A Design Science Approach for Developing Prediction Markets in an R&D Community

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ABSTRACT
The main objective of this research is to design and operate a prediction market inside an R&D community, to assess the emergence and the evolution of mobile technologies. To support this research, we iteratively developed and evaluated several prototypes. We intend to demonstrate the successful use of prediction markets for predicting the impact of a research activity. Furthermore, following a design science paradigm, we illustrate the design of our artifacts using build-and-evaluate loops supported with a field study, which consisted in operating the prediction markets in different settings.

Categories and Subject Descriptors
H.4.2 [**Information Systems Applications**]: Types of Systems – decision support.

General Terms
Design, Economics, Experimentation

Keywords
Prediction market, design science, e-marketplace, market maker, field experiment.

1. INTRODUCTION
In the context of their R&D activities, organizations scan their environment in order to understand the external forces of change that may affect their future position so that they can develop effective responses and strategies. We are specifically interested in assessing technological environments. In order to assess such landscapes, companies today use the Delphi method [20], game theory [31] and scenario planning [21], and investigate different models, such as actor-issues analysis, disruptive technology detection [4, 24], technology roadmaps [19] and multi-criterion decision models [26]. Moreover, the more advanced are starting to use computer-assisted design and visualization tools [28].

The most recent model they are examining is the so-called idea future, or prediction market[1]. This recent innovation suggests transferring the tools and methods for trading commodity and financial futures to futures markets for ideas. Such electronic markets trade on propositions as to whether events will occur or not, have applications for decision-making, and have proven themselves to be an accurate predictor of future events. The price of an idea reflects the beliefs that the proposition will be realized. Many groups have investigated the concept of this new kind of e-market, with different uses, as will be presented in the related work, section 2.2.

We formulate and explore the hypothesis that prediction markets are suitable for technology assessment and prediction in an R&D context.

Our research objective is to design a systematic approach to the development and operating of a prediction market for assessing the emergence and the evolution of mobile technologies within an R&D community. Based on this approach, we design and evaluate IT artifacts using build-and-evaluate loops, supported with a field study, which consisted in operating the prediction markets in different settings. We developed the prototypes and conducted three consecutive rounds of experiments over the past twelve months, with a wide range of actors.

The paper's structure follows the design science framework proposed by Hevner [17]. We start by introducing the content and the role of a prediction market in a technology assessment and R&D context (Awareness of problem). In the following sections, we expose each design iteration. Next, we provide a conclusion structured with seven design guidelines. We conclude with some final thoughts and expose further possible research.

2. Awareness of problem > prediction market in R&D settings
We adopted the IS Research Framework suggested by Hevner et al. [17] to conduct and structure our research (see Figure 1). We first expose the current situation of R&D and technology foresight in order to heighten awareness of the problem. We then provide a short description of the research camed out in technology assessment and foresight and what techniques have been used so far to study the phenomena of interest (Knowledge Base). We

[1] For a comprehensive list of prediction markets, visit http://www.chrisfmasse.com/3/3/markets/

also expose the different theoretical foundations used in current prediction market research and justify our methodology choice. Finally, we present the approach we used to build and evaluate the design artifact.

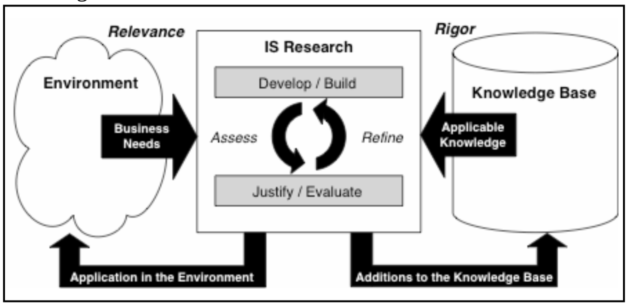

Figure 1. Information Systems Research Framework According to Hevner et al. [17]

2.1 Environment > technology assessment and foresight in a R&D community

The R&D community we consider in this research is a Swiss NSF program in the field of Mobile Information and Communication Systems[2] (MICS).

Technology foresight is not simple. At the beginning of the project, in 2001, the claim “First sensor networks deployed in 2004” did not appear in the NSF proposal; but four years later, sensor networks are a main stream research topic within MICS. The claim “A testbed for a voice-over Terminodes system in 200?” would have been a leitmotiv four years ago; but now it is no longer the first priority.

Is it possible to improve for the next phase without relying on better expert judgments but on a continuous prediction market, accessed by the entire MICS community? In 2005, claims similar to the followings would be considered in the prediction market: “CommonSense sensor networks used by independent farmers in 2008”, “Market-based dedicated unlicensed spectrum below 3Ghz, in January 2008”, “Percolation algorithms integrated in WMAX prototypes mid-2008, …

There is an assumption that an idea futures market allows us to reach a scientific consensus, with a betting pool on disputed science issues. The current odds could be treated as the current intellectual consensus. Betting odds could serve as a scientific barometer to guide public policy which, in turn, could increase the public’s interest and role in science [9].

