UFME7K-15-M Intelligent and Adaptive Systems

Introduction to the Module

Charlie Sullivan

24 January 2018

Intelligent and Adaptive Systems

A Brief Introduction

Dr J. Charlie Sullivan

charlie.sullivan@brl.ac.uk

Introduction

- Who am I?

Introduction

- Who am I?
- Dr (John) Charlie Sullivan

Introduction

- Who am I?
- Dr (John) Charlie Sullivan
- email:

Introduction

- Who am I?
- Dr (John) Charlie Sullivan
- email:
  - charlie.sullivan@brl.ac.uk

Introduction

- Who am I?
- Dr (John) Charlie Sullivan
- email:
  - charlie.sullivan@brl.ac.uk
  - john.sullivan@uwe.ac.uk

Aims of the Module

- This module aims to provide a brief overview of the field of intelligent and adaptive systems based on the techniques of ‘soft’ or adaptive computing.

Aims of the Module

- This module aims to provide a brief overview of the field of intelligent and adaptive systems based on the techniques of 'soft' or adaptive computing.
- It also aims to set these advanced techniques in the context of example applications in new and innovative areas.

Aims of the Module

- This module aims to provide a brief overview of the field of intelligent and adaptive systems based on the techniques of 'soft' or adaptive computing.
- It also aims to set these advanced techniques in the context of example applications in new and innovative areas.
- Most importantly, it aims to give some "hands-on" experience of using Intelligent and Adaptive architectures in Robotics-relevant applications

Assessment

- Exam (50%)

Assessment

- Exam (50%)
- Coursework Assignment (50%)

Assessment

- Exam (50%)
- Coursework Assignment (50%)
  - Individual Report

Assessment

- Exam (50%)
- Coursework Assignment (50%)
  - Individual Report
  - Word limit 4000

Assessment

Lectures give a brief overview of content.

- Exam (50%)
- Coursework Assignment (50%)
  - Individual Report
  - Word limit 4000
  - More details released soon

Teaching/Learning

- A practical “hands on” course

Teaching/Learning

- A practical “hands on” course
  - Learn by solving problems

Teaching/Learning

- A practical “hands on” course
  - Learn by solving problems
  - Generalise from specific examples

Teaching/Learning

- A practical “hands on” course
  - Learn by solving problems
  - Generalise from specific examples
  - No “spoon-feeding”

Teaching/Learning

- A practical "hands on" course
  - Learn by solving problems
  - Generalise from specific examples
  - No "spoon-feeding"
- Small amount of theory

Teaching/Learning

- A practical "hands on" course
  - Learn by solving problems
  - Generalise from specific examples
  - No "spoon-feeding"
- Small amount of theory
- Reading

Teaching/Learning

- A practical "hands on" course
  - Learn by solving problems
  - Generalise from specific examples
  - No "spoon-feeding"
- Small amount of theory
- Reading
- Reflection

Teaching/Learning

- A practical "hands on" course
  - Learn by solving problems
  - Generalise from specific examples
  - No "spoon-feeding"
- Small amount of theory
- Reading
- Reflection
- Discussion

Don't try to just memorise slides
↳ learn how to solve problems.

Tools

- MATLAB

Tools

- MATLAB
- Simulink

Tools

- MATLAB
- Simulink
- MATLAB toolboxes

Tools

- MATLAB
- Simulink
- MATLAB toolboxes
  - Neural Network Toolbox

Tools

- MATLAB → Mathworks tutorials
- Simulink → sim environment within matlab.
- MATLAB toolboxes
  - Neural Network Toolbox
  - Fuzzy Logic Toolbox

Timetable/schedule

- On Blackboard
  Module Timetable

Practicals

- This module aims to give practical “hands-on” experience of a range of methods

Practicals

- This module aims to give practical "hands-on" experience of a range of methods
- We are seeking to show how AI methods can be applied to real-world problems

Practicals

- This module aims to give practical "hands-on" experience of a range of methods
- We are seeking to show how AI methods can be applied to real-world problems
- `and compared with more conventional methods`

Practicals

- This module aims to give practical "hands-on" experience of a range of methods
- We are seeking to show how AI methods can be applied to real-world problems
- `and compared with more conventional methods`
- Lectures, where used, are primarily aimed at providing sufficient theory and background knowledge to support the practical work

Soft computing

- "a collection of methodologies, which aim to exploit tolerance for imprecision, uncertainty and partial truth to achieve tractability, robustness and low solution cost"

