Agent Based Models
and
It's Hardware Optimisation

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What is Agent Based Model

Agent Based Model :   simulates actions and interactions of individuals and organization in complex and realistic ways

Constitutes of three components:

- Agents
- Topology
- Environment

Motivation

Q: Why Agent-Based Models?

- a robust approach to simulate a real-world complex system

- an alternative framework to numerical/economic models

Q: Why Agent-Based Models in finance?

- interest in the banking sector

- e.g. Barclays improve decision making strategy

- Bank of England models corporate bonds and housing markets

- JP Morgan uses ABM to model credit risk.

Motivation- Cont.

Challenges of using ABM

- High Dimensionality:
  - many agents with differentiated roles and rules
  - rules of each agent can be complex
  - Non-agent environment setup
  - Interaction topology among agents and the environment

- Hardware Performance:
  - Locality of references
  - Memory bounds
  - Resources allocation

Our approach and progress

- Completed:
  - Design a simple Agent-based financial market
  - Optimisations
  - Intel® Arria® 10 FPGA Deployment
- Ongoing:
  - Design a complex Agent-based financial market ✔
  - Software optimisation ✔
  - Hardware optimisation + FPGA Deployment ✘

The Simple Agent Based Financial market - Agents

- Agent: {Zero-Intelligent Agents}
- Agent $\in \mathbb{R}^N$

Attributes:
1. Agent ID
2. Expected Sell price
3. Expected Bid price

Rules:
1. Hold at most 1 share
2. Attempt to gain profit

The Simple Agent Based Financial market - Environment

- Environment: {Financial market with one stock}
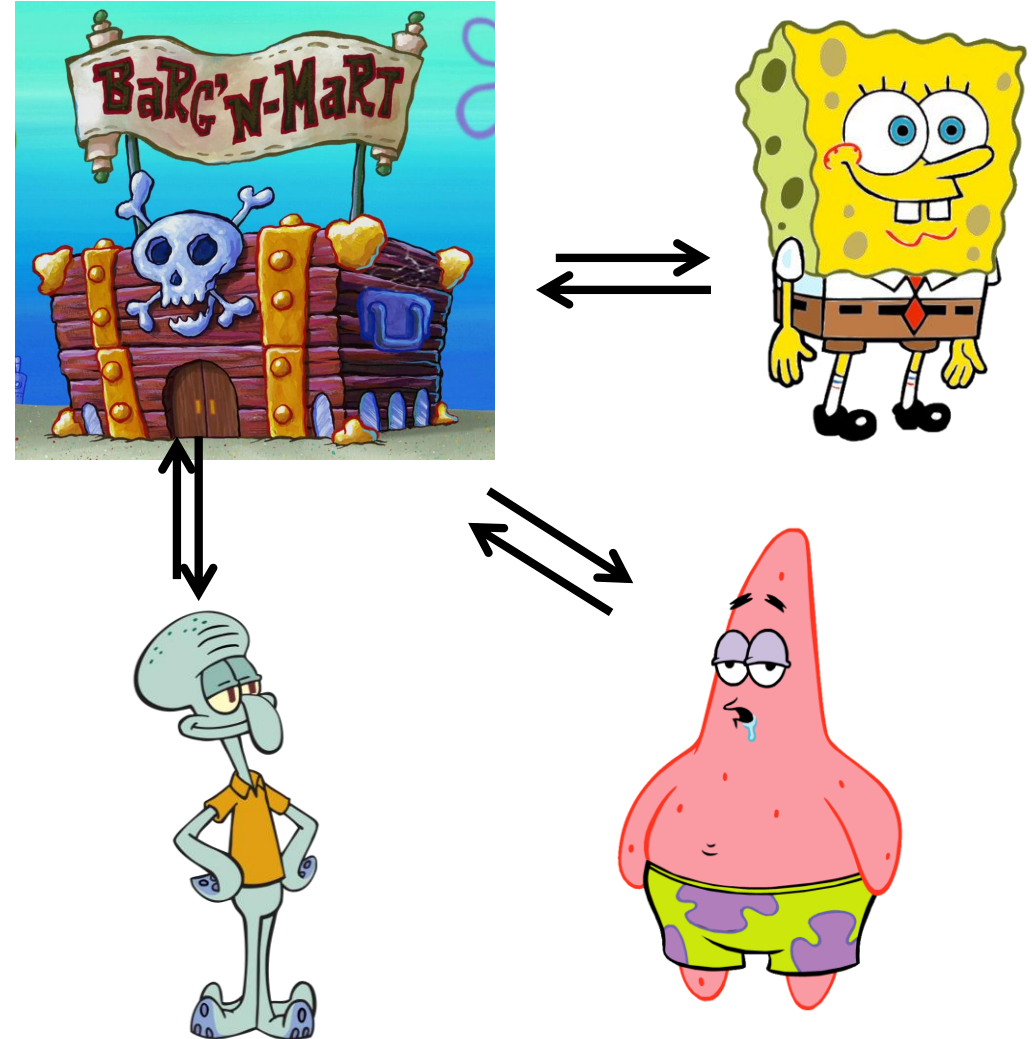- Environment $\in \mathbb{R}^I$