A double-auction prediction market for MICS technology foresight (named MarMix) should be a predictor of MICS technologies, with the following characteristics:

- 100 researchers, bettors,
- Initial capital of CHF 100 (play money) per researchers,
- Securities or contracts corresponding to MICS technologies and theories developed in the research labs.

The prediction market for MICS technology foresight would improve the following aspects:

- resource allocation for the project, for the management team,
- motivation of MICS researchers, potentially concerned by all the components of the MICS project,
- visibility of the project for the outside environment, for policy makers (NSF), the scientific community, and the public.

2.2 Knowledge base > Foundations & Related Work

In this section we present the foundations and methodologies used.

There are many definitions of idea futures (IF) markets, prediction markets, information markets, virtual stock markets (VSM), securities trading of concepts (STOC) markets. Hanson, one of the inventors of this concept recently wrote:

> "Information markets can be used to elicit a collective estimate of the expected value or probability of a random variable, reflecting information dispersed across an entire population of traders. The market prediction is not usually an average or median of individual opinions, but is a complex summarization reflecting the game-theoretic interplay of traders as they obtain and leverage information, and as they react to the actions of others obtaining and leveraging their own information." [16].

More recently, Bell developed some definitions to characterize scientific prediction exchanges (SPEx):

> "(a) A "scientific prediction exchange" is a forum that uses instrumentalities of interstate commerce to facilitate the buying and selling of prediction certificates.
>
> (b) A "prediction certificate" is a document promising to pay its bearer a specified amount of money on condition that a designated prediction judge names as true the document's prediction claim or claims.
>
> (c) A "prediction claim" is an answer to an unresolved question of science, technology, or public policy that can be resolved primarily by the application of skill. A prediction claim is not an answer to an unresolved question about the outcome of a sporting event or contest, or the future value of a securities transaction currently regulated by the Securities" [2].

In its first edition, The Journal of Prediction Markets published a literature review by Tziralis [30]. He used a classification framework based on the nature of prediction markets research. He identified four broad categories: description, theoretical work, applications and law and policy. The largest category covers the various applications of prediction markets, either of an experimental or a practical nature. As our research interest concerns the design of a prediction market, we will more widely review the various experiments.

Idea futures markets have been used in many different public contexts and used as case studies in many scientific papers. The Iowa Electronic Market[3] or IEM is a well-known small-scale, on-line, real-money, prediction market, run by the University of Iowa, in which contracts correspond to political or economic

[2] http://www.mics.org/

[3] http://www.biz.uiowa.edu/iem/

events. The Hollywood Stock Exchange[4] is an e-market along the same lines as the IEM, which allows people to use virtual currency to speculate on movie-related questions. Other examples include TradeSports[5], a futures electronic market or gambling forum, initially for sports events, and now for a rich set of political futures, financial contracts, and entertainment. The Foresight Exchange[6] is a play-money idea futures market to test the ability to predict the outcome of future events, check the odds of upcoming events, and make bets, among others for science and technology events. NewsFutures[7] also trades political, finance, and technology (pharmaceutical) events, with virtual currency but real prizes. The Tech Buzz Game[8] is a play-money market hosted by Yahoo! Research in collaboration with O'Reilly about the future of technology. It is also the first market using the dynamic pari-mutuel (DPM) automated market maker algorithm from Pennock[22]. A final example of public e-markets is the controversial and rapidly-aborted Policy Analysis Market, or FutureMap [10, 11, 13, 14] sponsored by the US Department of Defense, which should have allowed speculating about strategic and geopolitical issues. Recently a German mobile phone operator has also used a Mobile Phone Service exchange or MPSX with a better forecast accuracy than classical extrapolation models. Finally, Google launched an internal market to forecast product launch dates, new office openings, and many other items of strategic importance to Google.

Idea futures markets have also been used inside corporations. An internal market, Information Aggregation Mechanism or IAM, at Hewlett-Packard produced more accurate forecasts of printer's sales than the firm's internal specialists. At Siemens, an internal market was tested for predicting the progress (due date) of a software project better than conventional planning tools. The MIT Securities Trading of Concepts or STOC has used the pricing mechanism for marketing research using pseudo-securities market to measure preferences relating to new products.

Researchers from different disciplines study prediction markets: politics, economies, law, finance, decision science, and computer science.

