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Abstract

This paper discusses a model of decision making in environments characterized by information that may change more rapidly than the decision maker can respond. The exemplar environment is the spot market for currency. The discussion focuses on the part of the trading model that explains how spot currency traders anticipate the market.

Introduction

This paper discusses a model of decision making in rapidly changing environments (Smith, 1996). As defined here, rapidly changing environments present the decision maker with information that changes on the order of seconds - the rate of change is typically faster than the decision maker can respond. In many professional domains, such information often defines the risk the decision maker manages. Familiar examples include air traffic control (Smith & Hancock, 1995) and the markets for currencies and commodities (Smith & Johnson, 1995; Steil, 1993). The task of interest is trading foreign currencies in the spot markets.

Individuals become adept at process control in the face of rapid change. For instance, air traffic controllers successfully direct and divert aircraft through crowded and ever-changing sectors of airspace. Society and organizations rely on professional process control agents to keep vital social and economic systems going and to avoid disasters. The ability of individuals to act as skilled risk managers in rapidly changing environments prompted this inquiry into the knowledge and uses of knowledge that skilled decision makers invoke to assess and manage the risk posed by rapid change.

The discussion has three parts. The first introduces the domain of study, spot currency trading, and the framework for the model used to explain skilled decision making. The second part describes an experimental study of the decision making of professional traders conducted to elaborate the model. The third part compares the output of a computer simulation of the model and the behavior of traders in the experiment. The comparison focuses on how the model and the traders exercise feedforward control. Feedback control in currency trading was discussed by Smith and Johnson (1995).

Trading as Process Control

Spot Currency Trading

The currency trader is a banker who provides the fundamental financial service of converting one currency into another. The trader provides this service to other traders, to his bank's customers, or for his bank's account. The spot markets are the most volatile of the currency markets. They are electronic arenas for the exchange of currencies for immediate (within three working days) delivery. The immediacy of delivery differentiates spot markets from forward, futures, and options markets. There is one spot market per foreign currency. The word 'market' refers both to the arena for exchange and to the network of traders actively trading. The market's 'thinking' is the consensus opinion of active traders.

The trader's task is to manage the risk posed by holding 'positions' in foreign currencies. A position is the trader's current inventory of foreign currency. It exposes the bank's money to the volatile foreign currency markets. Trading risk is the concomitant opportunity for financial loss. In the United States, trading risk is measured in dollars. The spot trader's task is fraught with risk because the markets can (and do) turn on a dime at any time and without obvious provocation. The markets operate within the broader, quixotic context of international socio-political and economic events.

A position is better characterized as an evolving process than as a static object. Its value constantly changes with the prices shown in the market and turns in the market's thinking. The trader's task is to manage the value and risk of this process.

The Process Control Cycle

The paradigm of process control provides the framework for the model that explains how experienced currency traders manage the risk posed by the spot markets. The goal of the process control agent is to keep a process within operational limits as its environment continually changes (Moray, 1986). To exercise control over the process he monitors, the process control agent makes a series of non-independent decisions in real time. The series of decisions are (1) whether the process is operating within control limits, and (2) if not, what to do to ensure the process remains within or returns to those limits. The agent's task is to loop through these decisions and to make (or initiate) adjustments to the process when needed.

The agent's decision making is event-driven rather than planned-out or decision-analytic. More often than not, the agent decides the process is within limits and no adjustment is needed. His decision making becomes increasingly challenging as the rate of change in the environment increases.

