

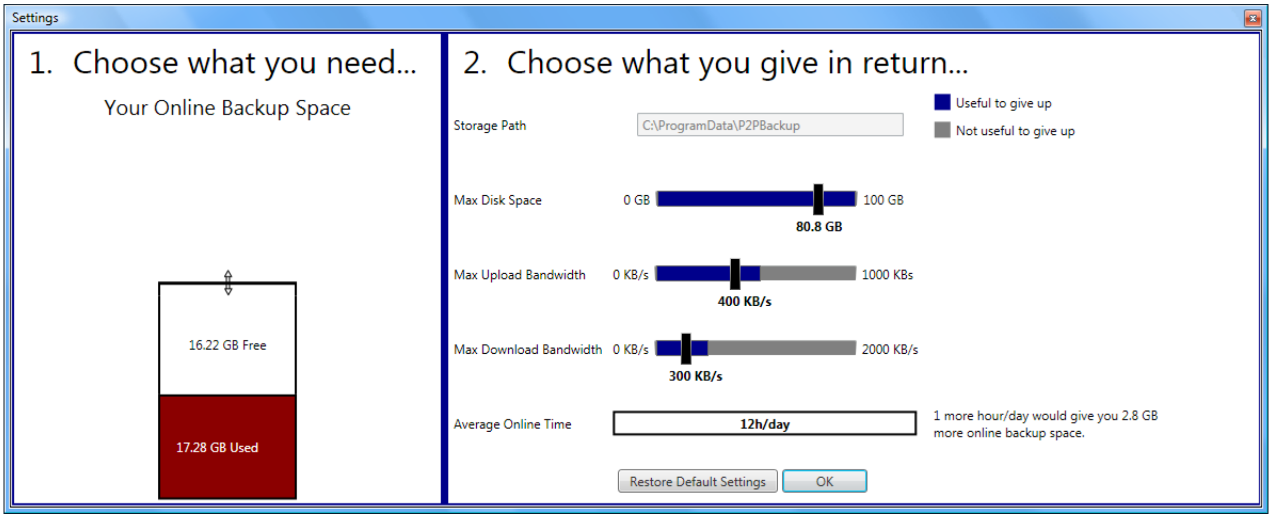

Figure 3: A user interface for a P2P backup application. On the right side, users can specify bounds on their maximum supply. On the left side, users see their current demand and the upper bound on how much they can consume given their supply choice.

4 Some Applications of Hidden Markets

In this section we discuss three concrete problems to illustrate the hidden market design challenge. We hope the description of these problems will help other researchers to get a more concrete idea how hidden markets could look like.

A Hidden Market for P2P Backup

We started to explore the hidden market design problem in our own work (Seuken et al. 2010a; 2010b), tackling the problem of designing a hidden market for a P2P backup system. 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. Our P2P backup system is novel in that it uses a market with a virtual currency to allocate resources.

The first challenge in designing this hidden market is the combinatorial nature of the problem. All users must provide a certain amount of all resources, even if they currently only consume a subset of them. For example, a user who only contributes storage space is useless to the system because no files could ever be sent or received from that user. We call these combinatorial requirements of the market the *bundle constraints* because only bundles of resources are worth anything. Displaying the bundle constraints in a simple way is a major challenge for the UI design.

A second challenge is that all users have different preferences regarding how much of each resource they want to supply. Some users might need their own disk space a lot and prefer to sacrifice their internet connection. Other users might use their bandwidth for services like VOIP or file-sharing and might prefer to give up space. We allow different users to provide different ratios of their resources, and we update prices regularly taking into account aggregate supply and demand. However, exposing prices to the users in an intuitive way is challenging, in particular because we do not want to make the users think of a monetary market.

We simultaneously designed the market and the UI. Our proposed UI (see Figure 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. The bundle constraints are realized via shaded areas of those sliders, telling the users indirectly which resource combinations are useful to the system. A bar chart showing how much more a user can back up given the current supply summarizes that user's account. The users can infer the current resource prices indirectly by moving the sliders while observing the bar chart. If the user moves a slider a little and the bar chart only changes a little, this means that the current price for that resource is relatively low. If the user moves a slider a little and the bar chart changes a lot, this means that the current price for that resource is relatively high. This allows us to communicate the market prices to a user in a non-explicit way. In particular, users can be unaware of the price-based market, and yet over time they will notice that for some resources they get more in return than for others.

