Real world complex systems and cross-disciplinary research

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from silos to interdisciplinarity

“The world has problems while universities have disciplines”

G. Wilson, JWUF, 2009
multidisciplinarity

- studying a research topic in several disciplines simultaneously
  - a painting: art history and mathematical geometry
- goals: limited to the framework of (home) disciplinary research
  - others as a “service industry”

[Nicolescu]
interdisciplinarity

- goal: transfer of methods from one discipline to another
  - new capabilities, new approaches, even new disciplines

[Nicolescu]
transdisciplinarity

• between, across, *beyond* disciplines
• goal: “understanding the world” (not just one disciplinary view of it)
  ▪ a unity of knowledge
Challenges
systems, and complex systems

• system:
  - a set of interacting components and relationships
  - with high level structure and behaviour
  - forming an integrated whole

• complex system – also:
  - strong local interactions resulting in global behaviour
  - heterogeneous mix of networks and hierarchies
    - physical, technical, social, ...
  - feedback between levels
  - self-organisation
  - growth, adaptation, evolution, change
  - emergence and innovation
  - ...

complex systems science

• a **complex problem** cannot be tackled by a single discipline alone
  ▪ multiple stakeholders with differing requirements and goals
  ▪ ‘soft’ social and ‘hard’ technical issues
  ▪ issues from multiple natural and engineered domains

• it requires an **interdisciplinary, complex systems** approach
“simple” complexity

- **multiple homogeneous agents** + **simple interaction rules** = complex behaviours
- eg: “boids”

- but *real world* complexity isn’t simple!

http://www.red3d.com/cwr/boids/
real world “complicated” complexity

- multiple **heterogeneous** agents + **complex environment** + multiple **complicated** rules of interaction and **growth** = real world behaviours

- eg: deer populations

[Ford10]
complex systems $\Rightarrow$ interdisciplinary working

- **multiple** domains
  - management, law, economics, engineering, psychology, systems biology, environment, ...

- **multiple** techniques
  - experiments, mathematics, statistics, computer models, ...

- no one person can be expert in all these!

- it takes *time* and *effort* to develop the necessary interdisciplinary teams
Process
• York Centre for Complex Systems Analysis

• we are an **interdisciplinary** team of 90+ staff and students
  
  
  ▪ we have associate members from other universities:
    ✷ Birmingham – Cambridge – Durham – Madrid – Manchester – Oxford – Warwick ...

• we focus on real world complex systems requiring interdisciplinary solutions – and a **common** mindset:
  
  ▪ systems thinking
    ✷ “**the totality is not, as it were, a mere heap, but the whole is something beside the parts**”
      – Aristotle, ~350 BCE [tr. W. D. Ross 1924]
    ✷ “**the whole is other than the sum of its parts**”
YCCSA problem domains, and tools

- Socio-technical Systems
- Ecosystem Interactions
- Novel Computation
- Resilient Systems
- System Simulation
- Gamification
- Robotics
- System Forensics
- Cancer
- Immunology
- Viruses
- Fisheries
- Complex Systems Science
  - Networks
  - Spectroscopy
  - Computational Modelling
  - Bio-inspired Search
  - Swarm Engineering
  - Narratives
  - Statistics
  - Mathematical Modelling
YCCSA’s three stage approach

• our process for building collaboration, trust and respect

1. coming together

2. thinking together

3. working together

• developed through EPSRC “Bridging the Gaps” TRANSIT funding, 2008
stage 1: coming together

- YCCSA process for building collaboration, trust and respect

- weekly “cake” seminars
  - 2 hour format

- reading groups
  - scientists / arts & humanities

- visitors

- workshops, ...

- goal: to learn each others disciplinary languages and cultures
stage 2: thinking together

- YCCSA process for building collaboration, trust and respect
- learning the system domain, from the different perspectives
- small, risk-free projects
  - YCCSA summer school
  - pump priming feasibility studies
- goal: to **co-create** research topics, proposals and projects
stage 3: working together

• YCCSA process for building collaboration, trust and respect

• funded projects

• co-supervising research students across disciplines
  ▪ CS/Biology; Chemistry/CS; Maths/Biology; Electronics/CS; ...
  ▪ goal: teams of students

• goal: to do transformative research

“I have never seen any scientific group working so well together and where communication is flowing so effortlessly across disciplines. What you have is truly remarkable.”

— Dr Paolo Dini, Senior Research Fellow, Dept Media and Communications, London School of Economics
Benefits
btw, it’s not for everyone!

- what kind of researcher are you / do you want to be?
  - all kinds are valid / valuable!
  - all kinds have costs and benefits

- research progress: guarantees v excitement
  - incremental development
    - “standing on the shoulders of giants”
  - radical novelty
    - breaking a path through unknown jungle

- disciplinarity: depth v breadth
  - single discipline
  - multidisciplinary
  - interdisciplinary
  - transdisciplinary
• YCCSA research students are fully integrated into our research culture and research activities

• “YCCSA students are an excellent advertisement for interdisciplinary research ... they feel supported and empowered to achieve high-quality research”
  – external review report

• “It is an advantage to have to explain research to non-specialists as the questions raised tended to be more unique and challenging.”
  – YCCSA research student
benefits of interdisciplinary working

• interesting way to work
  - it you like that sort of thing ...

• no one is expert in all domains and techniques

• so, everyone has something to learn from everyone else
  - no room for monster egos
    - everyone learns : students can teach their supervisors
    - learn to be comfortable saying “I don’t understand”
  - joy of learning, and of building a shared understanding

• excitement of research that is other than the sum of its parts
further reading