Moray and Rotenberg (1989) identify four categories of cognitive processes that support the process control agent's decision making: sampling, feedback control, feedforward control, and intervention, Figure 1. The goal of sampling is timely signal detection. Feedback control compares current
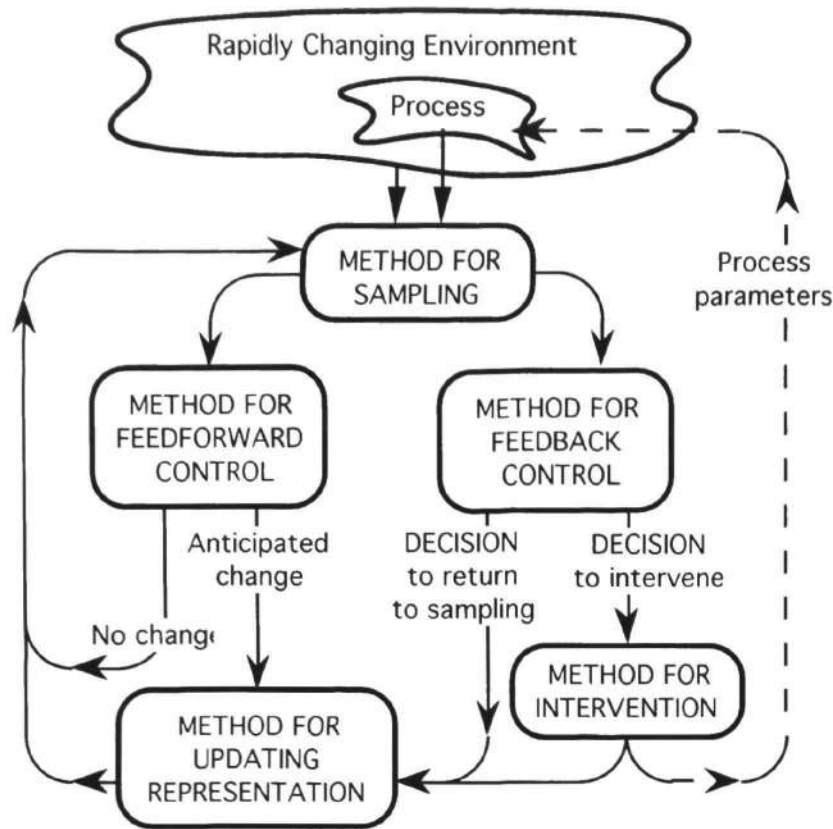
Figure 1: The process control cycle of methods for processing market information

The dynamic nature of the spot currency markets demands that decisions to trade reflect not only current prices and their rate of change but also the direction the market will drive prices (Soros, 1987/1994). Feedforward control generates and revises an expectation for the direction of prices (e.g., prices will rise, prices will fall). One of the objectives of an experiment with professional spot currency traders as subjects was to identify the knowledge and processing steps invoked as they engaged in feedforward control. Table 1 outlines the method for feedforward control hypothesized prior to conducting the experiment.

Simulation Study

This experiment sought to inform elaboration of the methods traders invoke to manage the risk of holding positions in the spot markets. Three professional spot currency traders from a mid-size Twin Cities commercial bank agreed to participate in the experiment. All three traders had more than four years of experience on the trading desk and were well-known in the spot markets. The experimental platform was a commercial PC-based training package (FXPlus©, Chisholm-Roth, Ltd., 1987) that emulated the Reuters© trading desk.

Each trader individually engaged a computer simulation of eight realistic and challenging market scenarios. The trader's task was to do his job: to make trades for his bank's customers, to manage his positions, and to square them by the end of the day. The traders were asked the 'think aloud'

information to thresholds that are functions of the direction and the rate of change of the monitored process. The comparison generates decisions of what to do to keep the process within limits. Feedforward control anticipates change in the process. The information processing that supports anticipating relies on a 'mental model,' a representation that generates expectations for the current state of the monitored process. Comparison of the expected state to current information allows the agent to infer the future status of the monitored process and to select an appropriate action. Interventions are the actions a process control agent takes to modify process parameters. Interventions change the process and indirectly alter the environment.

As a process control agent, the trader's job is to keep his position within control limits. Some banks impose explicit size, 'stop-loss', and price volatility limits (Zaheer, 1992); others expect their traders to set implicit limits. Limits on the rate of change of prices range from explicit hedging strategies to implicit thresholds of acceptable volatility (Steil, 1993).

Traders sample prices to exercise feedback control and read headlines to exercise feedforward control. They respond to changing prices with decisions (not) to trade. Trading is the action intervention - they take to keep their positions within limits. When they make a trade, they participate in the market that defines the prices they sample.

Table 1: Hypothesized Method for Feedforward Control

FEEDFORWARD CONTROL
Goal:
Anticipate the direction the market will drive prices.
Input:
Headlines about global events.
Prior expectations about the direction of prices.
Knowledge:
Categories of news that explain the influence of headlines on the opinions the market forms and on the market's behavior.
Processing:
Read a headline about a currency.
Attribute to the market a belief about the currency given the headline.
Infer the market's behavior given that opinion.
Revise expectation about the direction of prices.
Action:
Revise expectation for the direction of prices.

as they read the overnight reports and during the trading days. The concurrent verbal reports provided insight into a portion of the information that was immediately accessible for processing (Ericsson & Simon, 1984/95). The protocol was scored using categories determined *a priori* by the investigator. Categories conformed to the five goals pursued by the methods in the process control cycle, Figure 1.

Results

The traders invoked two distinct, sequential processes as they engaged in Feedforward Control. First, they anticipated the market's behavior. They then assessed the risk to their positions posed by the behavior they anticipated. The sequential processing indicated that the hypothesized method for Feedforward Control should be split in two.

