

# Modeling and adapting to Context changes: The case of stock market decisions making

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**Abstract.** A stock market decision making makes a compelling case for the use of context aware systems that can adapt to a context behavior known as ‘random walk’. To defend such a proposition the paper adopts the formulation typically used in sensor driven applications that involves critical context characteristics of pervasiveness and instability. From the pervasive perspective the paper concentrates on the ability to characterize a context-state trajectory behavior in real-time to proactively estimate the trend of context change. From the perspective of instability it discusses context related mechanisms such as hedging with derivative instruments as a way to caliber context aware system sensitivity to contextual changes. To validate the idea the paper introduces a special case of an equity option portfolio that is simultaneously delta, gamma and Vega neutral, to deal with extreme context-state exhibiting unpredictable time-varying behavior. Based on some preliminary results of real life experimentation the paper concludes with a continuing current debate on the distinctive merits of reactive versus proactive context.

## 1 Introduction

Context-aware systems aim at adapting responses to eventual context related changes. Typically, explored in mobile computing they are generally application specific, static in nature and are often confined to indoor research laboratories. The process of adaptation by use of context-aware application could be either reactive, the most frequent situation, or pro-active. In the first, the system reacts to whatever contextual situation is presented at that specific moment. In contrast, pro-activity is the ability to predict significant future events and preemptively act upon them. A stock market decision making situation, which is of interest here, makes a very propelling case for context aware systems as a way to adapt to a context behavior known as ‘random walk’. More specifically, it addresses the scenario of decision making in case of a portfolio that contains derivative instruments such as ‘put’ and ‘call’ options which precisely claim adaptation of risk to a changing context by applying an option based strategy. To formulate portfolio decision making in terms of

context awareness this paper first introduces (in section 2) a presentation of context characteristics that combines stock market portfolio considerations with those of sensor driven applications. An extreme case of context-state exhibiting unpredictable behavior is then introduced for illustrative purposes. Section 3 formulates the foundations of a model that have the ability to estimate context-state trajectory behavior in real-time. We defend the point of view that either small or large context changes over time can be of importance depending on their proximity to the boundary of the tolerance level. This justifies sensor driven solution in the form of an algorithm or a filtering mechanism within the proposed context aware system. In section 4 we discuss the implementation of context aware systems characteristics relating to mechanisms for adapting portfolio applications behavior by inferring from context characteristics. This implies an in-depth understanding of two critical context aware system characteristics: degree of pervasiveness and stability and their relationship. In the case of the stock market portfolio it means to minimally maintain the value and tolerable risk within the desired system state using derivative instruments for hedging. Namely we test a solution that combines a filtering component using an optimal Kalman filter with an equity option portfolio mechanism that is simultaneously delta (velocity of change), gamma (i.e.: acceleration of change), and Vega (i.e.: velocity of the volatility) neutral. We conclude by discussing the distinctive merits of the proposed hybrid approach in the case of extreme context state changes.

## 2 Context characteristics

We will adopt one of the most used sources for definitions of context and context awareness characteristics as proposed by Dey and Abowd (1999). They define context as any information that can be used to characterize the situation of an entity. An entity in our case is a stock portfolio application with a decision maker as a user, the stock price within the portfolio and the interaction between a user and the application. A system is context aware if it uses or infers input context characteristics to provide relevant information to the user.

There is an exhaustive literature about context modeling approaches (e.g., Kindberg et al 2000, Muhlenbrock et al 2004, Koile et al 2003, Taipa et al 2004, Lehman et al 2004, Ranganathan et al 2002, Roman et al 2002) that attempt to abstract and generalize context using middleware and toolkits as context-aware systems. An known weakness of many context models is their unsuitability for dynamically characterizing context. Existing models such as ontology-based models, (Wang et al 2004), (Chen et al 2003), and logic/predicate-based models, ( Gray et al 2001), (Henricksen et al 2002) are much more 'static' or constrained. In this paper, we adopt the Context Spaces model proposed in Padovitz, Loke et al (2004), which represents context as a multidimensional object in the application space, using insights from the state-space model. It allows to dynamically characterize context and promotes pro-activeness of a context-aware system. This is of high interest in input acquisition in the scenario of stock market application that ought to be in real time including the news from various, often distributed, sources. Pro-activeness is a key characteristic of context aware systems when the processing input is performed by a

