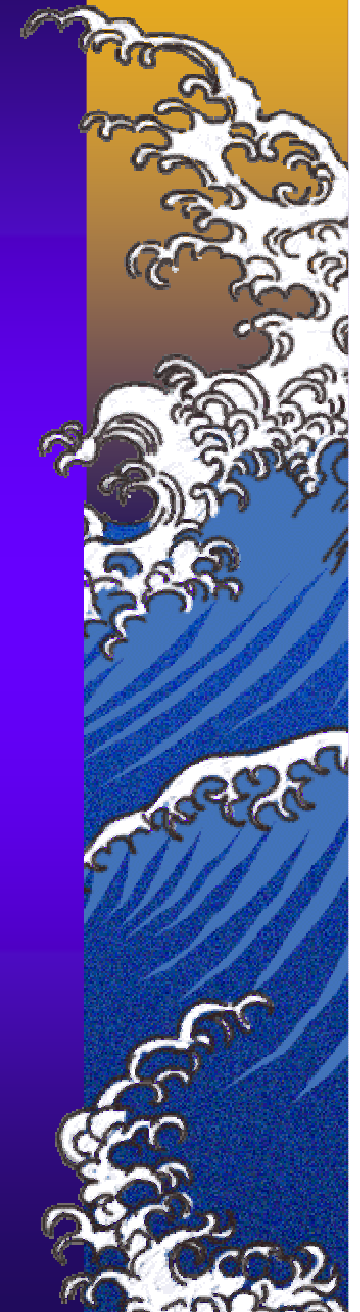# Computational Finance

Edward Tsang

Centre for Computational Finance and Economic Agents (CCFEA), University of Essex

IEEE Technical Committee on Computational Finance and Economics

http://cswww.essex.ac.uk/CSP/edward

Centre for Computational Finance and Economic Agents

CCFEA

- ♦ Economics
  - – Sheri Markose
  - – Olaf Menkens
  - – Abhinay Muthoo

- ♦ Computer Science
  - – Edward Tsang
  - – John Gan, Maria Fasli, Riccardo Poli

Students:
  - – 11 PhD
  - – 25 Doctoral+Master

- ♦ City Associates
  - – Nick Constantinou (HSBC) ++

- ♦ Secretary:
  - – Lynda Triolo

- ♦ Selected Projects:

  Markets, Forecasting, Bargaining, e-Payments, Herding

What Computational Finance?

- ◆ What is Artificial Intelligence?
  - – Not easy to define
- ◆ Defined by the activities in the community

- ◆ Understanding financial markets
  - – Artificial Markets
  - – Evolving Agents
  - – Bargaining Theory

- ◆ Challenging fundamentals in Economics and Finance
  - – Rationality
  - – Efficient market

