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AIRLINE DISRUPTION RECOVERY USING SYMBIOTIC SIMULATION AND MULTI-FIDELITY MODELLING

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ABSTRACT

The airlines industry is prone to disruption due to various causes. Whilst an airline may not be able to control the causes of disruption, it can reduce the impact of a disruptive event, such as a mechanical failure, with its response by revising the schedule. Potential actions include swapping aircraft, delaying flights and cancellations. This poster will present our research into how symbiotic simulation could potentially be used to improve the response to a disruptive event by evaluating potential revised schedules. Due to the large solution space, exhaustive searches are infeasible. Our research is investigating the use of multi-fidelity models to help guide the search of the optimisation algorithm, leading to good solutions being generated within the time constraints of disruption management. The poster will present the latest results of our research.

1 AIRLINE DISRUPTION MANAGEMENT

One of the major problems faced by airlines is disruption to their schedules. Although a great deal of time and money is spent on preparing an optimal schedule, it is very rare that a flight programme will be carried out as intended within the operation. This can be caused by a variety of issues such as weather conditions and aircraft failures. The impacts of a disruptive event can propagate through the system causing many more delays and cancellations, particularly if the airline has a high aircraft utilisation. The response of an airline seeking to manage the burden of a disruptive event can have a large effect on the outcome. Each action corresponds to revising the schedule in some way, whether it be delaying or cancelling flights or exchanging aircraft. The rescheduling of flights and reallocation of aircraft is called the Aircraft Recovery Problem (ARP).

Most of the literature on the solving ARP considers the use of mathematical programmes solved either exactly or using heuristics, such as the integer programming approach of Rosenberger, Johnson and Nemhauser (2003). This approach is capable of dealing with some of the complexity of the ARP, but treats it as a deterministic problem. However, the airlines industry is also highly stochastic. The consequences of a disruption are stochastic, as are further disruptions that could occur during the recovery period. The ability of standard deterministic programmes to incorporate this stochasticity is limited, particularly as the number of sources of variation is large.

2 SYMBIOTIC SIMULATION

Symbiotic simulation was first proposed in Fujimoto et al. (2002) as a means of allowing a simulation system to interact with the physical system it models in a mutually beneficial way. The exchange of information between the two systems has the potential to improve both the performance of the physical system and the representation of the simulation model by adapting it to new circumstances. At the time of triggering, multiple strategies can be tested using the simulation model and the output used to find a good solution. Part of its attraction is its ability to be reused in new situations through different initial conditions without requiring major programming alterations.

The use of symbiotic simulation in the ARP allows the simulation to match the system using the latest information. Furthermore, the various stochastic elements of the airline industry can be incorporated into the model without making the problem intractable. Once the analysis of solutions has been completed, the airline can then use the findings to inform their decision going forward. This completes the information exchange.

Our model is built within AnyLogic 7.3.6 (AnyLogic 2016) and consists of an airline operating between a set of airports with variation arising from flight durations, turn-around times, unscheduled maintenance and queueing for use of runways due to other aircraft.

However, high-fidelity simulation models have non-negligible computation time, which proves problematic for search and optimisation algorithms when there is such a large solution space and tight time constraints required for the ARP. The use of the simulation must be selective in order to find good solutions within a reasonable time.

3 MULTI-FIDELITY MODELLING

The work presented in the poster has been investigating the combination a low-fidelity mathematical model with a high-fidelity simulation to aid airlines in their response to a disruption. The low-fidelity model consists of an integer programme. This deterministic model is likely to have significant and unknown bias in its evaluations of a solution (Xu et al. 2014). However, it may hold important information regarding the relative performance of a solution. Therefore, we are experimenting with ways of using the ranking information from a low-fidelity model to guide the search of a simulation optimisation process to support airline operations controllers, producing a set of good solutions for consideration.

Firstly, we consider using a multi-objective ε-Constraint method to generate a set of solutions from the low-fidelity model, using additional objectives such as total delay and number of tail-number allocation swaps. This is compared with the method of finding the *M* best solutions within a limited time. The solutions from the low-fidelity model are then compared using an indifference-zone Ranking & Selection procedure. An alternative to this is to perform a local search around the solutions proposed, seeking further improvements.

Initial results from the study suggest that the performance estimates by the low and high fidelity models have significant correlation. This implies that the multi-fidelity approach is an appropriate method of selectively using the simulation. The poster will contain the latest results from these investigations.

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