by an automated mechanism on behalf of an user. The latter scenario implies knowing the user’s profile especially in terms of risk aversion and some method or algorithm describing what a user would want to do with this information. Mobility is of importance in the scenario where access or interaction with the decision maker is required. Tractability or traceability is another user related characteristic to ensure that he can a posteriori see why something has happened proactively. Finally, the output consequences are described by the context characteristics of connectivity, dynamics through interrelation, and choice of output presentations. For instance, the variation of the stock could be related to past data, to expected future results respectively termed technical and fundamental context analysis. Their output context characteristics and their representation are more related to the use including frequency to ‘fit’ day trading (high frequency) and occasional opportunistic trading (low frequency). They can also be derived or inferred, more or less uncertain or fuzzy, erroneous or biased, more or less precise or ambiguous or in some extreme cases which are considered here qualified as unpredictable.

In order to discuss the merits of a decision support system with context aware characteristics we are introducing an illustrative real life case with a focus on extreme dynamic context characteristics.

**Case:** Elan (ELN) is a leading worldwide specialty pharmaceutical company focused on the discovery, development and marketing of therapeutic products and services in neurology. As it could be seen from the global three months graph the company displays a very unpredictable time varying (dynamic) behavior with two sudden over 60% drops in a very short period of time : (figure 1)



**Fig. 1.** ELN’s price and volume graph representations over a one year period (source Yahoo Finance)

Context characteristics of ELN or any other company that belongs to the medical – drug sector are closely linked to the processes in drugs the medical sector of new medication development. The processes require a significant amount of time and financial investment as the number of potential compounds is reduced when progressing from discovery to approval and eventually to marketing. For every 5,000 compounds that enter preclinical testing, only five will continue on to clinical trials in humans, and only one will be approved by FDA for marketing in the United States. According to the Tufts Center for the Study of Drug Development, the cost of

developing a new drug averages about \$897 million over 10 to 15 years. All new therapies must undergo a stringent process of preclinical and clinical evaluation. After each developmental stage, the sponsor of the new product meets with the FDA to determine next steps and establish end points for future trials.

These various phases are closely followed by investors and have a major impact on stock prices at the time of successes and failures announcements. There is even a possibility that a medication once on the market be recalled pending further trials. Potential consequences of negative statements concerning the slower than expected progression toward commercialization or withdrawal from the market and subsequent class action, as for ELN case, are the key context input explaining the company assessment by investors and consequently a drop in its stock value. .

*“Prior stock price level was linked to a number of positive statements about the status of its clinical trials and the commercial potential of TYSABRI, a vaccine designed to treat patients with multiple sclerosis (MS). According to class action instituted by investors this has caused Elan’s stock to trade at artificially inflated prices. On February 28, 2005, Elan shocked the market by reporting that they were withdrawing TYSABRI from the market following reports of patients contracting PML, with at least one instance resulting in death. The announcement caused Elan’s shares to plummet, declining over 70% to approximately \$8 per share on February 28, 2005”*

In such a case the ability to predict changes is very important for minimizing the undesired portfolio behavior. The challenge is determining the nature and impact of context change with its temporal (dynamic) and spatial characteristics. With this in mind the main proposition of this paper is to explore potential contribution of models typically used in sensor driven applications in context aware systems..

### 3 A Model for Context Stability in Context -Aware Systems

Let us represent the notion of context stability by using the Context Spaces model, which is a general model for representing and reasoning about context (Padovitz, Loke et al 2004). Context Spaces uses geometrical metaphors to describe context and distinguishes between the context-state, which represents the actual condition of a system in specific context, and representations of real-life situations.

A situation is represented with a spatial object, termed *situation space* and is a tuple  $R_i = (a_1^R, a_2^R, \dots, a_N^R)$  consisting of regions of acceptable values. A region of acceptable values  $a_i^R$  is a domain of values for a specific information type (termed *context-attribute*) that characterizes the specific situation. It is defined as a set consisting of elements satisfying a predicate, thus may contain numerical or non-numerical information. For example, a region of acceptable values of price levels (say between \$7 and \$11 for ELN stock price), denoted by  $a_1^R$ .

