# LECTURE 10: Methodologies

An Introduction to MultiAgent Systems http://www.csc.liv.ac.uk/~mjw/pubs/imas

#### Pitfalls of Agent Development

- Lots of (single and multi-) agent projects...but agentoriented development received little attention
- We now consider *pragmatics* of AO software projects
- Identifies key pitfalls
- Seven categories:
  - political
  - management
  - conceptualanalysis and design
  - micro (agent) level
- macro (society) level
- implementation

## You Oversell Agents

- Agents are not magic!
- If you can't do it with ordinary software, you probably can't do it with agents
- No evidence that any system developed using agent technology could not have been built just as easily using non-agent techniques
- Agents may make it easier to solve certain classes of problems...but they do not make the impossible possible

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- Agents are not AI by a back door
- Don't equate agents and AI

## You Get Religious

- Agents have been used in a wide range of applications, but they are not a universal solution
- For many applications, conventional software paradigms (e.g., OO) are more appropriate
- Given a problem for which an agent and a nonagent approach appear equally good, prefer nonagent solution!
- In summary: danger of believing that agents are the right solution to every problem
- Other form of dogma: believing in your agent definition

## Don't Know Why You Want Agents

Agents = new technology = lots of hype!
 "Agents will generate US\$2.6 billion in revenue by the year 2000"

# Managerial reaction: "We can get 10% of that"

- Managers often propose agent projects without having clear idea about what "having agents" will buy them
- No business plan for the project:
  - pure research?
  - technology vendor?
  - solutions vendor?
  - ۵ ...

## Don't Know Why You Want Agents

- Often, projects appear to be going well. ("We have agents!") But no vision about where to go with them.
- The lesson: understand your reasons for attempting an agent development project, and what you expect to gain from it.

#### Don't Know What Agents Are Good For

- Having developed some agent technology, you search for an application to use them
- Putting the cart before the horse!
- Leads to mismatches/dissatisfaction
- The lesson: be sure you understand how and where your new technology may be most usefully applied.
   Do not attempt to apply it to arbitrary problems & resist temptation to apply it to every problem.

Generic Solutions to 1-Off Problems

- The "yet another agent testbed" syndrome
- Devising an architecture or testbed that supposedly enables a range agent systems to be built, when you really need a one-off system
- Re-use is difficult to attain unless development is undertaken for a close knit range of problems with similar characteristics
- General solutions are more difficult and more costly to develop, often need tailoring to different applications.

#### Confuse Prototypes with Systems Believe Agents = Silver Bullet Holy grail of software engineering is a "silver bullet": an order of magnitude improvement in software Prototypes are easy (particularly with nice) development GUI builders!) Technologies promoted as the silver bullet: Field tested production systems are hard □ COBOL :-) automatic programming Process of scaling up from single-machine expert systems multi-threaded Java app to multi-user graphical programming system much harder than it appears formal methods (!) Agent technology is not a silver bullet Good reasons to believe that agents are useful way of tackling some problems But these arguments largely untested in practice 10.9 10.10

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Believe Agents = Silver Bullet
Useful developments in software engineering: abstractions
Agents are another abstraction



#### Confuse Buzzwords & Concepts

 "Our system is a BDI system"...implication that this is like being a computer with 64MB memory: a quantifiable property, with measurable associated benefits.

#### Forget it's Software

- Developing any agent system is essentially experimentation. No tried and trusted techniques
- This encourages developers to forget they are developing software!
- Project plans focus on the agenty bits
- Mundane software engineering (requirements analysis, specification, design, verification, testing) is forgotten
- Result a foregone conclusion: project flounders, not because agent problems, but because basic software engineering ignored
- Frequent justification: software engineering for agent systems is non-existent

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Forget it's Software Forget it's distributed Distributed systems = one of the most complex classes of computer system to But almost any principled software design and implement development technique is better than none. Multi-agent systems tend to be distributed! Problems of distribution do not go away, just because a system is agent-based Typical multi-agent system will be more complex than a typical distributed system Recognize distributed systems problems Make use of DS expertise 10.15 10.16

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## Don't Exploit Related Technology