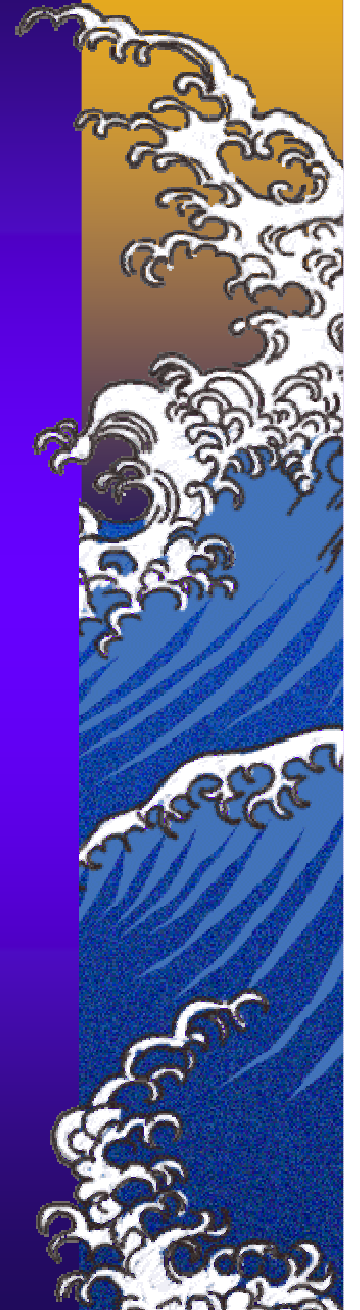- ◆ Forecasting
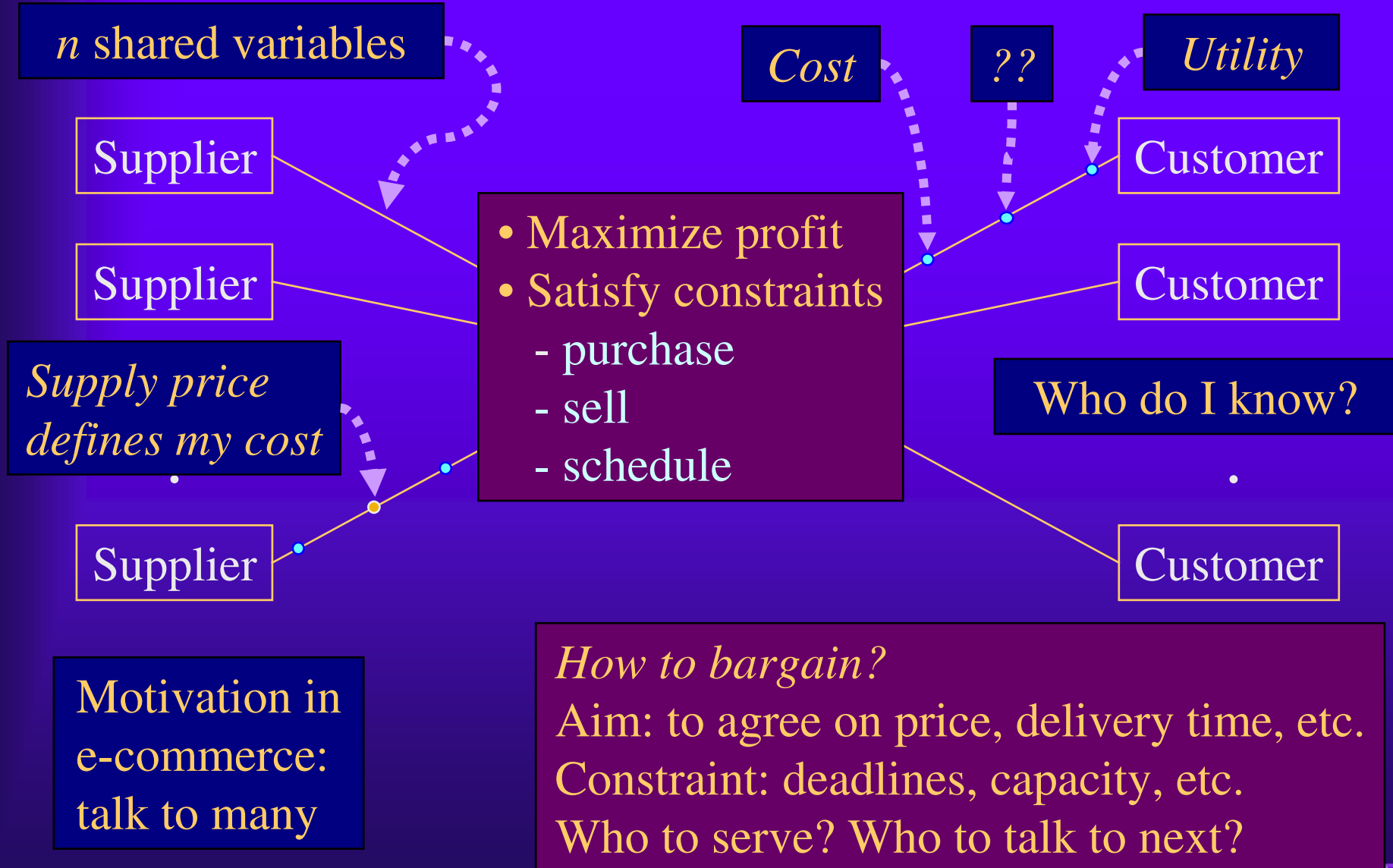 - – NN, EC, data mining
  - – Arbitrage

Why Computational Finance?

