BIO-INSPIRED COMPUTING

Course Overview

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BIO-INSPIRED COMPUTING

What is Biologically-Inspired Computation?

- Computer systems, devices, and algorithms based, more or less closely, on biological systems
- *Biomimicry* applied to computing
- Approximately synonymous with: bio-inspired computation, organic computing

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Two Kinds of Computation Motivated by Biology

- Computation applied to biology
  - bioinformatics
  - computational biology
  - modeling DNA, cells, organs, populations, etc.
- Biology applied to computation
  - biologically-inspired computation
  - neural networks
  - artificial life
  - etc.

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Natural Computation

- “Computation occurring in nature or inspired by that occurring in nature”
- Information processing occurs in natural systems from the DNA-level up through the brain to the social level
- We can learn from these processes and apply them in CS (bio-inspired computing)
- In practice, can’t do one without the other

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Biological Computation

- Refers to the use of biological materials for computation
- e.g. DNA, proteins, viruses, bacteria
- Sometimes called “biocomputing”
- Goal: Biocomputers
- Bio-inspired computing need not be done on biocomputers

Classical Computation vs Bio-Inspired Computation

- How do you tell the difference between dog and cat?
- How do you tell the difference between male and female face?
- How do you design a perfect flying machine?
- How would we design the software for a robot that could make a cup of tea in your kitchen?
- What happens if you:
  - Cut off a salamander's tail?
  - Cut off a section of a CPU?

Classical Computation vs Bio-Inspired Computation

Classical computing is good at:

- Number-crunching
- Thought-support (glorified pen-and-paper)
- Rule-based reasoning
- Constant repetition of *well-defined* actions.

Classical computing is bad at:

- Pattern recognition
- Robustness to damage
- Dealing with vague and incomplete information;
- Adapting and improving based on experience

Why don’t we have software that can do the following things well?

- Automatically locate a small outburst of violent behaviour in a football crowd
- Classify a plant species from a photograph of a leaf.
- Design robust railway timetables
- Make a cup of tea?

- These two things tend to come up a lot when we think of what we would *like* to be able to do with software, but usually *can't* do.
- *But these are things that seems to be done very well indeed in Biology.*
- *So it seems like a good idea to study how these things are done in biology – i.e. (usually) how computation is done by biological machines*

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Why Do Bio-inspired Computation?

- Biological systems are:
  - efficient
  - robust
  - adaptive
  - flexible
  - parallel
  - decentralized
  - self-organizing
  - self-repairing
  - self-optimizing
  - self-protecting
  - etc.

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Some of the Natural Systems We have

- adaptive path minimization by ants
- wasp and termite nest building
- army ant raiding
- fish schooling and bird flocking
- pattern formation in animal coats
- coordinated cooperation in slime molds
- synchronized firefly flashing
- soft constraint satisfaction in spin glasses
- evolution by natural selection
- game theory and the evolution of cooperation
- computation at the edge of chaos
- information processing in the brain

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Some of the Artificial Systems We have

- artificial neural networks
- simulated annealing
- cellular automata
- ant colony optimization
- artificial immune systems
- particle swarm optimization
- genetic algorithms
- other evolutionary computation systems

