STREAM – WATER EngD PROGRAMME

Artificial Intelligence Techniques for Flood Risk Management in Urban Environments

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Background

In recent years, flooding events in England and Wales, as well as the rest of the world, have resulted in flooding receiving greater than previous levels of public interest. In the winter of 2012, an estimated £1billion of damage was caused by flooding, and in the more widespread flooding in 2007, an estimated £3billion of damage was caused[1]. This means that improvements to flood risk assessments and a better understanding of the consequences of drainage system failure for systems being analysed and how those consequences can be mitigated, are vital for designing more robust drainage systems for the future.

Figure 1 – Examples of flooding related events in England & Wales

Risk-Based Analysis

HR Wallingford previously developed the "SAMRisk" toolset [2], which analyses a given drainage system in terms of expected annual damage (EAD) which is a cost measure of pounds sterling per average year in flood related damage costs. This allows a drainage system to be analysed in terms of the consequences of failure.

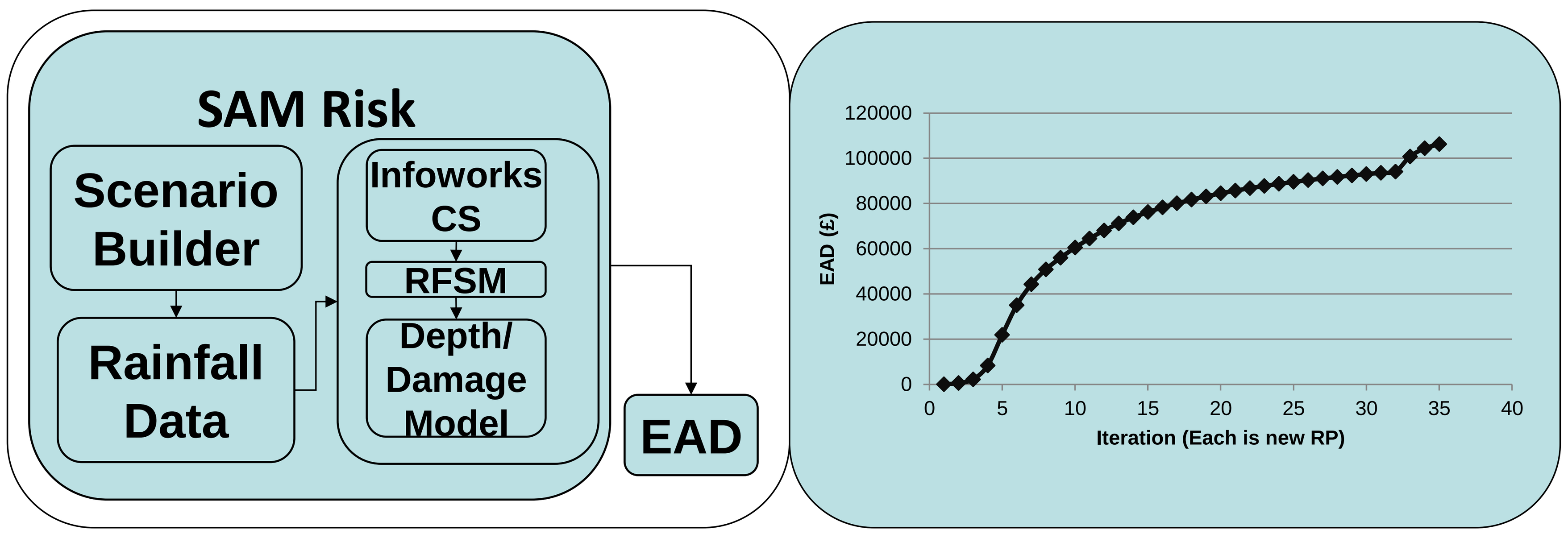


Figure 2 – Structure of SAM Risk toolset & progressive EAD determination for design rainfall

ADAPT

To build upon the success of the SAM Risk toolset, we've developed an application named "ADAPT – A Drainage Analysis & Planning Tool". This is a decision support system, which integrates the functionality of the SAM Risk toolset, with NSGA-2[3] and LEMMO[4] optimisation algorithms and newly developed cost and level of service models.