Wolfers [34] describes early experiments concerned with prediction markets, raises some market design issues, and concludes with some evidence as to the limitations of prediction markets. He also found that prediction markets prices typically provide useful (albeit sometimes biased) estimates of average beliefs about the probability of an event occurring [33]. Spann [29] evaluates the potential use and different design possibilities as well as the forecast accuracy and performance of virtual stock markets compared to expert prediction for their application to business forecasting. Furthermore, he proposes a new validity test for prediction markets forecasts. Berg [3] shows how prediction markets can be used for decision support. Chen [5] proposes and experimentally verifies a market-based method to aggregate scattered information so as to produce reliable forecasts regarding uncertain events; he empirically demonstrates that nonlinear aggregation mechanisms vastly outperform both the imperfect market and the best informed traders After introducing market scoring rules, Hanson [8] considers several design issues, including how to represent variables in order to support both conditional and unconditional estimates, how to avoid becoming a money pump via errors in calculating probabilities, and how to ensure that users can cover their bets, without needlessly preventing them from using previous bets as collateral for future bets. Plott [23] analyzes markets as information gathering tools, reports on the deployment of such an Information Aggregation Mechanism (IAM) within Hewlett-Packard for the purpose of making sales forecasts, and shows that IAMs performed better than traditional methods employed within Hewlett-Packard. To test how much extra accuracy can be obtained by using real money versus play money, Servan-Schreiber [27] sets up a real-world on-line experiment showing that play-money markets performed as well as real money markets. They speculate that real-money markets may better motivate information discovery while play-money markets may yield more efficient information aggregation. Wolfers [32] showed that the success of the prediction market in generating trade depends critically on attracting uninformed traders. Rhode [25] studied a century of manipulations of prediction markets. His work suggests that it is difficult and expensive to manipulate prediction markets beyond short periods of time. Studies on TradeSport point out that manipulations are reverted within minutes by other traders.

The first software platform and open source toolkits are appearing for building idea futures markets. NewsFutures[9] licenses its proprietary Prediction Trader platform[10] to enable the rapid development, operation, and administration of prediction markets. Prediction Trader is used to power MIT Technology Review's Innovation Futures: a prediction exchange concerning emerging technologies and the business of technological innovation. Hibbert [18] proposes developing an open-source toolkit for creating prediction markets, called Zocalo[11], in order to catalyze broader adoption of markets in academia, industry, and throughout society.

Finally, the first workshop dedicated to prediction markets has recently been organized: DIMACS Workshop on Markets as Predictive Devices (Information Markets), February 2005, Rutgers University. A mini-conference on Information and Prediction Markets also took place at the London Business School in December 2005.

2.3 IS research > building and evaluating a prediction market

We adopted the recommended build-and-evaluate loop for the design cycle. An artifact is built and assessed with a field study before being refined and reassessed. In our case, these field studies started with a small number of actors and conclude by involving more than 200 actors. We conducted three iterations of this loop, which are presented in this paper.

[4] http://www.hsx.com/
[5] http://www.tradesports.com/
[6] http://www.ideosphere.com/
[7] http://us.newsfutures.com/
[8] http://buzz.research.yahoo.com/

[9] http://www.newsfutures.com/
[10] http://us.newsfutures.com/home/trader.html
[11] http://zocalo.sourceforge.net/

3. First Design Sketch > an experimental prototype

We started our first iteration with the design of an experimental prototype, designed for a small number of actors. This first prototype was used for experiments within the Department of Information Systems of the University of Lausanne.

3.1 Suggestion > Experimenting a simple prediction market

This first experiment gave us the opportunity to test the various mechanisms of prediction markets and to implement the design choices elaborated during the design phase. We experimented with a simple prediction market with few actors. Chen [5] illustrated that small markets are able to make accurate predictions.

Prediction markets are currently not widely deployed within R&D centers and universities, so we were unable to use existing literature to define the properties of a prediction market dedicated to research.

In order to define the characteristics of our prototype, we carried out a series of talks during summer 2005 with researchers involved in the MICS project, and with the person in charge of the project. The main results from these discussions are related to two distinct points: confidentiality of the market and the protection of intellectual property.

Confidentiality for the actions on the market is the principal request of the researchers. Indeed, in order to guarantee the transfer of private information in the market, the traders must have the certainty that it will never be possible to discover the origin of the transaction, for political reasons between researchers and between the community and the Swiss National Science Foundation. In addition, anonymity protects the credibility of the traders who made poor predictions or predictions going against the mainstream.

Regarding respect of intellectual property, the fear is to see other researchers using claim descriptions to take up the research question. It is possible that a researcher takes the ideas in a claim not to evaluate their feasibility, but as a starting point to carry out, on own account, the research suggested. Because we had no time to study this problem in detail, we chose to retain only claims which are based on published proposals, articles or on project submissions.

3.2 Build > Customizing a prediction market framework

Following this first exploratory stage, we studied the various public prediction markets to determine the principal functions that have to be integrated into our prototype. We noticed four principal use cases:

- user account management,
- portfolio management,
- claims management,
- performance presentation.

Of these four use cases, the third was treated in a different way from other prediction markets. Indeed, to guarantee the transmission of information between the researchers and the market, each trader was allowed to trade on the available claims, but was also allowed to propose new claims in connection with his field of research. This led us to define a process of an IPO in four stages: claim proposal, discussion on the formulation of the claim, price determination, by putting limit orders on the claim and finally opening of the trade on the market.

For our first draft we adopted the three Steps for Designing a Virtual Stock Market from Spann and Skiera [29].