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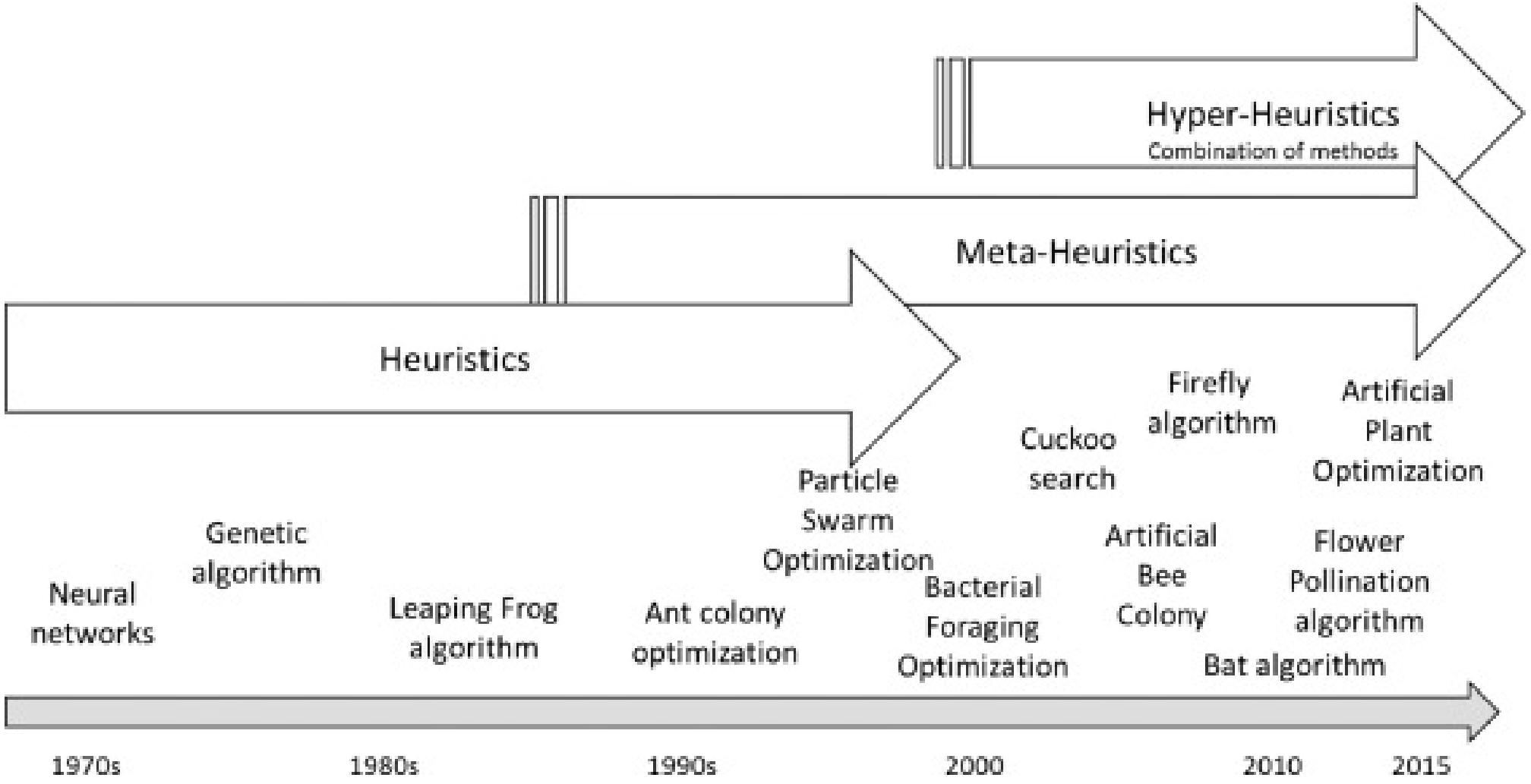
