Exploring Cyber-Physical System Designs With Genetic Algorithms

Can Genetic Algorithms Make Finding The Best Designs of Cyber-Physical Systems More Efficient?

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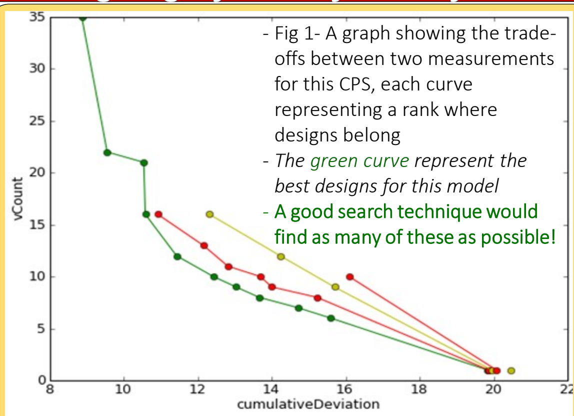
Project Aims and Objectives

- Implement genetic methods in Python
- Analyse if genetic methods, basic and more advanced variations, perform more efficiently in finding the best designs of cyber-physical systems

What are Cyber-Physical Systems?

- Cyber-Physical Systems (CPSs) combine computing processes with physical processes, human and other elements to deliver a global behaviour
- They exist all around us- from heart pacemakers to electrical power grids!

Designing Cyber-Physical Systems

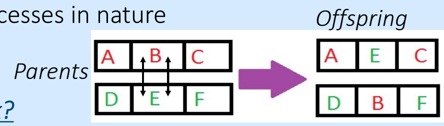


- Fig 1- A graph showing the trade-offs between two measurements for this CPS, each curve representing a rank where designs belong
- *The green curve represent the best designs for this model*
- A good search technique would find as many of these as possible!

- After testing, designs belong in a rank containing equally good designs-like each one of the curves in fig 1 above
- Engineers might need to explore vast numbers of alternative designs to optimise trade-offs in a process called Design Space Exploration (DSE)
- Genetic methods, or algorithms, could make this process more time- and effort – efficient!

What are genetic algorithms?

A process for optimising and searching for solutions inspired by evolutionary processes in nature



- ***How do they work?***

1. Initial set of designs are tested and ranked
2. Two parent designs are chosen from the previous generation's best designs
3. Offspring designs are generated and tested when a parent's chosen parameter is swapped with the other parent's corresponding parameter-like the diagram above!
4. After testing, all designs that have been tested are ranked again
5. Process is repeated until no improved designs are found consistently

Why is this important?

- Sustainability: Designs found could reduce carbon emissions and raw material use to develop more environmentally-friendly cyber-physical systems
- Industry: Engineers could spend less time and effort creating new designs
- Economy: The best designs could save on financial costs such as energy and raw materials

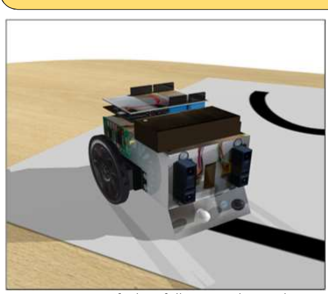


Fig 2- Picture of a line following robot with 4 design parameters and 625 alternative designs. Each of the design parameters control where sensors are positioned.

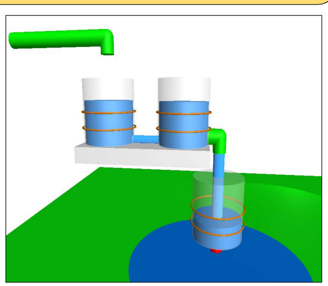


Fig 3- Water tank with 2 design parameters and 25 alternative designs. Each design parameter controls where sensor is located.

Methods

- Two case studies were used: A line following robot and a water tank- as shown in fig 2 and fig 3 respectively
- All design alternatives were explored and then ranked first
- Both case studies were run several times using the genetic algorithms and results were averaged to plot graph below

Results and Conclusions

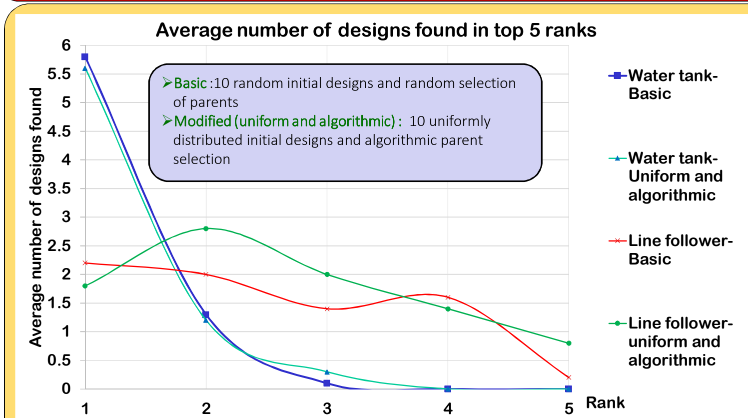


Fig 4. Graph showing the average number of the designs for the top five ranks in each of the case studies used

Case study	Design space explored	Portion of best designs found
Line follower	4%	10%
Water tank	60%	50%

Conclusions

- Genetic algorithms can usually find better designs more quickly when design spaces are large, whereas they perform less efficiently in small design spaces
- Genetic algorithms work better with fewer parameters than they do with models with more parameters
- Modifications to genetic algorithms made little difference to finding best designs, but found more of a range of relatively good designs in other high ranks

Acknowledgements

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Newcastle University

References
1. Jeffrey Johnson and Philip Picton, 1995, *Concepts in Artificial Intelligence*, Volume 2, Milton Keynes, Butterworth Heinemen
2. John Fitzgerald, Peter Gorm Larsen and Marcel Verhoef, 2014, *Collaborative Design for Embedded Systems: Co-modelling and co-simulation*, Springer Berlin Heidelberg