- Contains shares of single stock
- Responsible for exchanging shares between agents.

The Simple Agent Based Financial market - Topology

1. Select number of steps S
2. For each steps in S
   - Select N/2 agents
   - For each agent, pair with an unselected agent
   - Exchange shares (via Market)
   - Update agent parameters
3. Terminate

Optimisations

- Use single precision instead of double precision floating point

- Loop unrolling: Unrolling agent pairing

- Environment in on-chip memory

- Parallelisation of parameter update

FPGA deployment with OpenCL

Experimental Setting:
$S = 500000, N = 500$

The **Complex** Agent Based Financial market - Agents

- Same environment and similar topology settings, but more variation on agents.

- Agent: {Zero-Intelligent Agents,

    Heterogeneous Agents with Market-Mediated, Directed Interactions}

- Agent $\in \mathbb{R}^{N+M}$

Complex Agent Based Financial market: Attributes, Rules

Attributes:
1. Agent ID
2. Expected Sell price
3. Expected Bid price
4. Sentimental Index

Rules:
1. Can hold **more** than 1 share
2. Gain profits strategically
3. Observe and communicate with other agents within the market

Complex Agent Based Financial market:
## Environment and Topology

1. Select number of steps S

2. For each steps in S
   - Select one agent in the market but not the agent itself
   - The agent use its knowledge on the market (Sentimental index, observation and communication between agents) to decide buy/sell/hold
   - If the agent decides to buy/sell, look for an agent with the lowest sell price/ highest bid price, and decide the amount of shares to trade.
   - The agent submit a request to the trading agent (via market)
   - Update agents parameter