Applied Soft Computing Journal

Elements of Soft Computing

- Fuzzy logic

Elements of Soft Computing

- Fuzzy logic
- Neural Networks

Elements of Soft Computing

- Fuzzy logic
- Neural Networks
- Evolutionary Computation

Elements of Soft Computing

- Fuzzy logic
- Neural Networks
- Evolutionary Computation
- algorithms based on swarm intelligence

Elements of Soft Computing

- Fuzzy logic
- Neural Networks
- Evolutionary Computation
- algorithms based on swarm intelligence
- other probabilistic methods of optimisation

Elements of Soft Computing

- Fuzzy logic
- Neural Networks
- Evolutionary Computation
- algorithms based on swarm intelligence
- other probabilistic methods of optimisation
- our focus is on the application of these methods to Engineering problems and to Robotics in particular

Adaptive control

- "control method used by a controller which must adapt to a controlled system with parameters which vary, or are initially uncertain"

Wikipedia

Intelligent Control

- focuses on learning and AI in the context of control systems. It is a more 'Engineering' oriented sub-area.

Intelligent Control

- focuses on learning and AI in the context of control systems. It is a more 'Engineering' oriented sub-area.
- Intelligent Control can be divided into the following major sub-domains:

Intelligent Control

- focuses on learning and AI in the context of control systems. It is a more 'Engineering' oriented sub-area.

- Intelligent Control can be divided into the following major sub-domains:
  - Neural network control

Intelligent Control

- focuses on learning and AI in the context of control systems. It is a more 'Engineering' oriented sub-area.

- Intelligent Control can be divided into the following major sub-domains:
  - Neural network control
  - Fuzzy (logic) control

Intelligent Control

- focuses on learning and AI in the context of control systems. It is a more 'Engineering' oriented sub-area.

- Intelligent Control can be divided into the following major sub-domains:
  - Neural network control
  - Fuzzy (logic) control
  - Neuro-fuzzy control

Intelligent Control

- focuses on learning and AI in the context of control systems. It is a more 'Engineering' oriented sub-area.

- Intelligent Control can be divided into the following major sub-domains:
  - Neural network control
  - Fuzzy (logic) control
  - Neuro-fuzzy control
  - Genetic control

Intelligent Control

- focuses on learning and AI in the context of control systems. It is a more 'Engineering' oriented sub-area.

- Intelligent Control can be divided into the following major sub-domains:
  - Neural network control
  - Fuzzy (logic) control
  - Neuro-fuzzy control
  - Genetic control
  - Intelligent agents

Intelligent Control

- focuses on learning and AI in the context of control systems. It is a more 'Engineering' oriented sub-area.

- Intelligent Control can be divided into the following major sub-domains:
  - Neural network control
  - Fuzzy (logic) control
  - Neuro-fuzzy control
  - Genetic control
  - Intelligent agents → eg swarms.
  - Bayesian control

IAS in Robotics

Which aspects of robotics require an Intelligent / Adaptive Systems approach?

- General tasks

IAS in Robotics

Which aspects of robotics require an Intelligent / Adaptive Systems approach?

- General tasks
  - Control

IAS in Robotics

Which aspects of robotics require an Intelligent / Adaptive Systems approach?

- General tasks
  - Control
  - Perception

IAS in Robotics

Which aspects of robotics require an Intelligent / Adaptive Systems approach?

- General tasks
  - Control
  - Perception
  - Classification/decision making

IAS in Robotics

Which aspects of robotics require an Intelligent / Adaptive Systems approach?

- General tasks
  - Control
  - Perception
  - Classification/decision making
- More specific tasks

IAS in Robotics

Which aspects of robotics require an Intelligent / Adaptive Systems approach?

- General tasks
  - Control
  - Perception
  - Classification/decision making
- More specific tasks
  - Localisation

IAS in Robotics

Which aspects of robotics require an Intelligent / Adaptive Systems approach?

- General tasks
  - Control
  - Perception
  - Classification/decision making
- More specific tasks
  - Localisation
  - Mapping

IAS in Robotics

Which aspects of robotics require an Intelligent / Adaptive Systems approach?

- General tasks
  - Control
  - Perception
  - Classification/decision making
- More specific tasks
  - Localisation
  - Mapping
  - Planning

IAS in Robotics

Which aspects of robotics require an Intelligent / Adaptive Systems approach?

- General tasks
  - Control
  - Perception
  - Classification/decision making
- More specific tasks
  - Localisation
  - Mapping
  - Planning
- Even more specific

IAS in Robotics

Which aspects of robotics require an Intelligent / Adaptive Systems approach?

- General tasks
  - Control
  - Perception
  - Classification/decision making
- More specific tasks
  - Localisation
  - Mapping
  - Planning
- Even more specific
  - Object recognition

IAS in Robotics

Which aspects of robotics require an Intelligent / Adaptive Systems approach?