Anticipating the Market

Headlines often prompted the traders to talk about the market and to attribute beliefs to the market. Their statements about the market (often an unspecified third person plural) indicated they had invoked knowledge that enabled them to anticipate the direction of prices. Comments about the market were often followed by statements concerning the implication of the attributed beliefs on the trader's positions. These statements assessed the risk of holding positions. The following excerpt of protocol from Trader 1 in Scenario 8 contains a clear case of sampling news, anticipating the market, and assessing risk. The sequence of statements captures the trader's approach to feedforward control. The annotations (in parentheses) identify the related method.

Session Time
(Sampling)
6:55 News Screen
   14:10 Washington, 17 May US wholesale prices rose 0.6 pct in April, a slight increase over the 0.5 pct rise in March, Department of Commerce said.
(Anticipating the Market)
6:58 Wholesale prices up point six as expected. Wait, wholesale {scans overnight report} zero point four, so they're not going to like the dollar on that one
(Assessing Risk)
7:02 and I'm okay against Swiss, let's get rid of some yen
(Making a Trade)
7:04 Dealing Screen for Yen

This passage makes explicit four of the six steps in a method for Anticipating the Market, Table 2. The other two steps are evident in other excerpts of protocol. The trader read the headline and compared the value reported in the headline "point six" to the value the market was said to expect "point four." The comparison prompted him to attribute a belief to the market given the news: "they're not going to like the dollar on that one." The attributed belief is consistent with an unstated inference that the market would respond to the news by driving down prices. The trader then assessed the risk of holding his positions given the inferred direction of prices. The anticipated selling would help his

short dollar-franc position but hurt his long dollar-yen position. The assessment of risk provoked a decision to trade.

Table 2: Method for Anticipating the Market as informed by Experiment 1

ANTICIPATING THE MARKET
Goal: Anticipate the direction the market will drive prices
Input: Headlines. Currencies. Prior expectation about the direction of prices for those currencies. Prior expectation for the topic of the headline.
Steps for processing market information: 1) **Read** a headline, extract topic and gist 2) **Check** for prior expectation for related headline 3) **Associate** topic of headline with a category of news 4) **Compare** expected and reported headlines. 5) **Attribute** to the market a belief about the currency given the headline. 6) **Identify** the direction the market will drive prices given the attributed belief at one of three qualitative levels: up, steady, down.
Action: Revise (generate) expectation for the direction of prices. Revise (generate) expectation for headline topic. Trigger method for Assessing Risk.

The method for Anticipating the Market updates or generates a pair of expectations. The first anticipates the direction of prices. The second makes the gist of the headline the standard for comparison for that headline the next time it is encountered.

The trading model explains the traders' behavior as they read the overnight report as repeated looping through the method for Anticipating the Market. The method generates a suite of prior expectations for headline topics. During the trading day, the method draws upon these expectations to infer the market's response to headlines. By generating expectations for headline topics, the method is able to account for the comparisons the traders make when reading headlines.

Categories of News: Criteria for Assessing the Market's View of News In the experimental scenarios, all three traders invoked knowledge that enabled them to (1) extract the topic and gist of a headline, (2) compare the gist or announced value to a prior expectation for the topic or to an implicit standard, and (3) identify how the market can be expected to act given the outcome of the comparison. The protocols and trading behavior are the basis for the ten categories of news that cover this knowledge, Table 3. The ten categories of news are intended to be mutually exclusive and exhaustive. They are both the source of generality for the method and a principled account of the traders' knowledge about world events as revealed in the experiment.

The first four categories are the most common. News about economic growth and central bank policy are both assessed using the specification for comparison "positive

Table 3 The ten categories of news invoked by the method for Anticipating the Market

Category	Topics (members of the category)	Specification for Comparison	Market Standards (implicit standards for comparison in the absence of priors)
Economic growth	Gross domestic product	Positive change is bullish for the relevant currency (Good when up)	Bullish when above 0%
Political uncertainty	President rushed to hospital	Necessarily bearish for the relevant currency; for priors: buy the rumor, sell the fact	
Inflation	Wholesale price index (WPI)	Negative change is bullish for the relevant currency (Good when down)	Bullish when below 2% year-on-year
Central bank monetary policy/Government fiscal policy	Interest rates Foreign trade	Positive change is bullish for the relevant currency (Good when up)	
Unemployment	Nonfarm payroll data	Negative change is bullish for the relevant currency (Good when down)	Bullish when below 6% year-on-year
Old news	Central bank bought paper	Ignored	
Forecasts	Estimate of next quarter's WPI	Ignored	
Immaterial	Yeltsin to visit Minnesota	Ignored	
Up trend	Currency strong Peace accord	Necessarily bullish for the relevant currency	
Down trend	Currency weak	Necessarily bearish for the relevant currency	

change is good for the relevant currency," that is, the market can be expected to react favorably to news of increasing growth and to news of rising interest rates. The two categories are distinguished by the implicit market standards the traders invoked to anticipate the market. The traders assessed topics in the category Economic Growth by checking for a positive or negative value; they acted as if the standard for comparison was 0%. In contrast, the traders assessed topics in the category Central bank policy by checking for positive or negative change regardless of value; they acted as if there were no absolute standard for comparison.