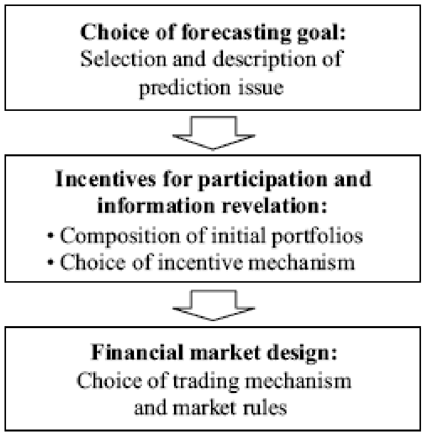

Figure 2. Steps for Designing a Virtual Stock Market from Spann and Skiera [29]

3.2.1 Choice of forecasting goal

We chose a basic model, namely the forecasting of the occurrence or nonoccurence of a particular event, for example, the validation of a particular theory at a defined date. The payoff function related to this model is a "Winner takes all" function, represented by Span et al. [29] by:

$$d_{i,T} = \begin{cases} v & \text{if particular event occured,} \\ 0 & \text{otherwise,} \end{cases} \qquad (i \in I),$$

$d_{i,T}$ = cash dividend of the stock modeling the outcome of the ith event at time T,
I = index set of events,
T = point or period in time that is relevant for the determination of the outcome of the event,
v = cash dividend value.

3.2.2 Incentives for participation and information revelation

Based on the fact that there are no significant differences between real-money and play-money markets, as shown by Servan-Schreiber [27], we designed the market as a play-money market with tournaments based on individual performance level. Moreover, we included a play-money reward for traders who created new claims on the market, based on the quantity of contracts sold during the claim's life. Our choice of a play-money market was driven by the suggestion that researchers involved in the MICS project are more likely to trade with play-money than with their own money. This configuration also allows us to attract less informed players, who do not take any personal risk, but improve the liquidity of the market [32]. Finally, this setup of the market has the advantage of enabling us to omit the legal considerations related to a real-money market, as stated in [1, 2, 6].

3.2.3 Financial market design

To avoid falling into the problems of small markets (lack of movements and liquidity), we chose a continuous double auction mechanism with a market maker. This choice ensures that the traders can express their forecasts at any time, whatever the positions of the other traders, and that they still have the opportunity to pass limit orders. For this first prototype we selected logarithmic market-maker mechanism.

Finally, we developed a draft of an ontology for defining the contracts. Contrary to the principal active markets, the contracts being based on research in progress must not only be clearly defined, but must also include all the necessary information for a good comprehension of the research in question.

To support our design, we reviewed all the open-source prediction markets available at the time of our first experiment and decided to improve the work of Peter McCluskey on USIFEX[12]. His prediction market had the advantage of having been developed with a robust object-oriented programming methodology. In addition, USIFEX was also the most complete software, implementing the majority of our requirements.

3.3 Evaluation > Operating the prediction market

To evaluate our design, we operated the prediction market and conducted several exploratory interviews with the actors having participated in the experiment at the end of October 2005. We used the prediction market for a one hour laboratory experiment with 15 researchers trading five contracts, followed by a two-week experiment during which about thirty traders were able to trade the same five contracts.

The considerable difference in the number of participants between the two experiments showed us that the basic mechanisms of futures markets are not known by the researchers and that consequently, without direct supervision and an incentive mechanism, researchers are not motivated to trade on such a market.

3.3.1 Weaknesses of the IT artifact

The first observation resulting from the interviews was that the researchers are by no means familiar with the necessary concepts to play on a prediction market. The underlying concepts such as limit orders, selling short, compensation of the portfolios are not mastered by the traders, which results in errors or discourages them from playing on the market.

The second observation is related to the interface: The study of the use cases led us to develop a multi-part prototype so as to cover the various functions. This disturbed the traders, who did not find the necessary information to take the right decision of investment and who did not have the overall picture of their individual performances on the various titles, nor the comparison between the other traders.

[12] http://www.usifex.com/

During this first experiment we collected various information on the use of the market by the traders. This data enabled us to determine the rate of participation of the users, the movements on the various claims as well as the rate of return of the users, as seen on table 1. After analyzing the data we note that there are very few users who played regularly apart from the one-hour workshop and almost no users played during the two weeks if they had not taken part in the workshop. At the contract level we see that most of the transactions were carried out during the workshop, although we also see a peak of activity before the expiration of the ANIMALERIE claim, which was linked to the results of a vote on the construction of a new breeding farm for the university.

Table 1. Key numbers resulting from the first experiment

Number of traders	28
Number of active traders (> 3 orders)	11
Average orders by trader	26
Number of claims	5
Number of orders	286
Number of contracts	5093

This analysis helped us illustrate the use of a prediction market in a concrete and observable setting. However, it had several limitations that prevented us from obtaining a deeper understanding of the problem.

For this purpose, we revised our design and developed a second prototype. In the next section we show the results of a highly improved prediction market that will give us more insights.

4. Second Design > Improving Interaction for a large-scale experiment

After our first small-scale experiment, we decided to run a second large-scale experiment to test the design of the prototype. This second experiment took place at the Business School of the University of Lausanne with 99 traders, playing during six weeks on 16 claims in summer 2006. During the whole experiment, we had a total of 3'071 transactions, representing 144'248 contracts.

At the same time, we ran another experiment with the same prototype, dedicated to the prediction of the organizing city of the 2014 Winter Olympic Games, with 50 traders coming from various sport federations and specialized medias.