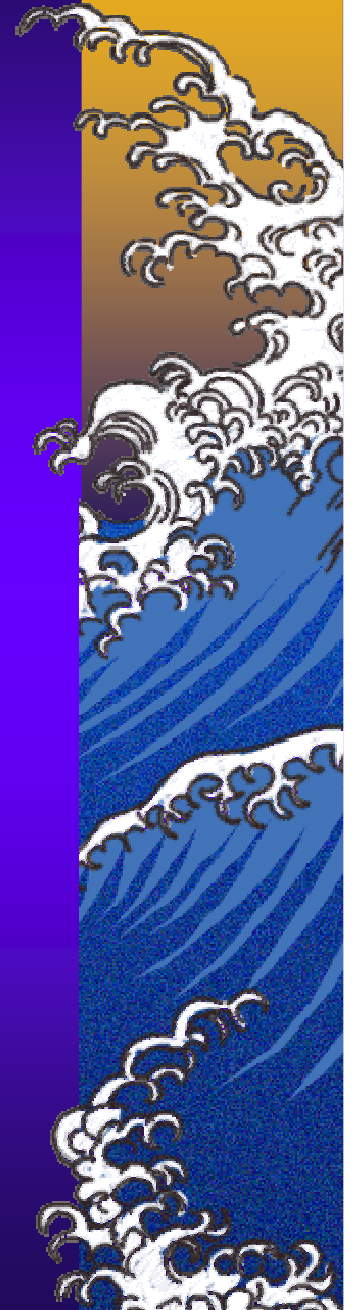| What can be done now:	Enabling technology:
Large scale simulation	Must faster machines
Data warehouse	Much cheaper memory
Building complex models	Agent-technology
Efficient exploration of models	Evolutionary computation
Decision support	experimental game theory, constraint satisfaction

Automated Bargaining

Automatic Bargaining Overview

n shared variables

Cost

??

Utility

Supplier

Supplier

Customer

Customer

• Maximize profit
• Satisfy constraints
  - purchase
  - sell
  - schedule

Supply price defines my cost

Who do I know?

Supplier

Customer

Motivation in e-commerce: talk to many

How to bargain?
Aim: to agree on price, delivery time, etc.
Constraint: deadlines, capacity, etc.
Who to serve? Who to talk to next?

Forecasting

Is the market predictable?

What exactly is the forecasting problem?

Pounds 2 week bars (dyn.)   Royal Bank of Scotland Group (The) PLC & Banks   Ord

Forecasting

- **Will the price go up or down? By how much?**

- **What prices do we have? Daily? Intraday (*high frequency*)? Volume? Indices? Economic Models?**

