Foreign Exchange Case Study

1 Description

The foreign exchange market, usually referred to as "forex" or simply as FX, is the largest financial market in the world with an average daily trading volume of more than $3 billions. It is an Over-the-Counter market where all the transactions are executed electronically, all day long (24/7), within a network of banks, brokers and traders. Despite its tremendous size, the forex market environment is very volatile and liquid [1]. Currency trading is driven not only by statistical analysis or pattern matching but also by speculations and rumours [2, 3]. Exchange rates vary continuously, and due to the huge trading volumes even a slight rise or decrease in the last decimal place of a quotation can result in huge profit or loss. For this reason continuous monitoring of the market is vital, while transactions need to be executed fast, timely and reliably. Additionally, forex brokers carry out on a daily basis a huge volume of transactions and completing the orders at, or very close to, the market price when their traders made the transactions is crucial for the company. On the other hand, a trader might not be able to observe the market and place trades during the entire day, while this process becomes intractable when the trader deals with multiple currency pairs. To facilitate their actions, traders usually employ an "expert advisor", i.e., a mechanism that can perform automatic trading and suggest future activity.

2 Forex Service-Based System

A forex trader typically uses a software system, also known as platform, for online forex trading. The platform usually employs remote third-party services, accessed over the internet, for carrying out partial system functionality. Our forex trading platform (FXP) incorporates the following abstract services:

- a *market watch service*, which provides real-time bid/ask prices for selected currency pairs
- a *fundamental analysis service*, which provides information on driving forces (economical, social, political) that may affect the forex market
- *technical analysis service*, which supports chart generation (e.g., line, bar and candlestick charts) and statistical analysis for the identification of trends and patterns
- an *order service*, which allows a user to perform a transaction, i.e., to enter or exit a trade
- an *alarm service*, which sends notifications to the trader about various events

Multiple service-providers could support concrete implementations that provide the functionality required by the abstract services in the FXP service-based system. Each service comprises an interface with which a service consumer can invoke the service at runtime as well as a service-level-agreement (SLA), a contract that defines various QoS characteristics, e.g., reliability, performance, and cost, that both parties (provider and consumer) are obliged to comply with.

Certainly the development of a software system using remote third-party services requires less time, cost and expertise, compared to an identical monolithic system. Nevertheless, there is no guarantee that the generated system will always satisfy its requirements, mainly because QoS characteristics (e.g., reliability, performance) of remote third-party services are likely to vary over time resulting in SLA violation. In the FXP system, we consider an SLA violation to be the inability of a service to carry out the required operation within the prescribed time window.

2.1 System Workflow

The FXP workflow (Figure 1) starts executing as soon as a trader logs into the forex trading platform supplied by his or her retail broker. The trader can activate the *expert advisor mode* by providing his trading objectives or by selecting an action strategy. The system then enters an infinite loop where it analyses exchange rate charts and other market activity, identifies signals and patterns that satisfy the trader's objectives and automatically carries out the trade. In particular, the system uses the *market watch service* to extract the exchange rates (bid/ask price) of the selected currency pairs. This data is forwarded to the *technical analysis service* that evaluates the current trading conditions and determines future price movement, and replies by sending a result value suggesting a course of action. An "objectives met" signal causes the invocation of the *order service* with which the user is able to carry out a trade, an "objectives unsatisfied" signal returns control to *watch market service*, whereas an "objectives unsatisfied and high variance" signal causes the invocation of the *alarm service* to notify the trader immediately about discrepancies/opportunities not provisioned by trading objectives or action strategy. The trader can also assess the economic outlook of a country using a *fundamental analysis service*. This service collects, analyses and evaluates information (e.g., news reports, economic data and political events) for currencies of interest and provides an assessment of the value of a country's currency in the forex market. If the trader is satisfied with this assessment, he can sell or buy currency by invoking the *order service*. Finally a notification is sent to the trader confirming the successful completion of a trade.