4.1 Suggestion > An improved human-computer interface

Based on the results of the first experiment, we decided to completely rewrite the user interface to improve the user experience. Our goal was to develop a very intuitive interface in terms of usability, hiding the excessive financial aspects of the marketplace, in order to reduce the learning curve, as illustrated in figure 3.

4.2 Build > An open-source application framework

In order to support our research, we completely rewrote the user interface. We also optimized our first prototype, based on USIFEX, the Python programming language and the PostgreSQL database server, to support large-scale experiments. To prevent the manipulation of the market price, we also included an authentication mechanism based on the university authentication infrastructure, which prevented the students from simultaneously creating multiple accounts.

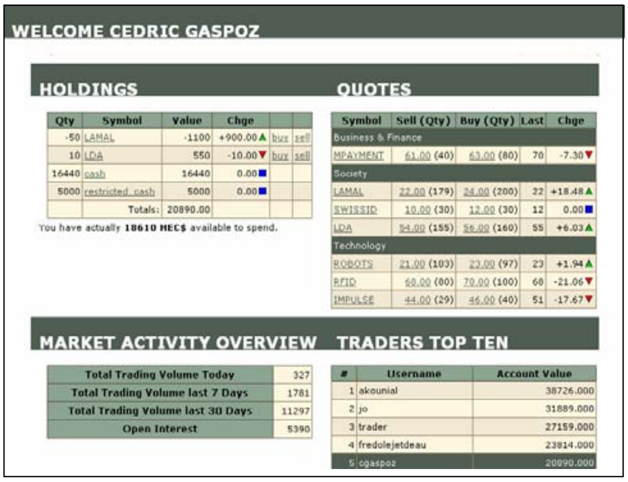

Figure 3. The MarMix Prediction Market with a new user interface

This second iteration gave us the opportunity to improve the design of the market's functionalities. Based on the four use cases presented in section 3.2, we improved the interactions between the market and the traders as follows:

In order to play on the market, the trader needs, on one hand, enough private information to optimize his return on investment, but also needs, on the other hand, enough information from the market to take the right investment decision. For this purpose, we implemented various decision support information such as graphics with daily, weekly, monthly and complete quote histories, historics of the daily quotes with trends and summaries, various top ten lists such as the biggest movements, gains, losses, the most active traders, claims. We also extended the real-time quotes with short- and long-term trends for each claim. Most of this information is included on the new trader's cockpit.

This personal cockpit summarizes all the important information needed to play on the market in one place, e.g. actual quotes, individual performance on each claims, most active claims, daily, weekly and monthly exchange volume and the overall performance of the trader. The last indicator is used to reward the best players at the end of the experiment.

This new interface also allowed us to introduce the concept of performance per contract, which, to our knowledge, is not available on the current prediction markets. If the total performance enables us to obtain information on our global capacity to predict the results of the claims on the market compared to other traders, the individual performance on each claim enables us to measure in detail the quality of each of our forecasts. This indicator also enables traders to obtain the necessary information to optimize the value of their portfolio, this value not only depending on the quality of the information related to the underlying claim, but also depending on short-term profit based on fluctuations in the price.

Concerning the reactions of the traders on the market, we tried to find a compromise between the complexity of the financial instruments and the absence of financial knowledge between the traders, as illustrated in figure 4. For this reason, we removed the notion of stop orders on this new interface, to keep only market and limit orders. These two order types are mandatory to use both double auction and automated market maker way of placing orders.

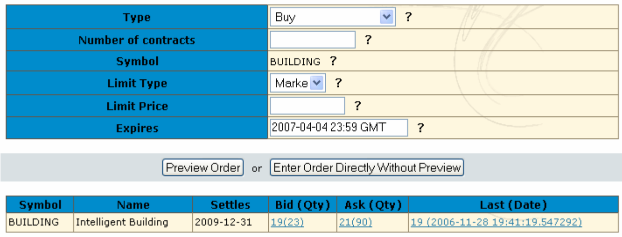

Figure 4. The order screen of MarMix

We also added a "1-Click trading" option to allow traders to pass market orders by directly clicking on a quote or to pass limit orders by clicking on the reverse transaction on order books. This option will be enhanced in the next release to allow traders to enter their own confidence related to a particular claim and pass the corresponding order on the market.

Finally, we tried to remove as far as possible financial terms from the interface. It was not possible to do this overall and we had to maintain some financial concepts, for example the notion of limit orders.

4.3 Evaluation > A large scale experiment

To evaluate our second design, we operated a large scale prediction market with 99 active traders, most of whom were students in economics at the University of Lausanne. For this experiment, we decided to choose more generic claims, based on finance, society, technology and sport (FIFA World Cup).

Table 2. Key numbers resulting from the second experiment

Number of traders	114
Number of active traders (> 3 orders)	99
Average orders by trader	31
Number of claims	16
Number of orders	3'071
Number of contracts	144'248

Among the sixteen claims, the market correctly predicted the outcome of eight. Seven were not settled at the end of the experiment and the last claim missed the prediction. This claim was a sport claim relying on the rank of Switzerland at the FIFA World Cup, predicting that Switzerland will be eliminated during the Round of 16, based on probabilities calculated by the UBS Wealth Management Research[13].