- In any agent system, percentage of the system that is agent-specific is comparatively small
- The raisin bread model of Winston
- Therefore important that conventional technologies and techniques are exploited wherever possible
- Don't reinvent the wheel. (Yet another communication framework.)
- Exploitation of related technology:
  - speeds up development
  - avoids re-inventing wheel
- focusses effort on agent component
- Example: CORBA

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## Don't exploit concurrency Many ways of cutting up any problem. Examples: decompose along functional, organizational, physical, or resource related lines. One of the most obvious features of a poor multiagent design is that the amount of concurrent problem solving is comparatively small or even in extreme cases non-existent Serial processing in distributed system! Only ever a single thread of control: concurrency, one of the most important potential advantages of multi-agent solutions not exploited If you don't exploit concurrency, why have an agent solution?

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#### Want Your Own Architecture

- Agent architectures: designs for building agents
- Many agent architectures have been proposed over the years
- Great temptation to imagine you need your own
- Driving forces behind this belief:
  - "not designed here" mindset
  - intellectual property
- Problems:
  - architecture development takes years
  - no clear payback
- Recommendation: buy one, take one off the shelf, or do without

#### Think Your Architecture is Generic

- If you do develop an architecture, resist temptation to believe it is generic
- Leads one to apply an architecture to problem for which it is patently unsuited
- Different architectures good for different problems
- Any architecture that is truly generic is by definition not an architecture...
- If you have developed an architecture that has successfully been applied to some particular problem, understand *why* it succeeded with that particular problem
- Only apply the architecture to problems with similar characteristics

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#### Use Too Much AI

- Temptation to focus on the agent-specific aspects of the application
- Result: an agent framework too overburdened with experimental AI techniques to be usable
- Fuelled by "feature envy", where one reads about agents that have the ability to learn, plan, talk, sing, dance...
- Resist the temptation to believe such features are essential in your agent system
- The lesson: build agents with a minimum of AI; as success is obtained with such systems, progressively evolve them into richer systems
- What Etzioni calls "useful first" strategy

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## Not Enough AI

- Don't call your on-off switch an agent!
- Be realistic: it is becoming common to find everyday distributed systems referred to as multi-agent systems
- Another common example: referring to WWW pages that have any behind the scenes processing as "agents"
- Problems:
- lead to the term "agent" losing any meaning
- raises expectations of software recipients
- leads to cynicism on the part of software developers

See agents everywhere

- "Pure" A-O system = everything is an agent! Agents for addition, subtraction,...
- Naively viewing *everything* as an agent is inappropriate
- Choose the right grain size
- More than 10 agents = big system

## Too Many Agents

- Agents don't have to be complex to generate complex behavior
- Large number of agents:
   emergent functionality
- chaotic behavior
- Lessons:
  - keep interactions to a minimum
  - keep protocols simple

## Too few agents

- Some designers imagine a separate agent for every possible task
- Others don't recognize value of a multi-agent approach at all
- One "all powerful" agent
- Result is like OO program with 1 class
- Fails software engineering test of coherence

#### Implementing infrastructure

- There are no widely-used software platforms for developing agent systems
- Such platforms would provide all the basic infrastructure required to create a multi-agent system
- The result: everyone builds there own
- By the time this is developed, project resources gone!
- No effort devoted to agent-specifics

#### System is anarchic

- Cannot simply bundle a group of agents together
- Most agent systems require system-level engineering
- For large systems, or for systems in which the society is supposed to act with some commonality of purpose, this is particularly true
- Organization structure (even in the form of formal communication channels) is essential

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#### Confuse simulated with real parallelism

- Every multi-agent system starts life on a single computer. Agents are often implemented as UNIX processes, lightweight processes in C, or JAVA threads
- A tendency to assume that results obtained with simulated distribution will immediately scale up to *real* distribution
- A dangerous fallacy: distributed systems are an order of magnitude more difficult to design, implement, test, debug, and manage
- Many practical problems in building distributed systems, from mundane to research level
- With simulated distribution, there is the possibility of centralized control; in truly distributed systems, such centralized control is not possible

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#### The tabula rasa

- When building systems using new technology, often an assumption that it is necessary to start from a "blank slate"
- Often, most important components of a software system will be *legacy*: functionally essential, but technologically obsolete software components, which cannot readily be rebuilt
- Such systems often mission critical
- When proposing a new software solution, essential to work with such components
- They can be incorporated into an agent system by wrapping them with an agent layer