A Hidden Market for Smart Grids

The hidden market for the P2P backup application did not involve any real money. When no money is involved, users might have an especially hard time to understand the market aspects of a system. However, even when real money is involved and prices are natural in a domain, there are still other aspects of a market that can be hidden.

One such domain where hidden markets seem particularly suited are *smart grids*, the next generation of electricity networks (U.S. Department of Energy 2003). One major problem in the generation and distribution of electricity is that it is very costly to store electricity. However, the demand and the supply for electricity can vary significantly, even over short periods of time. On the demand side, a sudden increase in the outside temperature may induce many people to start their air conditioners. On the supply side, clouds blocking the sun might significantly reduce the amount of solar power generated. The major advantage of smart grids is the combination of traditional electricity networks with digital technology that enables the remote control of consumers' appliances in their houses. This allows the system to react to sudden changes in the electricity market. For example, at times of low demand for electricity, the system might turn on individual user's washing machines in their homes. At times of peak demand for electricity, the system might turn off or reduce the power consumption of selected appliances (e.g., temporarily decrease the power given to air conditioners). Additionally, smart grids also allow to charge consumers different prices for their consumption, conditional on current market conditions, via the use of *smart meters*.

Currently, governments are investing billions of dollars into the development of smart grids, hoping that this will reduce overall energy consumption, inhibit the steady increase of energy prices, lead to more energy independence, and make energy systems more robust against failures. Consequently, significant research efforts have recently gone into the design of smart grids. However, to the best of our knowledge, only little attention has been paid towards the design of good user interfaces to interact with these new energy markets. Given that the whole concept of smart grids relies on the active involvement of individual home users, it seems crucial to develop UIs that encourage user involvement and make it easy for the users to express their preferences.

Consider an example in which a user's washing machine is remote controlled. A user might load the washing machine in the afternoon, but might be happy if the machine is done anytime between now and the next morning. Thus, the smart grid could start the machine during the nighttime when electricity is cheaper. However, users might also have a certain negative utility if the washing machine is running while they are sleeping. What kind of UI would allow the users to properly express their preferences regarding how much they are willing to pay more in electricity costs if the washing machine were not running during the night? Now consider a user whose air conditioner can be remote controlled. The user might set the AC to his most preferred temperature, but would be willing to accept a slightly higher room temperature if this allows to save him some money. However, obviously the user would not accept a huge temperature increase just to save a few pennies. Again, how would we design a UI that elicits the user's preferences regarding this trade-off?

When it comes to these decisions about accepting changes in a user's home environment in exchange for saving a little bit of money, the user is again making decisions at the atomic level. For any individual decision, the cognitive costs for making the decision outweigh the potential savings associated with it. Thus, clearly we must provide the users with interfaces that let them specify their preferences in a more general way, such that the users must only infrequently interact with the market. Additionally, we can imagine interfaces that alert the users only when large price changes happen and the optimal decision cannot be made based on the user's past selection. In any case, it seems absolutely crucial to make these UIs as easy to use as possible for smart grids to become successful. The worst case that could happen would be a completely deployed smart grid where the individual users simply cannot be bothered to express their preferences to the system because the UI is too complex. Then, the feedback loop between the electricity market and the user would be lost and all the efficiency gains would be foregone.

A Hidden Market for Display Advertising

So far, we have presented one hidden market that works without using money, and one market that explicitly uses money. We now consider a market where real money might be flowing, but without the knowledge of the users.

Consider the problem of online display advertising. For example, when you read a New York Times article, you might see a banner ad and many small ads throughout the article. A recent study by Jain et al. (2010) has shown that for an average length article, the presence of ads slows down a user by about 27 seconds, compared to a version without ads (taking into account page load time, reading time, and navigation time when searching for information). Jain et al. discuss the important point that for many content providers the expected profit from display advertising is very small, often on the order of 0.1 cents per page view. Now, if we consider the time lost by the users and compare that to the profits gained by the content provider, then the users' time is valued at about 13 cents per hour. We expect that for most users, the marginal value of time is much higher than that and consequently many users would be happy to pay the content provider 13 cents if they could get their one hour of time back. This illustrates that the display advertising market exhibits a market failure and has reached a non-Pareto-optimal equilibrium.