This large-scale experiment gives us the opportunity to see how the market reacted to the information. As stated in many papers, prediction markets should quickly react to new information. We did indeed observe this rapid reaction for many claims. The easiest way to notice it is by comparing the quotes of the SMI-07 claim on MarMix with the quotes of the Swiss Market Index (SMI). The SMI-07 claim: SMI will be over 7'800 at the end of July 2006 was opened the 9^{th} of June and settled the 31^{th} of July.

[13] http://www.ubs.com/1/e/ubs_ch/wealth_mgmt_ch/research.html

In figure 5, we can see both quotes and how the SMI-07 curve slightly anticipated the variations of the SMI. Around the 15th of July, we note that the prediction market anticipated the rate's recovery two days in advance.

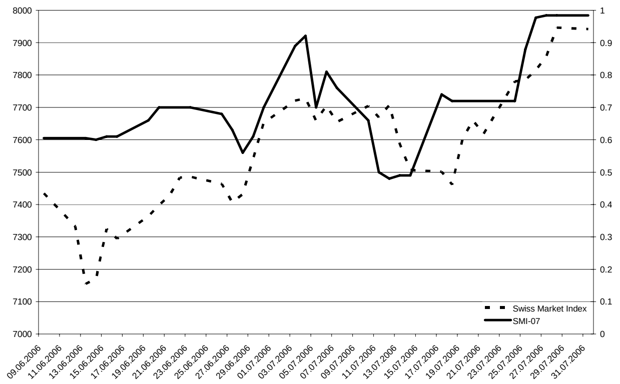

Figure 5. Variation of the Swiss Market Index and the SMI-07 claim on MarMix

4.3.1 Strengths and weaknesses

In comparison with the first design, we noticed that 89% of the registered traders were active during the six weeks. This result confirms that a better user interface was crucial. With a short ten-minute presentation, most of the traders understood the principles and how to play on the market. We also tried to communicate the information to the traders via many different channels such as email and information displays at the university. The latter played an important role in motivating the traders, and in some cases was more important than the prize itself.

We also rapidly realized that the chosen automated market maker algorithm, inspired by Hanson [12], was not designed to support large-scale experiments. The market price overreacts if many small orders and, in particular, short orders are put in, allowing traders to make disproportionate profits. Although this algorithm worked well on a small market, the number of concurrent orders placed at the same time on this large market showed the limits of our choice. Entering 20 buy or sell orders was enough to change the market price by up to 40%.. Moreover, this function did not take into account the open orders in the book to establish the market price.

$$px = \min + (\max - \min) \times \frac{1}{1 + \exp^{(0.1 \times j)}}, \qquad \text{whith} -125 < j < 125$$

After reviewing the literature we chose the design proposition of Robin Hanson based both on a combinatorial market maker algorithm and on a book of orders [7]. This proposition is based on two other publications by Hanson, the Logarithmic Market Scoring Rules [15] and the Combinatorial Information Market Design [8]. This implementation is currently used in many prediction markets, including Zocalo.

Finally, this second experiment gave us the opportunity to test our prototype over a long period of time, with a large market and a huge number of transactions. Except for the problems with the market-maker algorithm, we consider this second prototype robust enough to run our last experiment.

5. Refined Design > Research in progress

We had promising results with our second experiment, and therefore we decided to pursue this research by continuing to explore the ability to assess and forecast mobile technology with the use of prediction markets. This third experiment is currently in progress within the MICS project until the end of 2008 with more than one hundred researchers. We have to assess new problems such as the traders' incentive, claims description and the considerable participation variations during the whole experiment. Although the market will remain open during the four years of the project, we will have participation peaks during the bi-annual project events.

5.1 Suggestion > Ubiquitous access

We improved our second prototype slightly for this third experiment, based on a better automated market maker and a more adapted ontology for technological claims. Moreover, we included the possibility to play by mobile phone, allowing us to run experiments during workshops or conferences. For this third phase, we limited the market to claims about mobile information and communication systems.

Table 3. Claims' list at the beginning of the third iteration

CAR	Large scale (10 vehicles) vehicular network test
AVALANCHE	Sensor-networks deployed by the Swiss Federal Institute for Snow and Avalanche to detect the risks of avalanche in alpine regions
RFID	Mobile Phones with RFID in Switzerland
ROBOTS	Robots detect a ringing phone among a hundred faster than humans
MPAYMENT	At MICS meeting of 2009, the majority of the participants will pay their train ticket by mobile phone
BUILDING	Users helped by ludic interfaces are better than intelligent buildings in energy saving

5.2 Build > Ontology for technological claim

In order to support our third iteration, we improved MarMix by the development of a specific ontology to describe the technological claims. The goal of this ontology is to standardize the description of the claims so as to allow researchers coming from other fields to quickly understand the underlying concepts. Our ontology takes the concepts of the futures markets and adds the specific concepts of the description of scientific research.