The method for Anticipating the Market triggers the method for Assessing Risk, passing to it the expected direction of prices.

Assessing Risk

The method for Assessing Risk assesses the risk of holding a position in the potentially volatile spot currency markets, Table 4. Traders define risk as the opportunity for loss (e.g., Shapira, 1995). The opportunity for loss varies directly with the size of the position and the difference between the current price and price at which the trader acquired the position (her break-even rate). The first step recalls the qualitative levels of (1) the side of the position (long or short) and (2) the expected direction of prices (rising or falling). The second step invokes a qualitative calculus to assess the risk of

holding the position given the expected direction of prices. The calculus assigns a positive sign (+) to long dollar positions and to rising prices, and a negative sign (-) to short dollar positions and to falling prices. It applies the rules of multiplication to calculate the product of the signs. When the product is positive (+), the assessment is positive: risk is relatively low. When the product is negative, the assessment is negative: risk is relatively high.

Table 4: Method for Assessing Risk

> **ASSESSING RISK**
> **Goal:**
> Make an explicit assessment of the risk of holding a position given the anticipated direction of prices
> **Input:**
> Size (long or short) of position.
> Expected direction of prices.
> **Steps for processing market information:**
> 1) **Recall** position size and expected direction of prices
> 2) **Calculate** the risk of holding a position in the relevant currency using qualitative equations linking position size, the expected direction of prices, and assessed risk
> **Action:**
> Revise (generate) risk assessment for position.

SPOT and the Traders

The trading model is an account of the knowledge and uses of knowledge that are brought to bear to generate observable trading behavior. SPOT is a rule-based implementation of the trading model. Comparison of Spot's behavior to the behavior of the traders in the experiment gauges the sufficiency of the trading model to perform the task done by professional traders.

The trading model explains variability across traders within a scenario as responses to differential input. The only source of variability in how Spot ran (and in the profits or losses it took) was the input it received. Each input file contained only the information a trader sampled and the time when he sampled it. Differential input across traders drove Spot to invoke knowledge at different times and with different implications. This differential led Spot to emulate the rank order and differential level of profits (losses) taken by the three traders in each scenario. Spot's ability to take profits (losses) like the traders' is evidence that the knowledge invoked by a single trading model as it applies one set of methods can emulate the occasionally divergent trading behavior of three professional currency traders. This result supports the argument that the knowledge and uses of knowledge captured by the trading model swamp the impact of individual differences.