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#### Ignore *de facto* standards

- There are no established agent standards
- Developers often believe they have no choice but to design and build all agent-specific components from scratch
- But here are some de facto standards
- Examples:
  - □ CORBA
  - D HTML
  - KQML
- FIPA



## Mobile Agents

- Why mobile agents?
  - low-bandwidth networks (hand-held PDAs, such as NEWTON)
  - efficient use of network resources
- There are *many* issues that need to be addressed when building software tools that can support mobile agents...
  - security for hosts and agents
  - heterogeneity of hosts
  - dynamic linking

#### Security for Hosts

We do not want to execute foreign programs on our machine, as this would present enormous *security* risks:

- If the agent programming language supports pointers, then there is the danger of agents corrupting the address space of the host ⇒ many agent languages don't have pointers!
- UNIX-like access rights on host
- Safe libraries for access to filestore, process space, etc.
- Some actions (e.g., sending mail) are harmless in some circumstances, but dangerous in others how to tell?

### Security for Hosts

- Some agent languages (e.g., TELESCRIPT) provide limits on the amount of e.g., memory & processor time that an agent can access
- Secure co-processors are a solution have a physically separate processor on which the agent is run, such that the processor is in 'quarantine' ('padded cell')
- Some agent languages allow security properties of an agent to be verified on receipt.
- Hosts must handle crashed programs cleanly what do you tell an owner when their agent crashes? Trusted agents?

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#### Security for Agents

- Agents have a right to privacy!
- We often do not want to send out our programs, as to do so: might enable the recipient to determine its purpose, and hence our intent
- The agent might be modified (sabotaged!) in some way, without its owners knowledge or approval
- An agent can be protected in transit by using conventional encryption techniques (e.g., PGP)
- In order to ensure that an agent is not tampered with, it is possible to use *digital watermarks* rather like check digits

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- We can divide mobile agents into at least three types:
  - autonomous
  - on-demand
  - □ 'active mail'-type

#### Autonomous Mobile Agents

- By autonomous mobile, we mean agents that are able to decide for themselves where to go, when, and what to do when they get there (subject to certain resource constraints, e.g., how much 'emoney' they can spend)
- Such agents are generally programmed in a special language that provides a go instruction... best known example is TELESCRIPT

## On-Demand Mobility

- The idea here is that a host is only required to execute an agent when it explicitly demands the agent
- The best known example of such functionality is that provided by the JAVA language, as embedded within html
- A user with a JAVA-compatible browser can request html pages that contain *applets* – small programs implemented in the JAVA language
- These applets are downloaded along with all other images, text, forms, etc., on the page, and, once downloaded, are executed on the user's machine
- JAVA itself is a general purpose, C/C++ like programming language, (that does not have pointers!)

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## 'Active-Mail' Agents

- The idea here is to 'piggy-back' agent programs onto mail
- The best-known example of this work is the mime extension to email, allowing Safe-Tcl scripts to be sent
- When email is received, the 'agent' is unpacked, and the script executed... hence the email is no longer passive, but active

#### Telescript

- TELESCRIPT was a language-based environment for constructing mobile agent systems
- TELESCRIPT technology is the name given by General Magic to a family of concepts and techniques they have developed to underpin their products
- There are two key concepts in TELESCRIPT technology:
  - places
  - □ agents
- Places are virtual locations occupied by agents. A place may correspond to a single machine, or a family of machines

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### Telescript

- Agents are the providers and consumers of goods in the *electronic marketplace* applications that TELESCRIPT was developed to support
- Agents are interpreted programs, rather like TCL
- Agents are *mobile* they are able to move from one place to another, in which case their program and state are encoded and transmitted across a network to another place, where execution recommences
- In order to travel across the network, an agent uses a *ticket*, which specifies the parameters of its journey:
   destination

completion time

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## Telescript

- Agents can communicate with one-another:
   if they occupy different places, then they can connect across a network
  - if they occupy the same location, then they can meet one another

## Telescript

- TELESCRIPT agents have an associated *permit*, which specifies:
  - what the agent can do (e.g., limitations on travel)
  - what resources the agent can use
- The most important resources are:
- 'money', measured in 'teleclicks' (which correspond to real money)
- lifetime (measured in seconds)
- size (measured in bytes)
- Agents and places are executed by an *engine*
- An engine is a kind of agent operating system agents correspond to operating system processes.

