Disclaimer

This document is for information only and does not constitute an offer or recommendation to buy or sell any investment, or otherwise transact in any investments. Past performance is not necessarily a guide to the future. Whilst all reasonable care has been taken to ensure that the stated facts are accurate and opinions are fair and reasonable neither Cantab Capital Partners LLP nor any of its members, partners or employees shall be responsible in any way for the contents of this document. It is not, under any circumstances, intended for distribution to the general public.

All opinions and estimates included in the document are subject to change without notice and Cantab Capital Partners LLP is under no obligation to update or revise information contained in the document. Cantab Capital Partners LLP disclaims any liability for any loss, damage, costs or expenses (including direct, indirect, special and consequential) howsoever arising which any person may suffer or incur as a result of viewing or utilising any information included in this document.

Cantab Capital Partners LLP is authorised and regulated by the Financial Conduct Authority in the United Kingdom (Firm Reference No 455487).
Registered in England No. OC317557. Registered office: City House, 126-130 Hills Road, Cambridge, CB2 1RE, UK.
© Cantab Capital Partners LLP
Cantab Capital is a multi-asset fund manager, with in-house execution.
Two modelling problems looking for a good home

- Not from cash equity
- But from widely traded markets
- But concrete and simple to state
- But lacking an elegant solution
Two modelling problems looking for a good home

■ Not from cash equity
■ But from widely traded markets
■ But concrete and simple to state
■ But lacking an elegant solution

And a qualitatively different problem, with a solution
OTC FX price action

- Price
- Time

© Cantab – Part of GAM Systematic. Authorised and Regulated by the Financial Conduct Authority.
OTC FX price action – 40x zoom
OTC FX price action – 2400x zoom
OTC FX price action – 72000x zoom
OTC FX price action – 72000x zoom

Free money for 10ms!
OTC FX price action – 72000x zoom
OTC FX price action – 72000x zoom

CANTAB to broker A: “I’ll take that bid”

CANTAB to broker B: “I’ll take that offer”
OTC FX price action – 72000x zoom

CANTAB to broker A: “I’ll take that bid”

CANTAB to broker B: “I’ll take that offer”

Broker A to CANTAB: “Deal!”

© Cantab – Part of GAM Systematic. Authorised and Regulated by the Financial Conduct Authority.
OTC FX price action – 72000x zoom

CANTAB to broker A: “I’ll take that bid”

CANTAB to broker B: “I’ll take that offer”

Broker A to CANTAB: “Deal!”

Broker B to CANTAB: “No deal”

Free money for 10ms!
The Problem

How to model the probability of "last look"?

- CANTAB to broker A: "I’ll take that bid”
- CANTAB to broker B: "I’ll take that offer”
- Broker A to CANTAB: “Deal!”
- Broker B to CANTAB: “No deal”
Futures market price action
Typical top of book in a futures market
Typical top of book in a futures market

Number of lots on offer
Typical top of book in a futures market

Number of lots on offer

Number of lots on bid
Typical top of book in a futures market

Typical matching rule: variations on “price-time”

Number of lots on offer

Number of lots on bid
Price action(?) in a different futures market
Price action(?) in a different futures market

“one-tick” market
Price action(?) in a different futures market

“one-tick” market

Matching rule: variations on “pro-rata”
Most of the price information not found in the price
Most of the price information not found in the price

“buy pressure”
Most of the price information not found in the price

"buy pressure"

"sell pressure"
Most of the price information not found in the price

“buy pressure”

“sell pressure”

“buy pressure”
Most of the price information not found in the price

“Bid-offer imbalance” looks like a good indicator
The Problem

How to predict price action in a “one tick” market?
Price action in a heavily traded futures contract
Unorthodox price moves
Unusually high trading volume
Algo disaster

6 seconds
Lifecycle of a simple order

1. **initial state**
2. **place order**
3. **await accept**
Lifecycle of a simple order

initial state

place order

await accept

accepted

active

rejected

cancel request

await accept or cancel

aborted
Lifecycle of a simple order

- **Initial state**
- **Place order**
- **Await accept**
- **Wait accept or cancel**
- **Rejected**
- **Cancel request**
- **Filled**
- **Active**
- **Active, await cancel**
- **Final fill**
- **Finished**
- **Aborted**
Lifecycle of a simple order

- **initial state**
- **place order**
- **await accept**
- **accepted**
- **active**
- **filled**
- **final fill**
- **cancel request**
- **await accept or cancel**
- **accepted**
- **active, await cancel**
- **cancel request**
- **cancelled**
- **finished**
- **aborted**
Lifecycle of a simple order