Figure 2 compares process data generated by Spot and one of the traders in Scenario 7. These data   position size, profits, and decisions to trade   document that Spot made decisions as the trader did. Specifically, the data show that Spot generally (1) made similar decisions to trade at similar times, (2) responded to the same headlines as the trader with
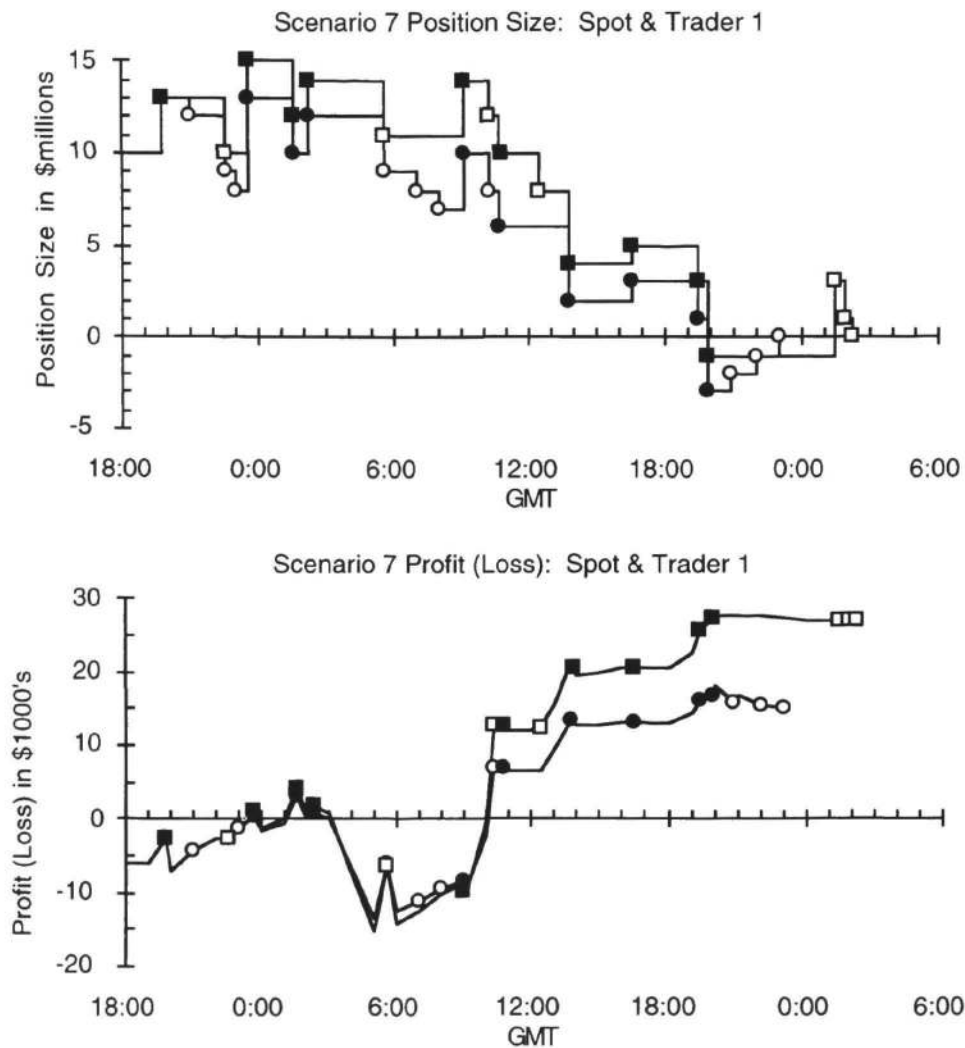

Figure 2 Comparison of Spot and a Trader's Process Data. Graphs contrast position size (above) and profit and loss (below). Circles represent Spot's trades, squares the trader's trades. Open symbols represents trades made by calling another trader. Closed symbols represent trades made by quoting.

similar attributions of behavior to the market and similar assessments of risk, and (3) held positions of similar size and profitability throughout the trading day. The correspondence between Spot's decision making and that of all three traders is an existence proof of the sufficiency of the trading model as an account of the knowledge and processing steps invoked to perform the task of trading currencies in the spot markets.

A second experiment used Spot's decisions in a novel market scenario to predict the traders' decisions. The comparison was favorable and counter-intuitive. The ability to predict behavior is a strong test of any theory of decision making.

Discussion

The steps in the method for Anticipating the Market are not straightforward. Attributing a belief to the market and inferring its behavior require knowledge that explains how news of world events influences the market's thinking. Such knowledge extends beyond the content and implications of headlines (e.g., French unemployment up 1.2%) and beyond the beliefs the market forms and how the market acts. The method requires knowledge that enables thinking about how the market thinks.

The method adopts the intentional stance (Dennett, 1987). It treats the market as a unified, composite agent that acts rationally and makes a pair of assumptions. First, it assumes that each individual trader in the market acts in a manner that he believes serves his goals. Second, it assumes that each trader has the same goals - to avoid large losses and make a net profit while making trades at prices that are attractive to his customers. These assumptions imply that the market, in the aggregate, behaves in a manner that it believes will enhance profitability. They also imply that understanding how the market forms its beliefs is the key to explaining how the market acts.

The locus of the spot currency trader's expertise is timely trading that takes profits and trims losses in anticipation of changes in the direction of prices. Tables 2 and 3 outline the knowledge and uses of knowledge that enable the trader to anticipate the direction of prices. The trader's thinking about the market's thinking generates expectations for incipient market behavior and the risk posed by holding positions.

The trading model has both immediate and wide-reaching implications. The immediate implication for the trading desk is that banks need traders who are adept at thinking about how the market thinks. Accordingly, facility with the process of attributing beliefs to others is a valuable trait for a trader to possess. Relatively little is known about this cognitive ability beyond its utility in the practice of deception (Thagard, 1993) and its presence in non-human primates (Cheney & Seyfarth, 1990) and human children (Vasek, 1986). It stands to reason that good traders may also be adept at detecting deception in others. A more wide-reaching implication is that skill at trading is less a function of knowledge developed on the job than it is of facility at a complex but primeval adaptation to social interaction (e.g., Cosmides & Tooby, 1992).

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