We decided to split the definition of the contracts into two parts. The first relates to the elements described as structural and which define the claim's terms and the second defines the claim's proposal.

5.2.1 Structural elements

The structural elements are defined in such a way that all traders were rapidly able to understand the main points of the properties of the contract by reading it. We can define these in a formal way and use a proper ontology to describe, for example, the manner of calculating the settle value of the contract and the terms of payment. The structural elements consist of the description, the judgement, the price and the type of the claim.

The description contains the symbol, the name, the underlying project, the author and the type of contract (yes/no, linear, …).

The judgement section describes the settle time, the manner it will be judged and by whom, and the trusted information sources for the judgement. It is also necessary to specify the applicable rules if there is no possibility of judging the claim or if the judgement cannot be settled. For example, if there is a claim about the discovery of the Higgs particle by CERN or Fermilab[14], it is necessary to specify what will be the value of the contract if a third laboratory discovers the particle first. This particular claim states that the value of the contract will be $50 if neither of the two laboratories discovers the particle.

The price section describes the price range in which the contract will evolve, as well as the method of calculating the price at the settle time. Claims could be of the type "winner takes all", but could also be linear or logarithmic functions. The date of payment should also be specified if it does not take place directly after the judgement.

5.2.2 *Claim proposal*

Due to the diversity of the prediction markets and the related claims, it is difficult to propose a generic framework for defining claim's proposal. We tried to characterize MICS claims based on the interviews carried out at the beginning of the project as well as on the active claims on the other markets. We noticed five important concepts: the sphere of activity, the state of the art, the goal of the research, the expected results and the measure of success, illustrated by the SLF claim in table 4.

The state-of-the-art section gives a short presentation of the research history. In this category we describe the previous steps necessary to formulate the goal of the research, the related work and present some major publications in the field. Such information will enable each researcher to situate the claim in its field of research.

The goal of the research describes the expected outcome of the research after a given time. These are global, long-term and not precisely defined goals, as they represent research in progress.

The expected results are the concrete elements, in the mid-term, that will result from the research. They may be products, demonstrations, patents, algorithms, creation of start-ups, standards or RFC.

The measure of success must precisely express the methods of evaluation of the awaited results. This evaluation should be objective and factual. We could, for example, specify the product's market share, the acceptance of a demonstration by the scientific community, the use of a patent, the publication of the results by the press.

Table 4. The SLF claim on MarMix

Symbol	SLF
Name	Sensor-Network deployed by SLF
Author	Cédric Gaspoz
Type	Boolean
Project	Cluster 2: Real-time avalanche and landslide analysis through sensor networks
Settle date	31.07.2009
Jury	Made up of 2 members of the SLF, 2 members of the project and 1 person in charge of MICS
Source	SLF report the tests carried out. If there is no report, raw data of the SLF can be used
Price	Minimum price: 0, maximum: 100
Payment	Winner-Takes-All (if the contract is TRUE: 1, if not: 0)

Field of research
Research on sensor-networks

State of the art
The fluid-dynamics models used so far in predicting mass movements such as avalanches rely on speculative equations and very little is known about the internal structure of avalanches. Field measurements only provide insight into shape characteristics (e.g., avalanche speed).

Goal of the research
The sensor network measures the displacement/velocity field inside a flowing bulk. Before the material is released, the sensor nodes are spread onto the surface or inside the material. After release, the information of each node is monitored to determine the flow structure. The main tasks are twofold: constructing a sensor network and interpreting the data to build more accurate fluid-dynamics models.

Expected Results
Deployment of a sensor-network under real conditions to predict the risks of avalanche

Measure of success
The SLF deployed a network of 100 nodes in an alpine area to predict the risks of avalanche. The results obtained by the sensors, as well as the treatments using fluid-dynamics models, allow us to obtain valid results with an error margin of 20% during a season (01.11 to the 30.04).

For the last iteration we also added the possibility of trading via cellular phones, based on the short text messages (SMS) exchange. In addition to the advantages in terms of portability, this development allowed us to simplify the interactions between the traders and the platform. We developed a language syntax to reduce the instructions to the minimum, and to ensure that the exchanged messages conform to the SMS format, as presented in table 5. This enables the user to send, for example, "MARMIX BUY 25 SENSOR" to pass an order of 25 contracts of the claim sensor at the market price on the MarMix prediction market.

Table 5. Example of text messages used to trade by cellular phone on MarMix

BUY	To buy a certain number of contracts at the market price or to place a limit order *For example: MICS BUY 23 RFID (LIMIT 0.67)*
QUOTE	To get a particular quote or all the active claims' quotes *For example: MICS QUOTE RFID or MICS QUOTE LIST*
HOLDINGS	To get an overview of the portfolio *For example: MICS HOLDINGS*
ORDERS	To manage open orders (delete or change the limit price or the quantity). *For example: MICS ORDERS DELETE 7879387*

In addition, to solve the problems encountered with our system combining a continuous double auction with a market maker, we have redesigned the automated market maker algorithm and all the price calculation methods and the matching of orders using the Combinatorial Information Market Design of Hanson [8] as well as his proposal to integrate it with a mechanism of continuous double auction [7]. We were also inspired by the work of Chris Hibbert on Zocalo for the implementation of these algorithms.