- **What data do we have? Prices only? Volume? Indices? Economic Models?**

— Up / Down / Neutral
— Banks
— FTSE 100
— 60 period Simple MA

- **Are Option and Future prices aligned? (i.e. are there arbitrary opportunities?)**
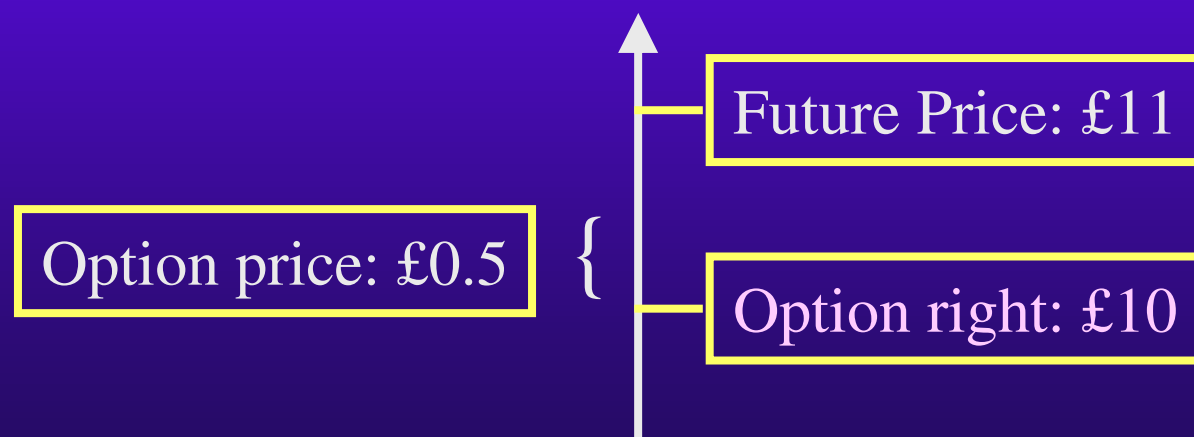
Jul   Oct   '04   Apr   Jul   25/11/04

Arbitrage Opportunities

- Futures are obligations to buy or sell at certain prices
- Options are rights to buy at a certain price
- If they are not aligned, one can make risk-free profits
  - Such opportunities should not exist
  - But they do in London

Option price: £0.5 {

Future Price: £11

Option right: £10

High Frequency Data: Example of an Order Book

	Price	Volume	Orders
Seller 4	3.86	2,000	1
Seller 3	3.85	10,000	5
Seller 2	3.84	5,000	1
Seller 1	3.83	1,000	1
Buyer 1	3.82	6,000	3
Buyer 2	3.81	8,000	3
Buyer 3	3.80	5,000	1
Buyer 4	3.79	17,000	3

Rationality

Rationality is the assumption behind many economic theories

What does being rational mean?

Are we rational?
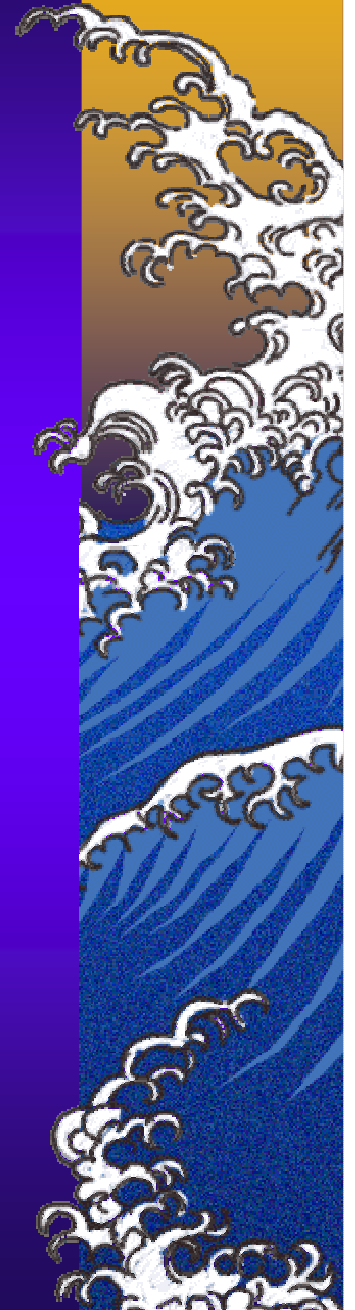
What is Rationality?

- Are we all logical?

- What if *Computation* is involved?