- General tasks
  - Control
  - Perception
  - Classification/decision making
- More specific tasks
  - Localisation
  - Mapping
  - Planning
- Even more specific
  - Object recognition
  - Facial recognition

IAS in Robotics

Which aspects of robotics require an Intelligent / Adaptive Systems approach?

- General tasks
  - Control
  - Perception
  - Classification/decision making
- More specific tasks
  - Localisation
  - Mapping
  - Planning
- Even more specific
  - Object recognition
  - Facial recognition
  - Voice recognition

IAS in Robotics

Which aspects of robotics require an Intelligent / Adaptive Systems approach?

- General tasks
  - Control
  - Perception
  - Classification/decision making
- More specific tasks
  - Localisation
  - Mapping
  - Planning
- Even more specific
  - Object recognition
  - Facial recognition
  - Voice recognition
  - etc

Robot Control

Let's consider a typical control system:

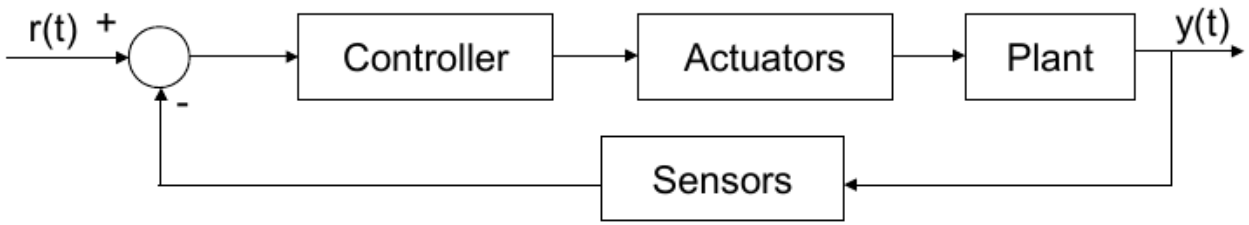

Figure 1: Typical Control System

- There is a great deal of control theory which enables us to design a controller for such systems

Robot Control

Let's consider a typical control system:

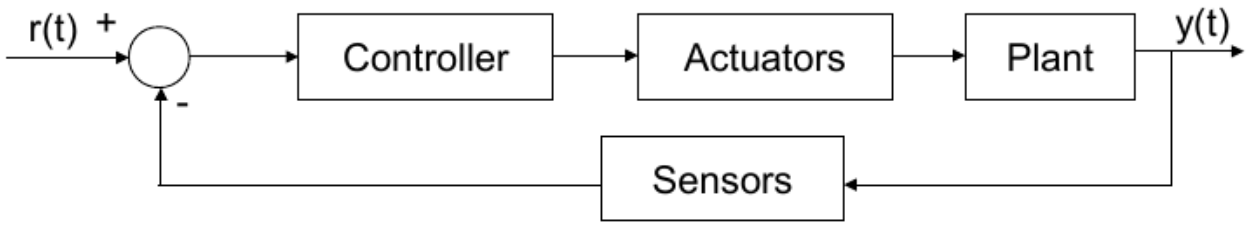

Figure 1: Typical Control System

- There is a great deal of control theory which enables us to design a controller for such systems
- `in theory!`

What about the real world?

Some aspects of real-world control problems which are problematic for conventional control theory:-

- Non-linearity

What about the real world?

Some aspects of real-world control problems which are problematic for conventional control theory:-

- Non-linearity
- Observability

What about the real world?

Some aspects of real-world control problems which are problematic for conventional control theory:-

- Non-linearity
- Observability
- Controllability

What about the real world?

Some aspects of real-world control problems which are problematic for conventional control theory:-

- Non-linearity
- Observability
- Controllability
- Stability

What about the real world?

Some aspects of real-world control problems which are problematic for conventional control theory:-

- Non-linearity
- Observability
- Controllability
- Stability
- Robustness

Non-linearity

- Conventional control theory is only really applicable in linear or nearly linear systems.

Non-linearity

- Conventional control theory is only really applicable in linear or nearly linear systems.
- However, most real robots are very non-linear.

Non-linearity

Nonlinear behaviors are sometimes divided into two classes:

- **Soft nonlinearities** are those which may be linearly approximated, such as x^2 or special types of hysteresis.

Non-linearity

Nonlinear behaviors are sometimes divided into two classes:

- **Soft nonlinearities** are those which may be linearly approximated, such as x^2 or special types of hysteresis.
  - Typically this means that as long as we do not stray too far from our operating point, we may use linear control methods since we can linearize the system.