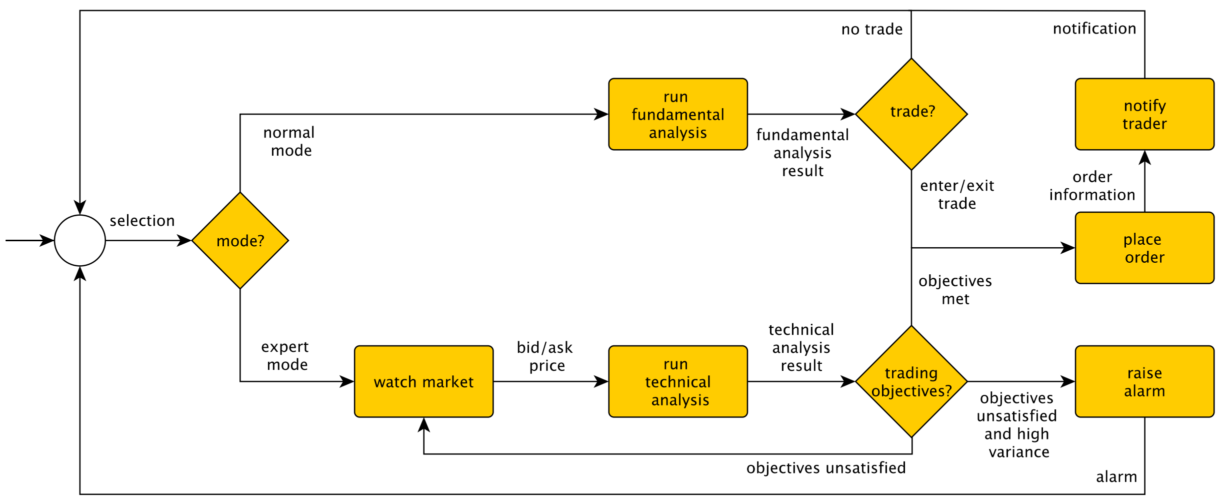

Fig. 1. Workflow of the FXP service-based system

2.2 System Requirements

The FXP system has a number of reliability and cost related QoS requirements that should be satisfied in order to provide reliable trading experience to its users. These high-level requirements are described below:

R1: The probability that the system fails to retrieve the exchange rates of a currency pair is less than $\bar{p_1} = 0.03$.

R2: The probability that a technical analysis failure occurs within $\mathrm{N} = 10$ executions of the workflow is at most $\bar{p_2} = 0.07$.

R3: The probability that one execution of the workflow ends in a service failure is at most $\bar{p_3} = 0.11$.

R4: The probability that an execution of the workflow ends in a place order request failure is at most $\bar{p_4} = 0.0003$.

R5: The probability fraction that a service failure occurs due to an alarm failure is less than $\bar{p_5} = 0.05$.

R6: If requirements R1 – R5 are satisfied by multiple configurations, i.e., combinations of concrete services, the system should select one of these configurations that minimises the total system cost given by function

$$system\_cost = \sum_{i=1}^{5} Cost_i$$

where $Cost_i$ denotes the cost incurred by one invocation of the i-th service.

While the system is running, it is possible that some of the services will not operate as promised, perhaps due to increased workload, and thus SLA violation is likely to occur. This undesirable situation might invalidate compliance of the system with its QoS requirements. In that instance, the system should adapt on the fly by selecting from the set of functionally equivalent services, a configuration that restores compliance with QoS system requirements R1 – R6.

2.3 Modelling The System

Consider that the FXP system comprises the following five abstract services $(as_1, \ldots, as_5)$: *market watch service*, *fundamental analysis service*, *technical analysis service*, *order service*, and *alarm service*. Abstract services $as_1 - as_4$ are implemented by $n_1 = 3, n_2 = 3, n_3 = 4$, and $n_4 = 2$ concrete services, respectively, offered by different service providers. The *alarm service* is realised through an in-house implementation. Formally, each concrete service $s_i^j, 1 \leq i \leq 5, 1 \leq j \leq n_i$, is specified by the following QoS characteristics:

- $\text{fail}_i^j \in [0, 1]$, the failure probability of the service
- $\text{cost}_i^j \in \mathbb{R}^+$, the cost incurred for each service invocation