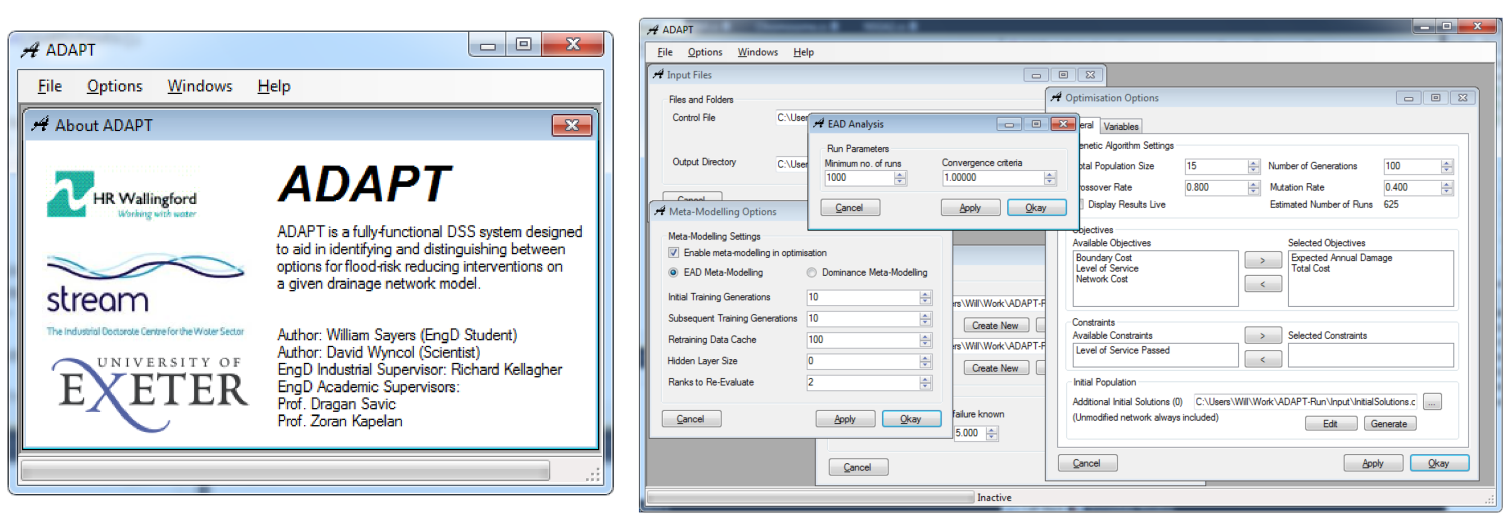
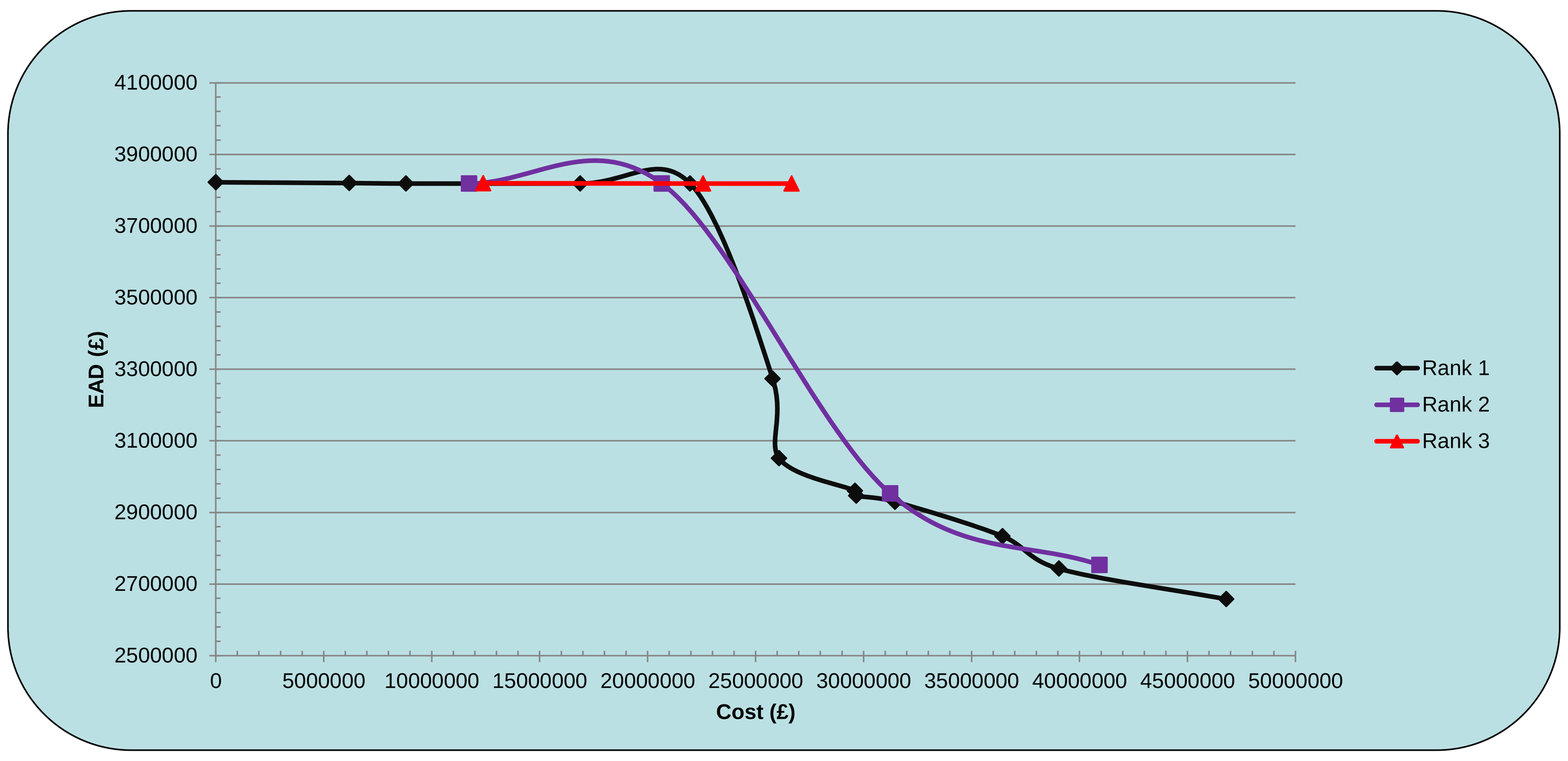