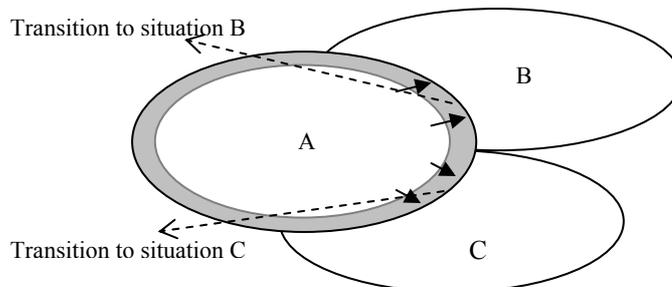
Actual specific values of context input information (that normally match situation spaces) are defined by the context state, i.e. collection of current real time or delayed readings. It is a tuple  $S_i^t = (a_1^t, a_2^t, \dots, a_N^t)$  defined over a collection of context

attribute-values, where each value at time  $t$  is represented by  $a_i^t$  and corresponds to an attribute  $a_i$ . For example, a context state  $S_1^t$  at time  $t$ , is made up of specific context attributes values such as, say, price-level ( $a_1^t$ ), volume-level ( $a_2^t$ ) and stock volatility-level ( $a_3^t$ ).

### 3.1 An Approach for Estimating Stability

Using the spatial concepts discussed above let us provide a more formal characterization of the notion of stability in a specific context for some situation. In general, we state that the closer a context state is to the edges of the situation space, a lesser degree of *stability* is gained (and a greater degree of *instability*), and the closer it is to the centre (or some other predefined subspace), a greater degree of stability is gained, for that particular situation. This characterization considers the distance that is required for a context state to be better associated with another context (when moving away from the particular situation space boundaries). For the purpose of this paper we will use this general notion of stability and instability and refer the reader to [Padovitz, Zaslavsky et al 2004] for a more formal definition.

The notion of approaching the boundaries of a situation space by the context-state towards instability of the specific situation is exemplified by the definition of Transition Areas in a situation space. Transition Areas are sub-region within the situation acceptable regions of values, bounded to the limits of the situation space. A simplified two-dimensional illustration presented in Figure 2 is an example for these special areas. Situation space's region of allowed values and the shaded area denotes a subset within this definition, which is the Transition Area.



**Fig. 2.** An illustration of the concept of transition areas between *situation spaces*

A transition area is defined by a boundary and denotes how vulnerable the application is from being unstable in the future. In trying to apply the notion of stability to portfolio decision making we have purposely excluded both the fundamental and ‘emotional’ factors traditionally used as they are not automated and generally considered by many as included in the technical analysis. Technical analysis, part of financial engineering infers price pattern and trends purely on the basis of historical data. In terms of transition areas, important “Events” occur when a

significant pattern has been formed, indicating a bullish, bearish or undetermined (neutral?) trend. The critical moment in time and space is pertinent when the price crosses a critical line or threshold that forms the boundaries of the situational space. There are several methods that discriminately emphasize one aspect of the change or another. These are known as long term or short term pattern formations or as indicators based on moving averages or as oscillators. The presentation of each method is beyond the scope of this paper; we will limit the discussion to some intuitively comprehensive oscillator methods that corresponds to a sensor driven technique for characterizing a state in a state-space trajectory. For instance ‘momentum’ oscillator is important because it signals the strength of price trend or trajectory direction. Another, known as MACD crosses upper line or the lower signal border lines (the event) signaling a bullish or bearish signal depending on the direction of the stock price trajectory crossovers. Figure 4 is a representation of the concept of transition area adopted from Context Spaces in the context of stock analysis. The figure also presents a dynamic table automatically interpreting the various analysis using oscillator methods.



**Fig. 3.** An illustration of the concept of transition areas for ELN

We are observing clearly two distinctive time periods; one of stability accompanied by a low transaction level and a second one of extreme instability with two almost consecutive dramatic down movement as discussed before.

In general, we consider the notion of *dynamic* Transition Areas within the situation space. As per our case this area dynamically changes according to a real-time prediction procedure assessing the risk of the context-state moving away from the domain of values defined for the situation (caused by the impact of a set of unpredictable and perhaps unobservable external factors over the attributes values that make up the state at a given time).

Coupled with the need for real-time estimation of sufficient boundary size at a given time  $t$ , we developed an algorithmic method that attempts to evaluate the impact of current unpredictable influences over the context-state rather than performing statistical analysis. In other words, rather than using a long-term analysis of the context-state trajectory, which tries to estimate a trend that might not reveal actual current influences over the trajectory, we analyze only the very recent state trajectory.

We focus on aspects that reflect natural real-time influences over the state, namely, the context-state current velocity and acceleration of the change.