- Does *Consequential Closure* hold?
  - If we know P is true and P → Q, then we know Q is true
  - We know all the rules in Chess, but not the optimal moves

- "Rationality" depends on computation power!
  - Think faster → "more rational"

"Bounded Rationality"

◆ Herbert Simon:
  – Most people are only partly rational, and are in fact emotional/irrational in part of their actions
◆ "Boundedly" rational agents behave in a manner that is nearly as optimal with respect to its goals as its resources will allow
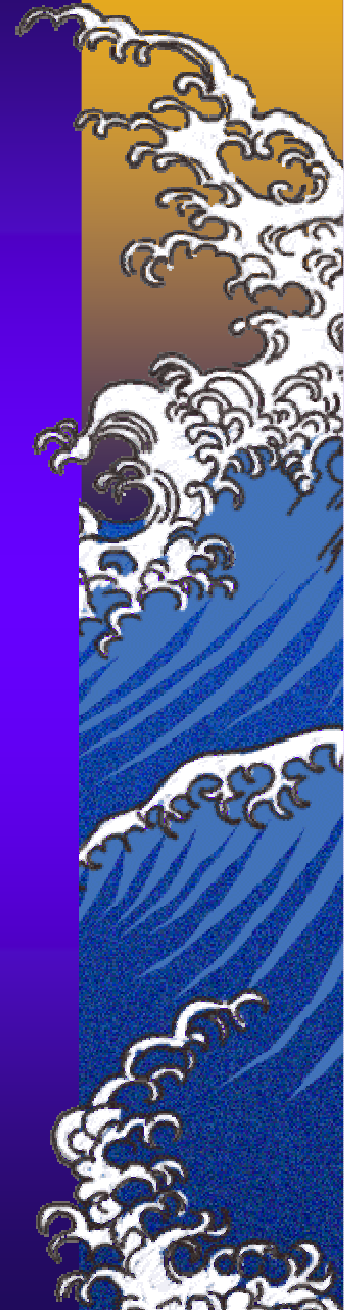 – Resources include processing power, algorithm and time available
◆ Quantifiable definition needed?

Efficient Market Hypothesis EMH

Forms of EMH

Random Walk Hypothesis

Efficient Market Hypothesis

♦ Financial assets (e.g. shares) pricing:
  – All available information is fully reflected in current prices

♦ If EMH holds, forecasting is impossible
  – <u>Random walk hypothesis</u>

♦ Assumptions:
  – Efficient markets (one can buy/sell quickly)
  – Perfect information flow
  – Rational traders

EMH Definition by Malkiel 1992

A capital market is said to be efficient if it fully and correctly reflects all relevant information in determining security prices. Formally, the market is said to be efficient with respect to some information set Φ, if security prices would be unaffected by revealing that information to all participants. Moreover, efficiency with respect to an information set, Φ implies that it is impossible to make economic profits by trading on the basis of Φ

◆ Different forms of EMH depends on Φ assumed

Forms of EMH depends on Φ assumed

♦ **Weak form of EMH**
  – Φ includes only history of prices or returns
  – No point analysing historical prices & volumes

♦ **Semi-strong form of EMH**
  – Φ includes all information known to all market participants (publicly available information)
  – No point studying annual reports or developing trading rules

♦ **Strong form of EMH**
  – Φ includes all information known to any market participant (incl. private information)
  – Even inside traders can't make abnormal profits

Random Walk Hypothesis

- Investment returns are serially independent
- Next period's return is not a function of previous returns
- Prices only changes as a result of new information
  - E.g. new, significant personnel changes
- Many empirical tests to validate EMH
  - No convincing results yet

Does the EMH Hold?

♦ It holds for the long term

♦ *"Fat Tail"* observation:
  – big changes today often followed by big changes (either + or –) tomorrow

♦ How fast can one adjust asset prices given a new piece of information?
  – Faster machines certainly help
  – So should faster algorithms

