# A Coevolution Genetic Algorithm for Conflict Resolution of Multi-user Satellite Observation Activities

Baorong Zhai, Hao Chen, Jun Li, Ning Jing
National University of Defense Technology
Deya Street, Kaifu District
Changsha, China
zhaibaorong@nudt.edu.cn, hchen@nudt.edu.cn, junli@nudt.edu.cn, ningjing@nudt.edu.cn

## ABSTRACT
With the development of Operationally Responsive Space (ORS), users can directly submit their satellite observation activities to support the emergency events. But it will cause conflicts among these requirements. This paper constructs a graph model for each satellite which maps the satellite observation activities into vertexes. Based the model, the conflict resolution of multi-user satellite observation activities is reduced to a multi-path scheduling problem in graph. The paths are not independent, but have to cooperate with each other to support the users' requirements better. A coevolution genetic algorithm is proposed to solve this problem and a heuristic rule based on Matthew Effect is described in detail to explain how the cooperation information works. A set of experiments is designed to evaluate the effectiveness of the proposed method and the results show that when the conflict is severe, the satisfactory degree of users with high priority can still get better results compared with others.

## Keywords
ORS; satellite observation activities; conflict resolution; graph model; coevolution; heuristic rule

## 1. INTRODUCTION
Users always want to receive satellite data in near real-time to support their urgent missions. But the traditional requirements-tasking-effects cycle of satellite application cannot make timely feedback to users. Firstly, the satellite controlling and scheduling centers (SCSCs) are usually centralized and far away from the frontline. Secondly, the SCSCs are general scheduling platforms which serve different kinds of users, so some particular needs which may be the critical requirements of users, are impossible to be satisfied. The traditional application mode is not only lack of urgent timeliness, but reduction in users' participation. The Operationally Responsive Space (ORS) is just presented based on this background[1]. It can send the satellite observation data to users directly to shorten the data transmission duration. Virtual Missions Operational Center (VMOC) is an open architecture interfaces designed for satellite controlling and scheduling based on ORS. It can connect the users to satellites directly to submit their satellite observation activities and acquire the observation data. This application model can greatly enhance the effectiveness and timeliness of urgent event information, but bring another problem. Users submit their satellite observation activities simultaneously or sequentially on their own behalf and want their observation activities to be accomplished. Satellites have many constraints due to the observation capabilities. It may cause conflicts among these observation activities owning to different users. Because of different priorities of users, correlations of requirements, capabilities and constraints of satellites, it has driven the conflicts more complicated. How to balance these factors and resolve the conflicts of multi-user satellite observation activities has become an urgent problem.


*GECCO'16 Companion*, July 20-24, 2016, Denver, CO, USA
ACM 978-1-4503-4323-7/16/07.
DOI: http://dx.doi.org/10.1145/2908961.2908980

In decision and game theory, graph form of conflict model was first developed by Kilgour [1],[2]. It is actually a state transition graph and each node represents a unique state of all players' choice. If there are $L$ players, $M$ options for each player, $N$ states for each option, then there are no more than $N^{L\times M}$ states. When the conflict problem is large-scale, it is impossible to construct the state transition graph.

## 2. GRAPH MODEL FOR SATELLITE OBSERVATION ACTIVITY
Operational commanders know the exact information they want. They can submit their specific requirements to the VMOC: for user *U*, he wants the satellite *S* to observe the target *T* with antenna sector scan mode *om* from start time *ts* and end time *te*. This kind of specific requirement is called a satellite observation activity. Due to satellite capabilities and constraints, when users submit lots of satellite observation activities to VMOC, it will cause conflict in all probability. Because of different priorities of users, correlations of requirements, capabilities and constraints of satellites, it has driven the conflicts more complicated. Then the conflict resolution of multi-user satellite observation activities (CRMSOA) is to decide which activities will be satisfied to balance these factors.

For each satellite, it has to decide the observation activities set, that is to select some of the observation activities according to some principle. These activities constitute a satellite observation series, from a start observation activity to an end observation activity. If the observation activities are mapped into nodes, the process of selection is just like the path scheduling problem in a graph. For each satellite *S*, a constraint graph model (CGM) is defined as ***G=<V, E, C>*** to represent the observation activities of satellite *S*, where ***V*** is the set of satellite observation activities, ***E*** is the set of edges between observation activities and ***C*** is the set of observation constraints according to the capabilities of satellites. The connectivity that two activities can be observed by the same satellite simultaneously or sequentially is mapped into a directed edge.

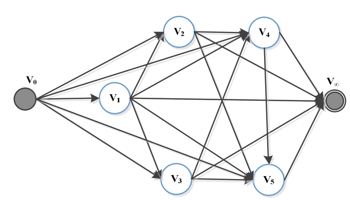


**Figure 1. An example of a satellite observation activities graph**

## 3. COEVOLUTION GENETIC ALGORITHM FOR CRMDOA

The classic path scheduling algorithm in graph theory, such as Dijkstra algorithm, can hardly solve the graph model of multi-user satellite observation activities. Firstly, the attributes of each edge is not consistent, but related to the preorder observation activities set. Second, the paths are dependent, so the optimal of each graph cannot ensure the optimal of entirety. In the proposed model, observation activities of each satellite are modeled as a constraint graph. In each graph, it can get its path through evolution individually, but the paths are dependent, they have to cooperate with each other to get the optimal.