We have identified two factors, represented by the measures  $\delta_t$  and  $\lambda_t$ , whose combination determine the dynamic boundary size at time  $t$ .  $\delta_t$  denotes a theoretical distance vector consumed by the context-state in the state trajectory. The term ‘distance’ is used to reflect the extent of change in the values of the specific context attribute that make up the context-state. Our algorithm estimates changes in the attributes values based on the present behavior of the context-state. It uses the equivalent of “first/second order derivatives” at time  $t$  of a context-state trajectory, computed as  $dS_t = S_t - S_{t-1}$  and  $d^2S_t = dS_t - dS_{t-1}$ . For the stock market scenario we refer to  $dS_t$  and  $d^2S_t$  as the local velocity of the price of the stock or Delta, and acceleration of the context-state known as Gamma.  $dS_t$  conveys the notion of velocity as it is the difference in position values of the state vector over one time interval, and  $d^2S_t$  conveys the notion of acceleration as it yields the difference between two subsequent velocities. The second factor  $\lambda_t$  denotes the sensitivity of computed Transition Areas to the proximity of the context-state to the situation’s boundaries. If the context state is already very near to the boundary then there might be too little time to balance, if so desired, the new trend. The proximity measure is sensitive to such cases and determines greater boundary sizes (if required) in advance.

By combining these two factors we have achieved an approach for estimating stability and instability of a system in a given context. We have also applied to identify irregular context behavior at runtime.

## 4 Implementation and experimentation

Let us examine the relevance of context stability model to stock market decision making. On that basis we have simulated a network of alarms in a defined area, whose values make up the context-state for a ‘portfolio safe’ situation space.

Each alarm in the experiment is an independent process, “continuously” (every tick) generating streaming quotes that reflect the true state of the event it measures. This data is dynamically changing with associated, to reflect natural changes in the environment. It is for instance natural that the price of ELN fluctuates up and down according to concerns or anticipations of the marketplace about the stock’s future price range. In general, any factor that suggests uncertainty on a stock’s future price performance can increase the instability reported known as implied volatility. On the other hand, factors that can result in stability or steady and consistent bullish or bearish trends reflected by low implied volatility. For example changes linked to expected seasonal factors are regarded as normal and they should not cause a change in the inferred situation in regard to the ‘portfolio safety’ context. In contrast to natural fluctuations, each alarm is also associated with inherent inaccuracy in the process of capturing the true state with however a different connotation that in sensor driven context assessment. Instead of typical sensor (as instrument) reading errors, the portfolio situation commands special attention to the source and quality of

information attached to the alarm. More specifically, in addition of using the classical Kalman Filter to provide optimal stochastic estimate for the true sensor readings, ELN case dictates an approach for incorporating imperfectly reported context. In the latter case a Bayesian optimal processor making use of Bayesian networks for reasoning about dependencies between context events could be used.

During the experimentation stage we simulated normal fluctuations and initiate unpredictable surges of value readings simulating the effects of or any other event that is not considered normal. Our objective is to infer possible future instability of the situation close to the start of the irregular activity, while at the same time minimize the handling of normal activity as suspicious activity that needs to be verified. For example, if a normal ELN stock price is around \$ 7.50 and an unexpected negative statement is made on the withdrawal of a medication from the market, we would like to infer instability as soon as possible, e.g. when the price is still around \$7.50 and not when it is already down to \$4 and dropping. The same way, normal fluctuations even around \$8 or 6.50\$ should not be treated systematically as causing situation instability. The context sensitive mechanism we have described was based on the use of derivative instrument in the form of Calls and Puts within the portfolio, allowing to expand the number of strategies to deal with context changes (Ajenstat 2004).

Context characterization through sensitivity indicators is made using well-known option sensitivity measures often referred to as the *Greeks: delta, gamma, Vega*. In our experiment we essentially make use of these with: (i) Delta indicating the price sensitivity of an option with respect to changes in the price of the underlying asset, here ELN. It represents a first-order sensitivity measure analogous to velocity in the discussed model for context stability. (ii) Gamma is the sensitivity of an option's delta to changes in the price of the underlying asset, and represents second-order price sensitivity analogous to acceleration in our model. (iii) Vega is the price sensitivity of an option with respect to changes in the volatility not included in the model. Their use is a function of the degree of instability. For instance, to insulate the value of an option portfolio from small changes in the price of the underlying asset, we have constructed an option based portfolio whose delta is zero. Such a portfolio is then said to be "delta neutral." To protect a portfolio from larger changes in the price of the underlying asset we have constructed a portfolio whose delta and gamma are both zero. Such a portfolio is both delta and gamma neutral. The most extreme case which is of special interest for a portfolio containing a stock like ELN we have designed a situation which is simultaneously delta, gamma, and Vega neutral. The composition of such portfolio is a weighted average of the corresponding Greek of each individual option with the weights representing the quantity of each option in the portfolio. . At the input level the boundary the system estimates change dynamically; crossing the filtered values indicates potential instability at the context aware level. It is then forwarded to a context validation procedure using the general model. (figure 4)