The solution to this problem is not straight-forward. If the web site simply charged all of its visitors a small fee and provided an ad-free version of the content in return, it would lose most of its visitors. This is due to what one might call the "penny gap": there is a discontinuity point in the demand function at 0, i.e., the demand for a particular product does not drop continuously when the price is increased from 0 to 1 cent, but instead, for many online services, this small price increase can cost them almost all users. But even if the website gave its users a choice about whether to see the site with or without ads, users would not want to register their credit cards with every website they regularly visit. Moreover, here we again face the problem of atomic economics. A user's cognitive cost for making the decision whether to view the ads or whether to pay a small amount of money for an ad-free website would already exceed the potential gains. Thus, it seems that a hidden market design could significantly improve the efficiency of this market.

One possible avenue for improving the efficiency of this market is by bundling the content provider's service with another service or product that derives high value from acquiring a new customer. If the bundling partner pays the content provider in return for acquiring the customer, the content provider could provide an ad-free version of the webpage to the user, thereby increasing overall efficiency. There are many conceivable bundling partners. For example, a wireless network provider like AT&T could be a potential bundling partner, paying the websites to eliminate ads when its users are visiting the website from their mobile devices (where ads are particularly disturbing). Along the same lines, a search engine could offer its users to pay the content provider if the user visits the website coming from the search engine because search ads generate much larger revenues than display ads. A third bundling partner could be a hardware manufacturer like Apple. When a user visits a website on the iPhone or the iPad, Apple could pay content providers for removing the ads because Apple can make much higher revenues from showing ads in their apps. In all of these examples, money would be flowing from the potential bundling partner to the content provider, but the user would not be involved in any monetary transaction, yet benefit from the ad-free website. However, this poses a new market design challenge. The users' preferences regarding the online content are important to determine the right price that should be paid to the content provider, but the user is no longer inside the feedback loop with the market. Thus, the resulting research question is how to indirectly involve the user in this market to set prices. One can imagine the use of machine learning techniques to learn users' preferences over time with only minimal user interaction (e.g., very infrequently asking the users a question regarding the ads). Collaborative filtering techniques could be used to identify users with similar preferences (here with respect to ads and time/money trade-off) and then use the aggregated data to infer the right price for the display advertisement. However, the design of such learning algorithms and the details of such a hidden market UI are all open research questions.

5 Categorization of Hidden Markets

We have identified the following three dimensions along which hidden markets can be categorized:

- Amount of Market Hiding
- Amount of Market Complexity
- Amount of User Interaction

The amount of market hiding describes the degree to which a semantic aspect of the market is hidden from the user. For example, in the P2P backup application, the UI is designed such that some users did not even know they were interacting with a market at all. Furthermore, this is an example of a "strongly hidden market": we completely hide the concept of account balances from the users and we avoid non-linear bundle pricing despite combinatorial constraints between supplied resources. In contrast, the suggested market for smart grids would only be "weakly hidden" because money will be natural in that domain and it will be clear to users that consuming off-peak energy will be cheaper, independent of the actual UI which users use to express their preferences. The hidden market for display advertising also exhibits a high amount of market hiding because we suggested to completely hide the payments from the users even though real money would be flowing.

The amount of market complexity describes how difficult it is for users to use the market interface. The P2P backup application provides a simplified interface, however, the users still need to interact with a combinatorial market and get used to the bundle constraints that are present. The adopted goal in the smart grid example is to reduce the market complexities as much as possible because encouraging user interaction seems most important in this domain.

The amount of user interaction describes the frequency and intensity of interaction required by an individual user for the market to work well. In the P2P backup application, most users needed to interact with the market, but only periodically (e.g., every few months). In the smart grid example, all users needed to interact with the market, potentially every day when prices are changing or when they make decisions about using appliances in their homes. For the display advertising market, we would hope that by using appropriate learning and aggregation algorithms, only a few users would need to interact with the market and only once in a while.

To summarize, we have seen that depending on the particular application/domain, hidden markets can vary significantly along three design dimensions. We believe that the general hidden market design process will involve the following three steps: first, we start with the problem domain at hand and identify the minimum amount of market hiding, the maximum amount of market complexity and the maximum amount of user interaction that is feasible in the domain. Second, we determine how the resulting constraints on the UI design space constrain the market design space. Third, we choose the optimal combination of UI design and market design for the particular application subject to the constraints identified before.

6 Evaluating Future Progress

Evaluating a hidden market design is inherently difficult because markets require a large number of users to even start working. Moreover, in many systems, individual users may have a start-up cost for getting used to the UI and only realize benefits from the market after using the system for a while. All of these things are difficult to measure in a lab or in simulation, before deploying the actual market. Nevertheless, we believe the following three methods can help evaluate a particular design.