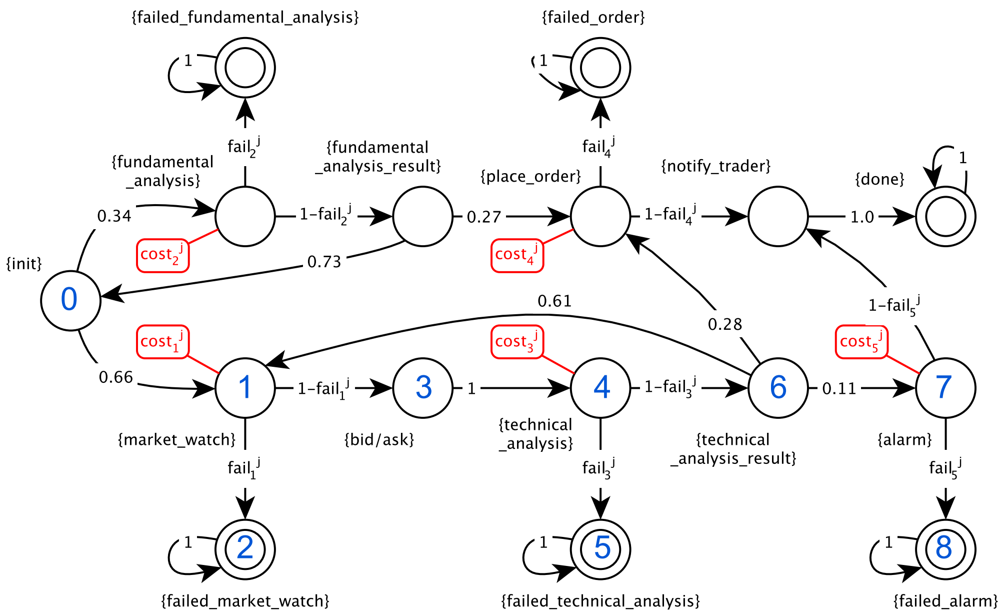

Fig. 2. DTMC model of the FPX service-based system

Figure 2 depicts the parametric discrete-time Markov chain (PDTMC) model of the FPX system. The parameters $\mathrm{fail}_i^j, 1 \leq i \leq 5, 1 \leq j \leq n_i$, indicate the failure probabilities of a particular service orchestration for realising the operations defined by abstract services $as_1 - as_5$. For instance, parameter fail_1^j represents the probability that the currently selected concrete service $s_1^j, 1 \leq j \leq n_1$, will fail to provide the bid/ask price within the required time frame. The solid rectangular boxes denote the cost incurred for each invocation of the associated service.

2.4 Formalising System Requirements

We formalise the QoS requirements R1–R6 of the FXP system using probabilistic computation temporal logic based on the PDTMC model shown in Figure 2. Requirements R1–R5 are expressed as probabilistic reachability properties while the expected cost for the function related to requirement R6 is produced by the evaluation of a probabilistic reward property.

R1: $P_{\leq 0.03}[F\ \text{“failed\_market\_watch”}]$

R2: $P_{\leq 0.07/10}[F\ \text{“failed\_techical\_analysis”}]$

R3: $P_{\leq 0.11}[!\text{“done”} \bigcup \text{“failed\_market\_watch”} \,|\, \text{“failed\_technical\_analysis”} \,|\, \text{“failed\_fundamental\_analysis”}$
$|\, \text{“failed\_order”} \,|\, \text{“failed\_alarm”}]$

R4: $P_{\leq 0.0003}[F\ \text{“failed\_order”}]$

R5: $P_{=?}[F\text{“failed\_alarm”}]/P_{=?}[F\text{“failed\_service”}] \leq 0.05$

R6: $R_{=?}^{\text{“cost”}}[F\ \text{“failed\_market\_watch”} \,|\, \text{“failed\_technical\_analysis”} \,|\, \text{“failed\_fundamental\_analysis”}$
$|\, \text{“failed\_order”} \,|\, \text{“failed\_alarm”} \,|\, \text{“done”}]$

References

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