3. Terminate

Complex Agent Based Financial market:
Environment and Topology Cont.
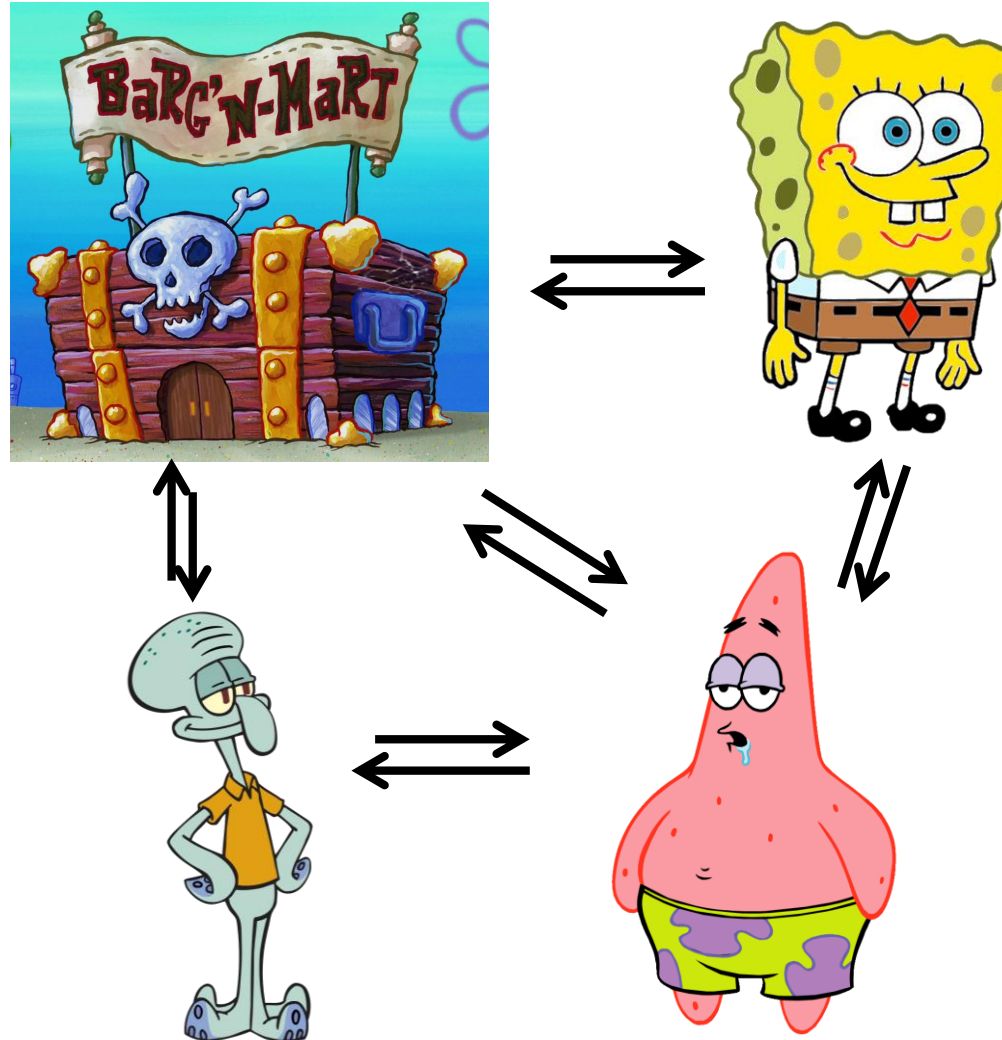
Complex Agent Based Financial market:
Software Optimisation

1. Probabilistic clustering method for agent behaviour analysis
2. Group agents with frequent communications and trading activities
3. Put groups in the same memory space to **reduce locality**
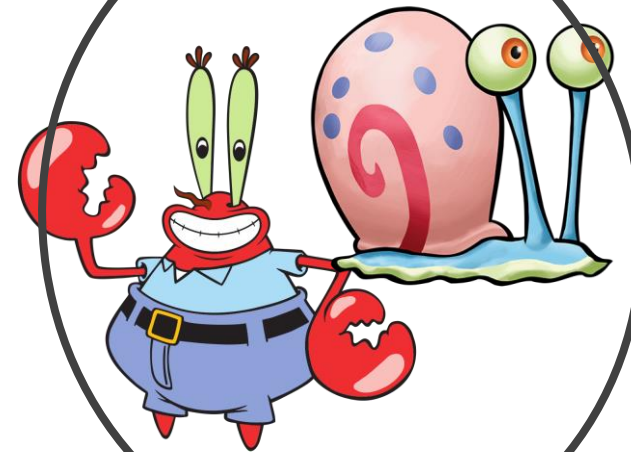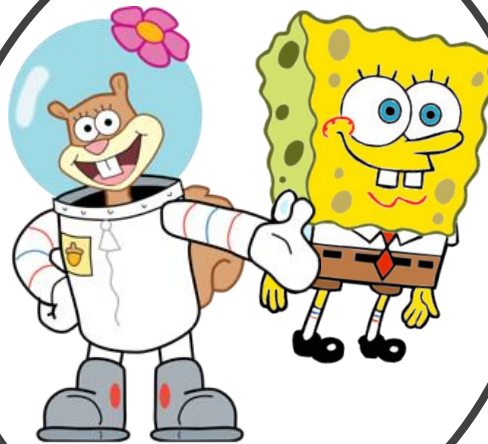
Future directions

- Improve software optimisation method

- FPGA synthesis of the complex market model

Summary

- Simple market model with hardware optimisations

- 3x speed up on FPGA against CPU

- developing complex model and its optimisations

Thank you!