[14] This claim is running on http://us.newsfutures.com/ under the name "Higgs' Particle"

Finally, to assure the confidentiality of the market, we completely anonymized the platform, and also restricted access to only members of the project community.

5.3 Evaluation > First experiment with researchers

To ensure that the study was relevant, we started the market during a MICS workshop in the presence of hundred researchers. We proceeded in the same way as in the Initial Design (see section 3.1) with a workshop in the presence of computer scientists and telecom engineers without any financial background, followed by a long-term experiment. However, we did not have permanent direct access to the whole research community and hence had only a few active traders.

To overcome the lack of motivation to trade, we decided to adopt a strategy based on market segmentation by fields of interest. We organized workshops in the various research centers in order to lead the researchers to use the platform and to give us the opportunity to better understand the reluctance to use this type of technology. In addition to these workshops, we also started a new column in the project newsletter to present the evolution of some claims, commented on by scientists from the related research field.

After a first series of interviews we noticed that interest is quite present within the community for this type of technology but the teams are centered on specific problems and that it is difficult to get them interested in questions outside their field of work. We think that the organization of workshops bringing together the participants by field of interest made it possible to create a certain dynamic on the platform, even if the traders limit themselves to a small proportion of the available claims.

Finally, the first months of this experiment enabled us to strengthen our requirements for the programming of the final version of our prediction market platform. Our goal is to develop very easy to deploy software requiring a minimum of external software. The final version will be based on the TurboGears[15] framework, which will help us to obtain an easily deployable product, but will also allow us to use the lastest technologies in the field of interfaces, thanks to the integration of AJAX components.

6. Conclusion > Seven Design Guidelines

In this section we provide a conclusion structured according to the seven design guidelines suggested by Hevner [17].

6.1 Design as an artifact

During the three consecutive iterations, we designed several artifacts, which consisted of constructs, models, methods, and instantiations (MarMix). The three iterations generated very different research outputs in the fields of user interface, automatic market maker algorithm, incentives for sharing information on the market and claims ontology.

6.2 Problem relevance

As stated in section 2.1 and based on previous research, the use of prediction markets seems to be appropriate and promising in technology foresight and R&D communities. However, this requires more studies, well-founded research and experiments in order to confirm this assumption.

6.3 Design evaluation

The designed artifacts need to be evaluated in order to demonstrate their qualities. There are various possible design evaluation methods. We decided to deploy and operate prediction markets in different contexts, observe the traders' behaviors, and assess the collected results.

6.4 Research Contribution

Our contributions span three dimensions: the Design Artifact, the Foundation, and the Methodology. (1) The Design Artifact is an original working prototype for a large-scale, long-term prediction market with an automated market maker. (2) At the Foundation level, we explored different algorithms for the market maker, and we have shown the advantages and problems of the algorithms used. We propose an ontology for describing claims in a technology environment. (3) From a Methodology perspective, we have developed a simple way to deal with the "IPO" process of new claims on the prediction market.

6.5 Research Rigor

To ensure the rigor of our research, we used well-established scientific models, for example the automated market maker algorithms suggested by Hanson [7]. Our design was also influenced by many of the other papers describing cases of application of prediction markets to various topics.

6.6 Design as a Search Process

We adopted a reasoning based on the design cycle which consists of build-and-evaluate loops. An artifact, the prediction market, is built, operated, and assessed before being refined and reassessed. We conducted three iterations during this research. Each time we generated design alternatives and evaluated them in the business environment. We iteratively tried to identify the deficiencies and tried to address them within next iteration.

With rather broad experiments in operational prediction markets, build-and-evaluate loops are central to this research. This illustrates particularly well the importance of the search process, which is too often neglected.

6.7 Communication of Research

The research needs to be communicated to both technology-oriented and management-oriented audiences. We exposed our research and results to a management-oriented audience through various publications in newspapers, radio interviews and university magazines. We also presented our research and results to the 5th MICS Scientific Conference 2006 in Zurich and at the Swiss Higher Education Network (SWITCH) Workshop at the end of 2006 in Bern.

7. Final Thoughts

In this research, we designed an IT artifact and a systematic approach to analyzing the deployment of a prediction market in an R&D community so as to assess the emergence and the evolution of mobile technologies. We confirmed the hypothesis that the prediction market seems to be suitable, in certain circumstances, for assessing the emergence and the evolution of

[15] http://www.turbogears.org/

mobile technologies in an R&D community. We demonstrated the suitability of the design science paradigm by using the build-and-evaluate loops.

In conclusion, we wish to underline that this research gives a first convincing answer to one of the five identified challenges faced by the design science research community (i.e. inadequate theoretical base (i), rigor and relevance trade-offs (ii), insufficient knowledge base for design purposes (iii), design perishability (iv), and lack of rigorous evaluation methods (v)) [17]. We conducted research that optimized the trade-offs between relevance and rigor. The field study conducted in prediction markets in an R&D community and the realistic and useful results obtained ensure the relevance of this research.

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