Artificial Market

Markets are efficient in the long run

How does the market become efficient?
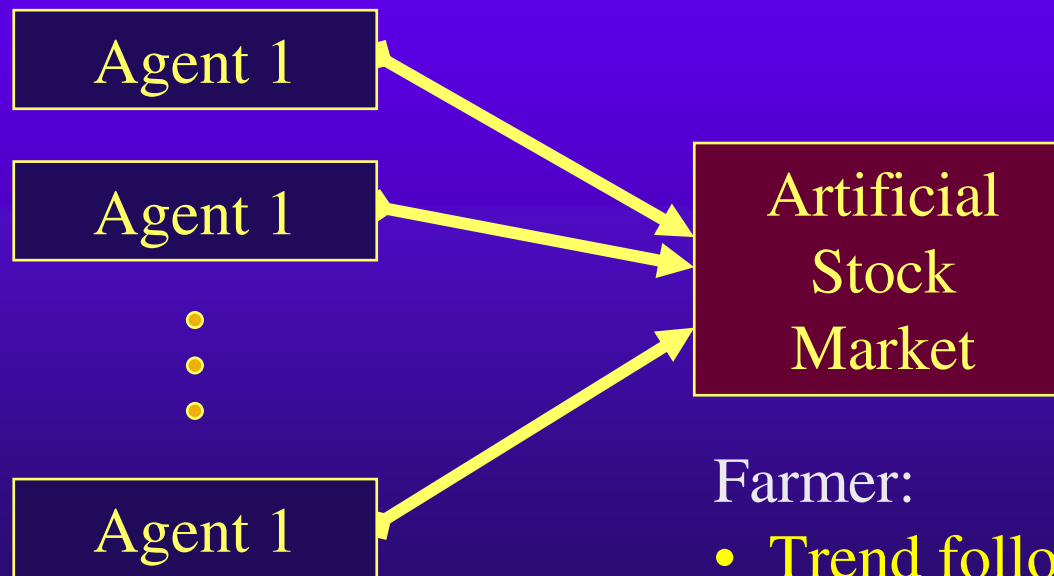
Do all agents converge in their opinions?
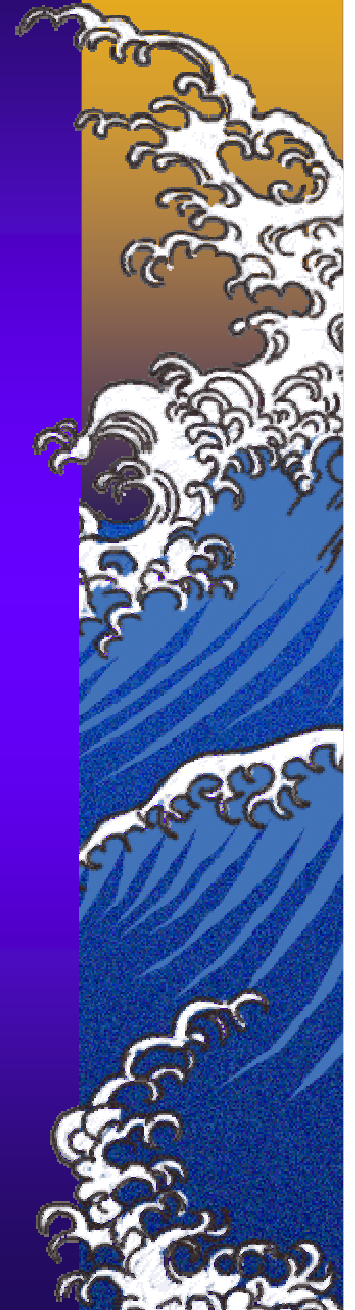
Agent-based Artificial Market

♦ **Built to understand market behaviour better**

Sante Fe Institute:
- Exogenous returns (set by experimenter)
- (Evolutionary) Classifier Systems

LeBaron:
- Endogenous returns
- Does market exhibit empirical features ("Stylized facts")?
- Effects of the traders' memory

Agent 1

Agent 1

⋮

Agent 1

Artificial Stock Market

Herding behaviour?