Coevolution is primarily a biological concept, "the change of a biological object triggered by the change of a related object" [3]. Coevolution is the combination of evolutionary computation and cooperation. Evolutionary computation uses iterative progress in a population, and the cooperated information is spread among the population to guide the evolution process to get a better solution as while as fasten the convergence [4]. In the field of artificial intelligence, genetic algorithm has been widely used in solving NP-hard problems [5]. Naturally, a coevolution genetic algorithm is brought up to solve this problem.

A good solution $\boldsymbol{S}$ should include as many observation activities with higher reward as possible, as well as the users with higher priority should be supported in general. For example, two solutions $\boldsymbol{S_1}$, $\boldsymbol{S_2}$, the satisfactory degrees of user $\boldsymbol{U_1}$ are 70% and 90%, while the satisfactory degrees of user $\boldsymbol{U_2}$ are 50% and 20%. Supposing the priority of $\boldsymbol{U_1}$ is no less than that of $\boldsymbol{U_2}$, it is believed that solution $\boldsymbol{S_2}$ is better than solution $\boldsymbol{S_1}$. That means if the satisfactory degree of user $\boldsymbol{U_j}$ with higher priority has reached to upper threshold $\varphi_1$, the unarranged satellite observation activities of user $\boldsymbol{U_j}$ should be reconsidered; otherwise, if the satisfactory degree of user $\boldsymbol{U_j}$ with lower priority has decreased to lower threshold $\varphi_2$, the satellite observation resources which have been assigned to user $\boldsymbol{U_j}$ should be released to higher priority user. This heuristic rule is just the Matthew Effect, "for unto every one that hath shall be given, and he shall have abundance; but from him that hath not shall be taken even that which he hath".

## 4. SIMULATION

The algorithm simulates at most 12 satellites and 14 users. Users are separated into three groups according to the priority, high priority users (User1, User5, and User8), low priority users (User4, User 7) and normal priority users (the rest of users). For each user, the observation activities are generated randomly, with number 10-30. The simulation process is designed like this: different user amount (with a fixed satellite amount) and different satellite amount (with a fixed user amount) are compared separately to evaluate the proposed algorithm. Each simulation is carried out 20 times independently and the value is normalized.

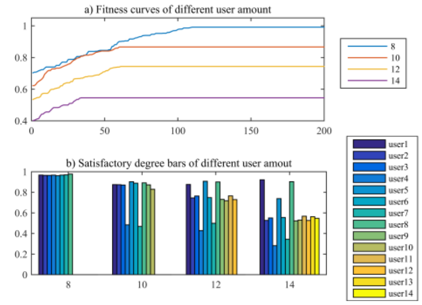


**Figure 2. The results of different user amount**

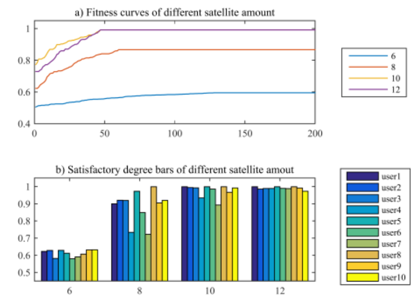


**Figure 3. The results of different satellite amount**

In Figure 2, with the increasing user amount, the fitness values decrease gradually. The number of satellite observation activities proliferates with the number of users, and then more and more satellite observation activities will be abandoned. Meanwhile, it becomes more difficult to find the global optimal through the evolution process as the conflicts intensify, so it will converge faster. With the increasing user amount, the satisfactory degree of users with high priority declines a little compared with others, but the satisfactory degree of users with low priority declines fiercely.

In Figure 3, the fitness values grow and the convergence speed fasten as the satellite amount increases. Users have more opportunities to arrange their observation activities to the new added satellites. The satisfactory degree of users with high priority is raised distinctly compared with others, while the satisfactory degree of users with low priority is raised gradually.

## 5. REFERENCES

[1] Kilgour DM, Hipel KW, Fang L. The Graph Model for Conflicts. Automatica 1987; 23(1):41-55.

[2] Fang L, Hipel KW, Kilgour DM. Conflict models in graph form: Solution concepts and their interrelationships. European Journal of Operational Research 1989; 41(1):86-100.

[3] Yip KY, Patel P, M.Kim P, M.Engelman D, McDermott D, Gerstein M. An integrated system for studying residue coevolution in proteins Bioinformatics 2008; 24(2):290-2.

[4] A.E.Eiben, M.Schoenauer. Evolutionary computing. Information Processing Letters 2002; 82(1):1-6.

[5] Schmitt, Lothar M. Theory of Genetic Algorithms. Theoretical Computer Science 2001; 259:1-61.