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#### Telescript

- Just as operating systems can limit the access provided to a process (e.g., in UNIX, via access rights), so an engine limits the way an agent can access its environment
- This is the so-called concept of "managed code" (e.g., Java, Visual Basic, Microsoft's .Net)

#### Telescript

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- Engines continually monitor agent's resource consumption, and kill agents that exceed their limit
- Engines provide (C/C++) links to other applications via application program interfaces (APIs)
- Agents and places are programmed using the TELESCRIPT language:
- pure object oriented language everything is an object apparently based on SMALLTALK
- interpreted
- two levels high (the 'visible' language), and low (a semicompiled language for efficient execution)
- a 'process' class, of which 'agent' and 'place' are subclasses
- persistent

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## Telescript

 General Magic claimed that the sophisticated built in communications services make TELESCRIPT ideal for agent applications!

#### Telescript

- Summary:
  - a rich set of primitives for building distributed applications, with a fairly powerful notion of agency
  - agents are ultimately interpreted programs
  - no notion of strong agency!
  - once thought likely to have a significant impact (was supported by Apple, AT&T, Motorola, Philips, Sony...) – but now company is extinct
  - actual impact more likely to be in the realm of ideas, rather than in this particular instantiation

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#### TCL/TK and Scripting Languages

- The (free) Tool Control Language (TCL pronounced 'tickle') and its companion TK, are now often mentioned in connection with agent-based systems
- TCL was primarily intended as a standard command language — lots of applications provide such languages, (databases, spreadsheets,...), but every time a new application is developed, a new command language must be as well. TCL provides the facilities to easily implement your own command language
- TK is an X window based widget toolkit it provides facilities for making GUI features such as buttons, labels, text and graphic windows (much like other X widget sets).

TK also provides powerful facilities for interprocess communication, via the exchange of TCL scripts

TCL/TK and Scripting Languages

- TCL/TK combined, make an attractive and simple to use GUI development tool; however, they have features that make them much more interesting:
  - TCL it is an interpreted language
  - TCL is *extendable* it provides a core set of primitives, implemented in C/C++, and allows the user to build on these as required
  - TCL/TK can be *embedded* the interpreter itself is available as C++ code, which can be embedded in an application, and can itself be extended

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## TCL/TK and Scripting Languages

- TCL programs are called scripts
- TCL scripts have many of the properties that UNIX shell scripts have:
  - they are plain text programs, that contain control structures (iteration, sequence, selection) and data structures (e.g., variables, lists, and arrays) just like a normal programming language
  - they can be executed by a shell program (tclsh or wish)
  - they can call up various other programs and obtain results from these programs (cf. procedure calls)

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## TCL/TK and Scripting Languages

- As TCL programs are *interpreted*, they are very much easier to prototype and debug than compiled languages like C/C++ — they also provide more powerful control constructs...
  - □ ... but this power comes at the expense of speed
- Also, the structuring constructs provided by TCL leave something to be desired
- So where does the idea of an agent come in? It is easy to build applications where TCL scripts are exchanged across a network, and executed on remote machines.

Thus TCL scripts become sort of agents

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## TCL/TK and Scripting Languages

- A key issue is *safety*. You don't want to provide someone elses script with the full access to your computer that an ordinary scripting language (e.g., csh) provides.
- This led to Safe TCL, which provides mechanisms for limiting the access provided to a script.
   Example: Safe TCL control the access that a script has to the UI, by placing limits on the number of times a window can be modified by a script.
- But the safety issue has not yet been fully resolved in TCL. This limits its attractiveness as an agent programming environment

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## TCL/TK and Scripting Languages

Summary:

- TCL/TK provide a rich environment for building language-based applications, particularly GUIbased ones
- But they are not/were not intended as agent programming environments
- The core primitives may be used for building agent programming environments — the source code is free, stable, well-designed, and easily modified