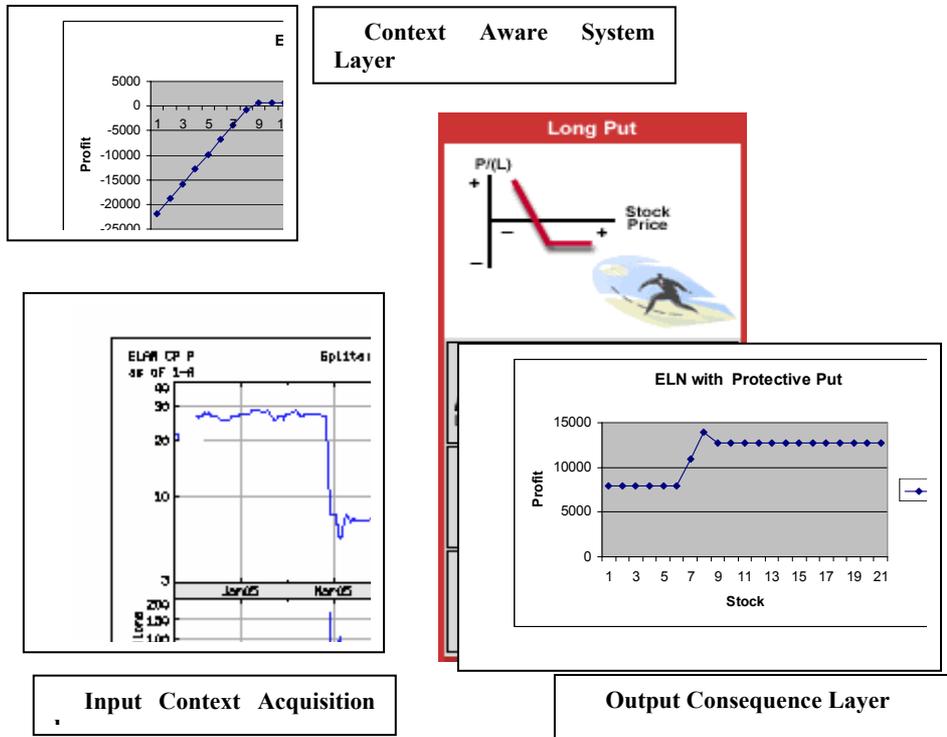


Figure 4: Derivative and filter based context aware system

The experimentation was conducted using an option strategy called ‘Long Put’, selected as proactive context aware mechanism. The strategy is chosen from a set of strategies designed in advance to compensate the negative effect of the change or to eventually take advantage of an opportunistic context... The strategy as schematized is risk safe but it has a limited reward potential. Its main agenda is to prevent major instability of the application by preserving the right to sell the stock at a fixed strike price when it is in fact moving down.

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## Concluding Remarks

We have discussed the need for predicting changes and maintaining stability in a context-aware system's state in the context of stock market portfolio and explored some of the scenarios in which such estimation can be beneficial. We have discussed Context Spaces model and proposed the general concepts of *stability* and *instability* as means to characterize large scale pervasive systems. Our approach is suitable for representing context in a large number of scenarios and most importantly, captures dynamic aspects of context, such as context trajectory. To examine system stability in regard to a given situation we have conceived dynamic boundaries that change according to the instability estimation of the situation.

The model and concepts of system stability and instability in a given context can be used in a general way in different cases. In this paper we have focused on the case of stock market portfolio and represented with our model as a context driven scenario. We have developed an approach for assessing the instability of the stock price building on the concepts described by the model.

We have implemented a method which analyzes temporal features of the context state trajectory in order to estimate future instability of the stock price. Modeling and methodology used in this case is very similar to a pervasive scenario of identifying instability of a 'fire safety' situation, which we have explored in [Padovitz et al 2005].

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