Farmer:
- Trend following agents +
- (Fundamental) value investors

More on markets analysis

♦ **Arifovic:**

– Endogenous foreign exchange markets

– Used GA to evolve decision rules that determine the agents' portfolios

♦ **Kirman:**

– complex dynamics generated from simple behaviour inspired by ants

– Agent-based model to studied fish market in Marseille
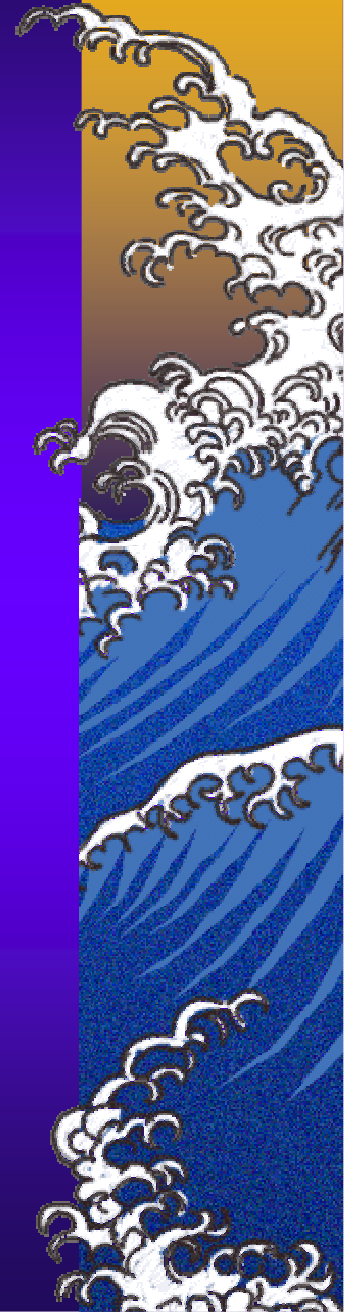
And many more interesting works observed / reported

Evolving Agents

Should agents adapt to the environment?

Co-evolution

The Red Queen Thesis

In this place it takes all the running you can do, to keep in the same place.

◆ **Chen & Yeh:**
- Endogenous prices
- Agents are GPs
- "Peer pressure" (relative wealth) lead to agents retraining themselves
- Retraining is done by "visiting the business school"

◆ **Markose, Martinez & Tsang:**
- CCFEA work in progress
- Wealth exhibits Power Law
- Wealth determines retraining
- Retraining is done by EDDIE

Evolving Agents

♦ Sunders:

– Zero intelligence agents

– Market efficiency can be obtained by zero-intelligence agents as long as the market rules are properly set.

– This result challenges the neoclassical models regarding the utility maximization behaviour of economic agents
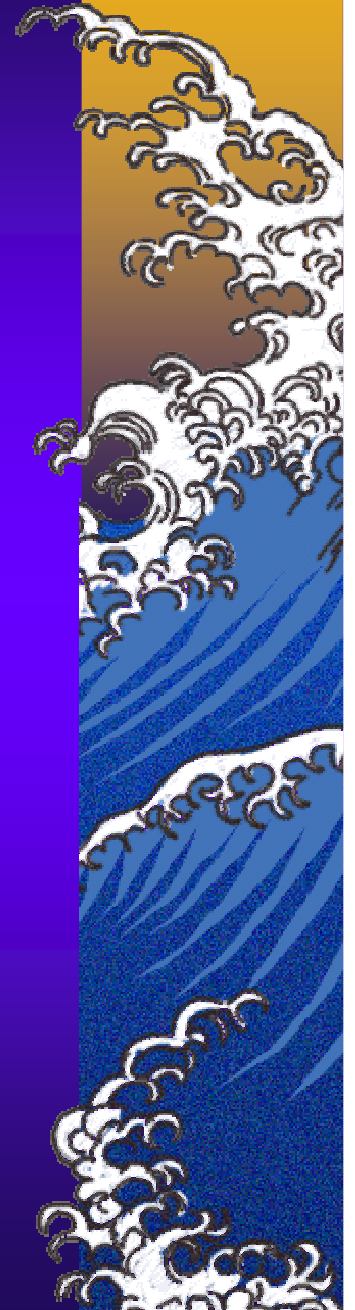
♦ Schulenburg & Ross

– Heterogenous agents (agents may have different knowledge)