Non-linearity

Nonlinear behaviors are sometimes divided into two classes:

- **Soft nonlinearities** are those which may be linearly approximated, such as x^2 or special types of hysteresis.
  - Typically this means that as long as we do not stray too far from our operating point, we may use linear control methods since we can linearize the system.
- **Hard nonlinearities** are those which may not be linearly approximated, such as: Coulomb friction, saturation, deadzones, backlash, and most forms of hysteresis.

Non-linearity

Nonlinear behaviors are sometimes divided into two classes:

- **Soft nonlinearities** are those which may be linearly approximated, such as x^2 or special types of hysteresis.
  - Typically this means that as long as we do not stray too far from our operating point, we may use linear control methods since we can linearize the system.
- **Hard nonlinearities** are those which may not be linearly approximated, such as: Coulomb friction, saturation, deadzones, backlash, and most forms of hysteresis.
  - Hard nonlinearities may easily lead to instability and/or limit cycles

Non-linearity

Nonlinear behaviors are sometimes divided into two classes:

- **Soft nonlinearities** are those which may be linearly approximated, such as x^2 or special types of hysteresis.
  - Typically this means that as long as we do not stray too far from our operating point, we may use linear control methods since we can linearize the system.
- **Hard nonlinearities** are those which may not be linearly approximated, such as: Coulomb friction, saturation, deadzones, backlash, and most forms of hysteresis.
  - Hard nonlinearities may easily lead to instability and/or limit cycles
  - unfortunately they appear in many real systems.

↑ eg motor limits.

never reaches target position.

Non-linearity

Some of the common types of non-linearity:

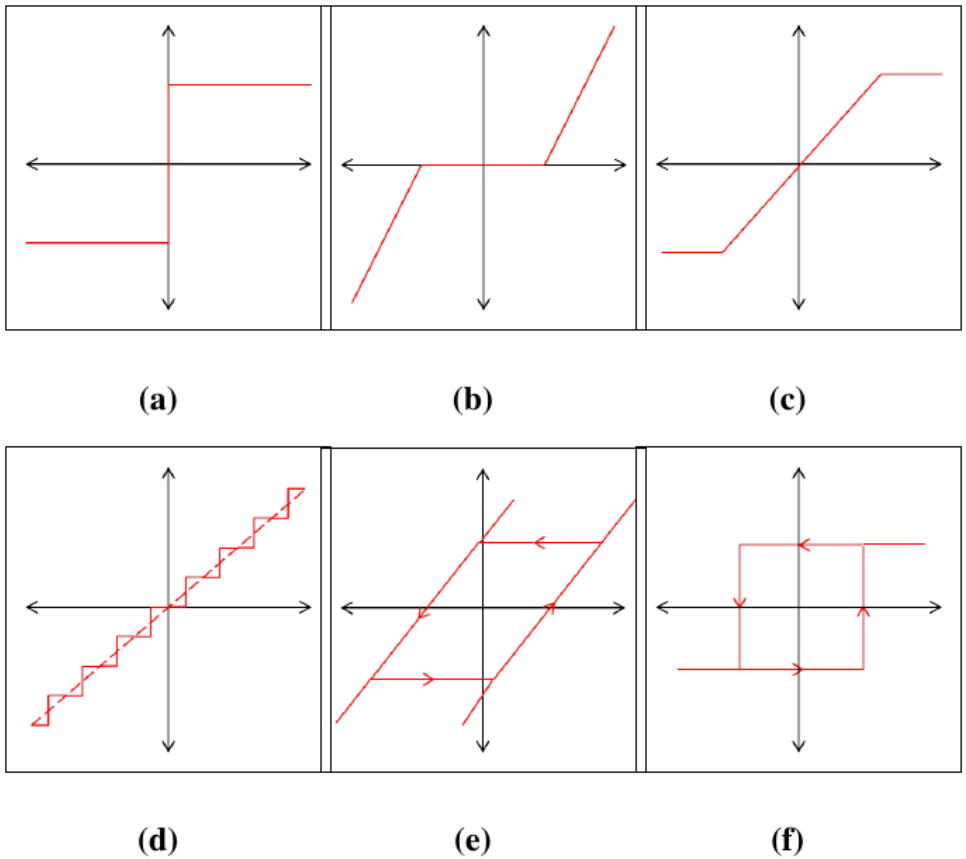

Figure 2: (a)Relay (b)Deadzone (c)Saturation (d)Quantization (e)Backlash (f)Hysteresis-relay

↑ eg analog-digital converters.