Figure 3 – Examples of ADAPT software in operation

Optimisation Speed

Multi-objective optimisations within ADAPT can use level of service, several measures of cost, or EAD as objectives to minimise or maximise. These objective functions have significant run-times (particularly EAD) which make the prospect of performing a large-scale optimisation with many variables prohibitively time consuming. Optimisation of objective run-times are therefore crucial to the project, a problem we have approached with the application of neural network meta-models, to provide approximate objective evaluations in a fraction of the time required for a full evaluation, as well as the testing of alternative optimisation algorithms.



What we have accomplished?

The ADAPT decision support system allows engineers in the water sector to analyse a drainage network in terms of the consequences of system failure – it further allows an optimisation to be performed on this data within a reasonable period of time, resulting in a Pareto-optimal range of possible flood risk interventions which serve to both inform the engineer on the ground, and to form the basis of possible solutions. We are currently conducting tests to identify pros and cons of different optimisation systems, as well as the most relevant return periods and storm durations to concentrate analysis on.

Summary

We have developed software that allows for performing an optimisation on consequence-based risk estimations (EAD) and cost estimations. We are currently at the stage of testing the developed software, to identify the benefits and drawbacks of different multi-objective optimisation algorithms for use within the software.

Further Reading

[1] Parliamentary Office of Science and Technology, "Urban Flooding," postnote, vol. 289, 2007.

[2] HR Wallingford, "SAM - System-based analysis and management of urban flood risks," Oxford SR700, 2009.

[3] K. Deb, A. Pratap, S. Agarwal, and T. Meyarivan, "A Fast and Elitist Multiobjective Genetic Algorithm: NSGA-II," IEEE Transactions on Evolutionary Computation, vol. 6, pp. 182-197, 2002.

[4] L. Jourdan, D. Corne, D. Savic, and G. Walters, "Preliminary Investigation of the `Learnable Evolution Model' for Faster/Better Multiobjective Water Systems Design," Evolutionary Multi-Criterion Optimization, pp. 841-855, 2005.