1. **Initial state**
2. **Place order**
   - **Await accept**
     - **Accepted**
     - **Active, await cancel**
     - **Cancelled**
     - **Rejected**
     - **Cancelled request**
     - **Await accept or cancel**
   - **Cancelled**
   - **Filled**
   - **Final fill**
3. **Finished**
4. **Aborted**
Model Checking

**Linear Temporal Logic**: “Precise provable statements about time”
Model Checking

Linear Temporal Logic: \( F(\text{finished}) \)

“In the future, we will be \text{finished}”
Model Checking

**Linear Temporal Logic:** \( F(\text{finished}) \)

"In the future, we will be finished"

- **Initial State:**
  - place order
  - rejected
  - cancel request

- **Await Accept:**
  - accepted
  - cancelled

- **Active:**
  - accepted
  - final fill
  - cancel request

- **Await Accept or Cancel:**
  - accepted
  - active, await cancel
  - final fill

- **Cancelled:**
  - final fill

- **Finished:**
  - aborted
Model Checking

Linear Temporal Logic: $\mathbf{G}(\mathbf{F}(\text{finished}))$

“Globally in the future, we will be finished”
Model Checking

Linear Temporal Logic: $G(F(\text{finished}))$

“Globally in the future, we will be finished”
Model checking

- Can deal with millions or even infinite number of states
Model checking

• Can deal with millions or even infinite number of states
• Provably covers *all* execution paths (unlike standard tests)
Model checking

- Can deal with millions or even infinite number of states
- Provably covers *all* execution paths (unlike standard tests)
- Extensions
  1. Boolean logic: $G(\text{order} \rightarrow F(\text{accepted} \mid \text{rejected} \mid \text{cancelled}))$
  2. Arithmetic: $G(\text{accepted} \rightarrow \sum \text{fills} + \sum \text{working} \leq \text{parent order})$
  3. Concrete time: $G(\text{order time} - \text{tick time} \leq \text{latency threshold})$
Model checking

- Can deal with millions or even infinite number of states
- Provably covers *all* execution paths (unlike standard tests)
- Extensions
  1. Boolean logic: $G \left( \text{order} \rightarrow F \left( \text{accepted} \mid \text{rejected} \mid \text{cancelled} \right) \right)$
  2. Arithmetic: $G \left( \text{accepted} \rightarrow \sum \text{fills} + \sum \text{working} \leq \text{parent order} \right)$
  3. Concrete time: $G \left( \text{order time} - \text{tick time} \leq \text{latency threshold} \right)$
Model checking

- Can deal with millions or even infinite number of states
- Provably covers *all* execution paths (unlike standard tests)
- Extensions
  1. Boolean logic: $G(\text{order} \rightarrow F(\text{accepted} \mid \text{rejected} \mid \text{cancelled}))$
  2. Arithmetic: $G(\text{accepted} \rightarrow \sum \text{fills} + \sum \text{working} \leq \text{parent order})$
  3. Concrete time: $G(\text{order time} - \text{tick time} \leq \text{latency threshold})$
Model checking

- Can deal with millions or even infinite number of states
- Provably covers *all* execution paths (unlike standard tests)
- Extensions
  1. Boolean logic: \( G(\text{order} \rightarrow F(\text{accepted} \mid \text{rejected} \mid \text{cancelled})) \)
  2. Arithmetic: \( G(\text{accepted} \rightarrow \sum \text{fills} + \sum \text{working} \leq \text{parent order}) \)
  3. Concrete time: \( G(\text{order time} - \text{tick time} \leq \text{latency threshold}) \)
Model checking

- Can deal with millions or even infinite number of states
- Provably covers all execution paths (unlike standard tests)
- Extensions
  1. Boolean logic: $\mathbf{G} \left( \text{order} \rightarrow \mathbf{F} (\text{accepted} \mid \text{rejected} \mid \text{cancelled}) \right)$.
  2. Arithmetic: $\mathbf{G} (\text{accepted} \rightarrow \sum \text{fills} + \sum \text{working} \leq \text{parent order})$
  3. Concrete time: $\mathbf{G}(\text{order time} - \text{tick time} \leq \text{latency threshold})$
- Does not require executing the computer code
Model checking

- Can deal with millions or even infinite number of states
- Provably covers all execution paths (unlike standard tests)
- Extensions
  1. Boolean logic: $G (order \rightarrow F (accepted | rejected | cancelled))$.
  2. Arithmetic: $G (accepted \rightarrow \sum fills + \sum working \leq parent order)$
  3. Concrete time: $G(order time - tick time \leq latency threshold)$
- Does not require executing the computer code

There are caveats and assumptions. Talk to us!
Two old(-ish) problems
  - “Last Look” in OTC FX
  - Price moves in pro-rata “one tick” markets

One new(-ish) solution: Quality assurance using “model checking”

Any takers? 😊