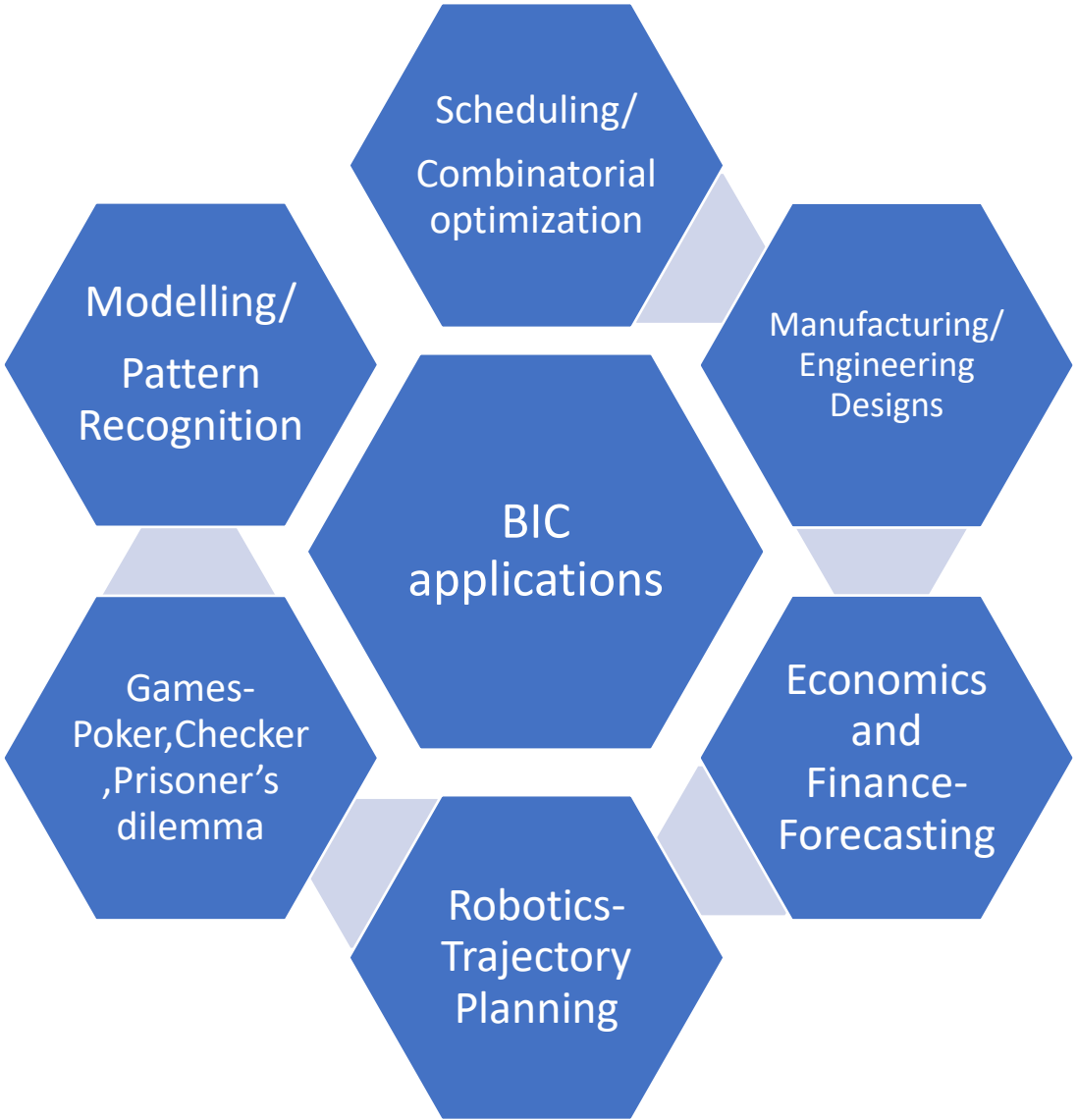
Top Algorithms in BIC