Machine Learning

- Machine learning "is the science of getting computers to act without being explicitly programmed"

Machine Learning

- Machine learning "is the science of getting computers to act without being explicitly programmed"
- In the past decade, machine learning has given us self-driving cars, practical speech recognition, facial recognition, effective web search, and a vastly improved understanding of the human genome

Machine Learning

- Machine learning "is the science of getting computers to act without being explicitly programmed"
- In the past decade, machine learning has given us self-driving cars, practical speech recognition, facial recognition, effective web search, and a vastly improved understanding of the human genome
- Pattern recognition and classification are fundamental problems faced in many robotics applications

What is Intelligence?

- A useful definition of intelligence... should include both biological and machine embodiments, and these should span an intellectual range from that of an insect to that of an Einstein, from that of a thermostat to that of the most sophisticated computer system that could ever be built. (Albus,1990)

What is Intelligence?

- A useful definition of intelligence... should include both biological and machine embodiments, and these should span an intellectual range from that of an insect to that of an Einstein, from that of a thermostat to that of the most sophisticated computer system that could ever be built. (Albus,1990)

- "Understanding intelligence as the interplay between emergence, search and representation across multiple time scales: evolution, development and learning" (Keith L Downing, Intelligence Emerging: Adaptivity and Search in Evolving Neural Systems)

Predictions about AI

- *"machines will be capable, within twenty years, of doing any work a man can do"* (Herbert A. Simon, 1965)

Predictions about AI

- *"machines will be capable, within twenty years, of doing any work a man can do"* (Herbert A. Simon, 1965)

- *"By the mid-2040s, however, . . . , the intelligence created per year . . . will be about one billion times more powerful than all human intelligence today. That will indeed represent a profound change, and it is for that reason that I set the date for the Singularity—representing a profound and disruptive transformation in human capability—as 2045."* (Ray Kurzweil, The Singularity is Near, 2005)

Smarter than humans?

- *"MIRI's mission is to ensure that the creation of smarter-than-human intelligence has a positive impact. We aim to make advanced intelligent systems behave as we intend even in the absence of immediate human supervision"*

Machine Intelligence Research Institute

Zadeh's perspective on AI

- Officially, AI was born in 1956 – there was widespread expectation that within a few years it would be possible to build machines that could think like humans.

`Lotfi Zadeh, Towards Human Level Intelligence,`

Zadeh's perspective on AI

- Officially, AI was born in 1956 – there was widespread expectation that within a few years it would be possible to build machines that could think like humans.

- The AI pioneers were firm believers in the ability of classical symbolic logic to lead to human-level machine intelligence.

`Lotfi Zadeh, Towards Human Level Intelligence,`

Zadeh's perspective on AI

- Officially, AI was born in 1956 – there was widespread expectation that within a few years it would be possible to build machines that could think like humans.
- The AI pioneers were firm believers in the ability of classical symbolic logic to lead to human-level machine intelligence.
- It took close to thirty years for probability theory to gain grudging acceptance.

`Lotfi Zadeh, Towards Human Level Intelligence,`

Zadeh's perspective on AI

- Officially, AI was born in 1956 – there was widespread expectation that within a few years it would be possible to build machines that could think like humans.
- The AI pioneers were firm believers in the ability of classical symbolic logic to lead to human-level machine intelligence.
- It took close to thirty years for probability theory to gain grudging acceptance.
- Today, so-called "New AI" is probability-based. Indeed, Bayesianism has become as fashionable as symbolic logic was in its time.

`Lotfi Zadeh, Towards Human Level Intelligence,`

Zadeh's perspective on AI

- Officially, AI was born in 1956 – there was widespread expectation that within a few years it would be possible to build machines that could think like humans.
- The AI pioneers were firm believers in the ability of classical symbolic logic to lead to human-level machine intelligence.
- It took close to thirty years for probability theory to gain grudging acceptance.
- Today, so-called "New AI" is probability-based. Indeed, Bayesianism has become as fashionable as symbolic logic was in its time.
- Clearly, adding probability theory to the armamentarium of AI is a step in the right direction. But is it sufficient? In my view, the answer is: No.

`Lotfi Zadeh, Towards Human Level Intelligence,`

Some further reading

Control

Bullinaria, J.A. & Li, X. (2007). An Introduction to Computational Intelligence Techniques for Robot Control. Industrial Robot, 34, 295-302. http://www.cs.bham.ac.uk/~jxb/PUBS/IR.pdf

Fuzzy Logic

L. A. Zadeh, *"Toward Human Level Machine Intelligence - Is It Achievable? The Need for a Paradigm Shift"* in IEEE Computational Intelligence Magazine, vol. 3, no. 3, pp. 11-22, August 2008. http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4567185&isnumber=4567176

Any questions?