First, we can use theoretical analysis to see how well the proposed design meets the criteria. For example, we can analyze the incentives of the market to determine whether strategic behavior will be problematic. Naturally, an incentive compatible market mechanism results in less complexity for users. Furthermore, we can work with simple user models and compare different market designs, for example with respect to efficiency or revenue considerations. Finally, we can analyze whether the amount of information we get from the hidden market UI is sufficient for the market to work well and will lead to a desirable equilibrium.

Second, we can conduct a usability study to evaluate the UI. Whether the design is good or not can be tested by inviting users into a lab, giving them concrete tasks to complete with the new application/product, and then evaluate whether the right mental models have been invoked such that the interaction with the market can be deemed successful. This is the approach we have taken to evaluate the UI for the P2P backup application (Seuken et al. 2010b).

Third, if we believe we have a reasonably good user model (perhaps established before via user studies), we can use an empirical evaluation of the underlying market via simulations. This can inform us about convergence properties of the market, its robustness against demand/supply shocks, etc. Thus, simulations can complement the evaluation of the UI via usability studies, because we will generally not be able to study long-term market behavior in the lab.

7 Related Work

In addition to a deep understanding of how existing markets work, recently researchers are also gaining a better understanding of how to design new ones (Roth 2008). This has given rise to a new field called *market design*. A fundamental assumption many designers of electronic markets make is that participants are sophisticated users able to specify bids in an auction-like framework (e.g., (Hahn 2001)). A particularly sophisticated UI design for a combinatorial market is described in (Sandholm 2007). However, unlike in sourcing auctions, the users of those new markets we have in mind are non-experts and thus such interfaces would not be practical and almost certainly lead to market failures.

Recently, HCI researchers have gotten more interested in topics at the intersection of UI design and economics. Hsieh et al. (2008) test whether the use of markets in synchronous communication systems can improve overall welfare. Hsieh and Counts (2009) explore a similar idea in the domain of Q&A applications where users could attach payments to their questions. While the use of the markets is similar in vein to our approach, i.e., using markets to most efficiently allocate resources, in both papers they used a very explicit UI showing monetary prices to the users. This is something the hidden market approach tries to avoid.

MySong (Morris, Simon, and Basu 2008; Simon, Morris, and Basu 2008) is an application that allows musical novices to compose new songs. The authors have successfully designed and tested an interface that lets users interact with complicated elements of the underlying machine learning system in an intuitive way. Although this work does not concern the design of market interfaces, the approach is similar to ours, in the sense that their user interface is also designed to hide the complexity of the underlying system while maintaining the important feedback loop.

Satu and Parikh (1995) compare live outcry market interfaces in scenarios like trading pits and electronic interfaces. They draw a distinction between trying to blindly replicate the real world in the UI, and locating "defining characteristics" that must be supported. In our work, we adopt this philosophy and attempt to mask the unnecessary affordances in the hopes that the relevant ones become easier to use.

An application that addresses directly the hidden markets problem is *Yoopick*, a combinatorial sports prediction market (Goel et al. 2008). This application provides an intuitive UI for trading on a combinatorial prediction market. The designers successfully hide the complexity of making bets on combinatorial outcomes by letting users specify point spreads via two simple sliders.

8 Conclusion

In this paper, we have introduced a new research challenge that we call *Hidden Market Design*. As market-based systems become ubiquitous, millions of non-sophisticated users will interact with them on a daily basis and thus these markets need special designs. The main goal of "weakly hidden markets" is to reduce the market complexities and provide UIs that allow users to seamlessly interact with these markets. "Strongly hidden markets" go a step further and completely hide some semantic concept of a market (e.g., prices, budgets, constraints). We have shown that the intersection of market design and UI design is of particular importance for this research agenda because the choice of the UI has a huge impact on users and furthermore constrains the market design space. Even though we cannot yet envision all of the different kinds of electronic markets that will emerge in the near future, we are sure that many of them will need to be hidden to be successful. We hope that this challenge inspires many researchers to make contributions towards hidden market design, to pave the way for more successful market-based systems in the future.

Acknowledgements

We are thankful to Desney Tan, Mary Czerwinski, Nikhil Devanur and Haoqi Zhang for helpful discussions on this work. The first author is supported in part by a Microsoft Research PhD Fellowship.

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