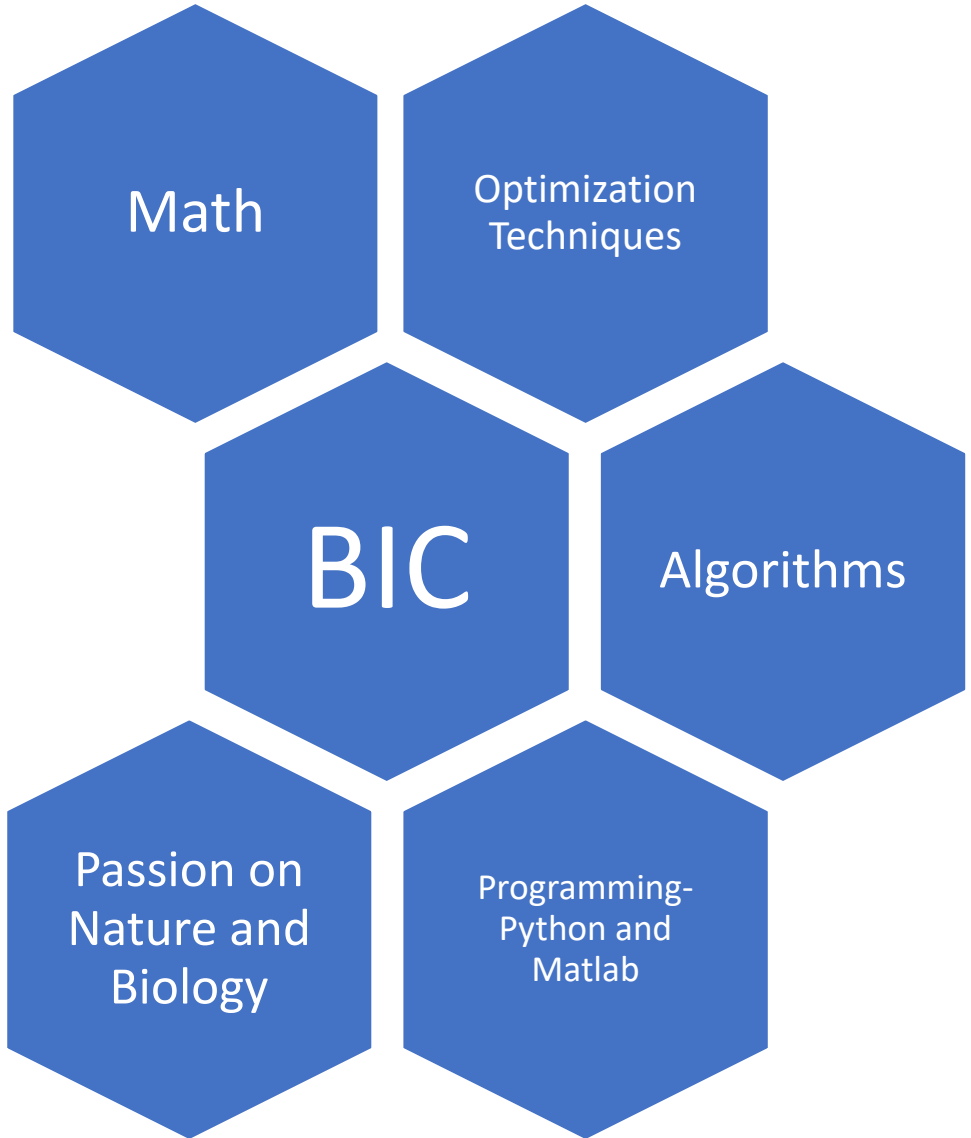
DATA ANALYTICS

Data Analytics is Omnipresent



DATA ANALYTICS

Skills Required



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Course Contents

Title	What it's about
Intro to BIC	The differences between BIC and `ordinary' computing, the kinds of problems we need BIC for (including basics of classification, optimisation, and problem complexity), motivation for BIC, and a broad overview of many BIC techniques and the kinds of problems they can solve.
Evolutionary Algorithms	Algorithms based on natural evolution, for solving real-world problems; various different algorithms based on this idea, several example applications
Swarm Intelligence	Algorithms inspired by natural swarming behaviour, with various applications (ant systems, particle swarm optimisation)
Other BIC methods	A selection of other prominent BIC methods, e.g. Artificial Immune Systems, Cellular Computing, Foraging algorithms.

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Takeaway from this Course:

- What `classical computing' is, and what kinds of tasks it is naturally suited for.
- What classical computing is not good at.
- An appreciation of how computation and problem solving are manifest in biological systems.
- Appreciation of the fact that many examples of computations done by biological systems are not yet matched by what we can do with computers.
- An understanding of the motivation (consequent on the above) for studying how computation is done in nature.
- A first basic knowledge of the main currently and successfully used BIC methods

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Course Evaluation (tentative)

Evaluation Scheme(Weightage will be announced later)
ISA1
ISA2
Assignments
Project(Research Paper Implementation)
ESA
Total= 100

Course References

Text Book:

1. “Natural Computing Algorithms”, Anthony Brabazon, Michael O’Neill, Seán McGarraghy, Springer, Natural Computing Series,2015

Reference Books:

1. “Fundamentals of Natural Computing”: Basic Concepts, Algorithms, and Applications. Nunes de Castro, Leandro , Chapman & Hall/ CRC, Taylor and Francis Group, 2007
2. “Bio-Inspired Artificial Intelligence: Theories, Methods, and Technologies”,Floreano D. and Mattiussi C., MIT Press, Cambridge, MA, 2008.
3. Research papers

THANK YOU

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