– Agents modelled by classifier systems

– Exogenous prices

– Beat buy-and-hold, trend follower and random walk agents

Centre for Computational Finance and Economic Agents

CCFEA

http://www.cfea-labs.net

CCFEA City Associates Board

- **Dr. Nick Constantinou**, CHAIR
  - Head Global Market Risk Management, HSBC
- **Giovanni Beliossi** and **Fred Sipiere**
  - FGS Capital LLP
- **Professor Willem Buiter**
  - CBE, Chief Economist : EBRD
- **Dr. Dave Cliff**
  - Head Complex Adaptive Systems Group, HP Labs, Europe
- **Lord Meghnad Desai**
  - Labour Party Peer; Emeritus Professor, LSE
- **Associates from the Market Infrastructure Division, Bank of England**
- **Dr. Sushil Wadhwani**
  - CBE, CEO Wadhwani Asset Management LLP
- **Dr. Lawrence Wormald**
  - Research Director, COR Risk Solutions
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  - Senior R&D Manager, BT

CCFEA Research Team

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Red Queen

Olaf Menkens Economics

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Game Theory

Giulia Iori
Volatility

Hakan Er
Arbitrage

Serafin Martinez
EDDIE Red Q

Biliana Alexandrova-Kabadjova
e-Payment

Nanlin Jin
Bargaining

Alma Garcia
Forecasting

10+ new CCFEA Students

Edward Tsang
EDDIE / GP

Maria Fasli
Agent Tech.

John Gan
Data mining

Riccardo Poli
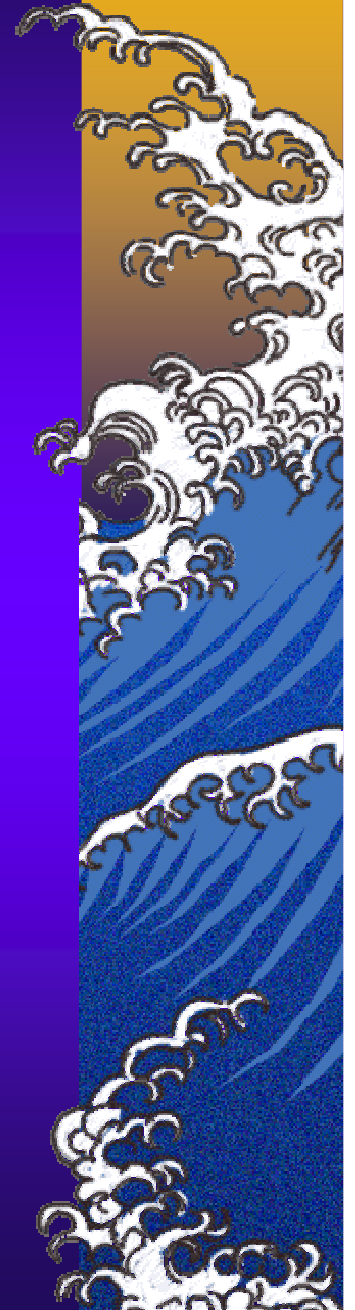Genetic Prog.

James Butler
EDDIE

Tung L Lau
Early Tools

Jin Li
FGP

Abdel Salhi
Genetic Prog.

Future of
Computational Finance

Opportunities and Challenges in CP

♦ Wide varieties of financial applications

♦ Different types of learning mechanism

♦ Different markets to simulate

♦ Challenges:

    – Large number of parameters to tune

    – What can the simulations tell us?

The Computational Finance Community

♦ Conferences:
  – IEEE International Conference on Computational Ineelligence for Financial Engineering
  – Annual Workshop on Economics with Heterogenous Interacting Agents (WEHIA 2005 at Essex, Markose, Sunders, Dempster)
  – International Conference on Computing in Economics and Finance
  – International Joint Conference on Autonomous Agents and Multi-Agent Systems

♦ Useful web sites:
  – Tesfatsion's Agent-based Computational Economics
  – Chen's AI-ECON Research Centre

♦ UK Network on Computational Finance and Economic to set up

♦ IEEE Technical Committee on Computational Finance and Economics

Questions, Discussion