STUDY ON DECISION CONFLICT OF UAV SYSTEM

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Abstract

Decision conflict refers to the disagreement occurred in decision making. There was no decision conflict in UAV system in the past when the UAVs were controlled remotely by operators. But since autonomy is an important trend in development of UAVs, there will certainly be problems of decision conflict when the autonomous capability of UAV system has been improved gradually. We consider in this paper a UAV (including the air vehicle and the payload) in the air as a decision system with self-learn capability, and a control station as a decision aid system with learning capability. We propose that decision conflict of UAV system will appear:

1） between UAV operator and control station;

2） between the control station and UAV in the air；

3） among cooperative UAVs.

We make a thorough study on the three above-mentioned decision conflicts of UAV system, and find the cause of them.

1 Introduction

Generally, an UAV system consists of the 5 parts as air vehicle, payload, data link system, control station, launch and recovery system, and other relative auxiliary systems. The air vehicle flies in the sky with airborne payload and the part of data link system. The other part of the data link stays with the control station, which may be in the air and also may be on the ground. The operators in the control station (including operators of the air vehicle and the payload) control UAV through the data link. The launch and recovery system is usually on the ground.

In the past, UAVs were all controlled remotely. The air vehicle is controlled entirely by the operator in the control station through data links without the capability of decision-making itself. The drawbacks for this method are it is liable to be interfered, is not flexible, and thus it can not be adapted to future combat environment. With the development of science and technology, the autonomous capability of UAV system is being improved. In order to be adaptable to the requirements of future combat, the autonomous UAV system in the future should be able to make decisions flexibly and autonomously according to the situation, and to aid the operators for decision-making. Unfortunately, the time when UAV can aid operator for decision-making and can make decision autonomously is also the time when decision conflict appears in UAV system. Are we ready for them?[1]

Decision conflict refers to the disagreement occurred in decision making. We discuss the possibility for UAV decision conflict in this paper. We think that in autonomous UAV system of the future, the part of UAV in the air, including the air vehicle and payload, is a decision-making system with capability of learning, while the control station is an aided decision-making system with learning capability. The decision conflicts of UAV will happen:

1. between UAV operator and control station;
2. between the control station and UAV in the air；
3. among cooperative UAVs.

2 Decision Conflict between UAV Operator and the Control Station

Obviously, UAV system is designed by the domain experts in UAV field, not by the control station operators. At the same time, UAV systems are controlled by the operators and not by the experts. In order to improve the performance, and be adapted to various actual conditions, the control station in the future should have learning capability during operation. Therefore, the controlled object of the operator is an UAV system with knowledge of domain expert and the capability of continuous learning.

During routine training, UAV operator obtains experience, while the control station acquires knowledge through learning. Though trained under the same environment, the mechanics for a human being to acquire experience is different from that for a machine to acquire knowledge. Can UAV operator and the control station obtain the same experience or knowledge? Can the new things learned by the control station be the same as the experience or intuition of the operator? Can the operator understand the new things studied by UAV system? If not, then decision conflict may come forth.

The operator may accumulate experiences and get good intuition during long-term training. But can he understand and master the large quantity of domain knowledge of the experts who designed the UAV systems? Or comparing experience and intuition with domain knowledge in decision-making, which should be more reliable and more important? Once the experience or intuition has conflicts with domain knowledge, decision conflict will appear.

One of the advantages of UAV is that it is only used during war-time, and for ordinary time, it is only used for training. When the predicted scenario during war time is combined with domain knowledge and things learned during routine training, will it has the effect of one plus one larger than two? Will its aided decision wiser than that of the operator?

After all, the application of UAV during war-time is different from the routine training. But the knowledge acquired by the control station during training and the experience of UAV operator obtained in training must be used in the protean war time. When the environment changes greatly, a person can make decision by intuition, but a machine can't. Could their decisions be consistent?

Control station is an aided decision-making system. UAV operator has the final determination right, but he must take the suggestion of control station as a reference. If conflict occurs between UAV operator and the control station, which side is right?

3 Decision Conflict between Ground Control Station and UAV in the Air

In order to protect the UAV, and decrease the opportunity of being found and attacked, the communication between UAV operator and UAV (including the air vehicle and the payload) in the air must be kept as minimum as possible. That is why people want to improve the autonomous capability of UAV system. For UAV vehicle in the air, the mission management system and vehicle management system are some kinds of decision-making systems, which can decide what to do in the next step according to the information from its sensors and the prearranged mission. UAV operator may obtain rough global or perfect information, but is short of detailed local information; on the other hand, UAV may obtain detained local information, but is lacking of rough global information. The UAV operator and UAV can not exchange information because of the limited communication, and UAV can make decision by itself since it is a decision-making system with self-learn capability. On such a condition, if UAV operator sends an instruction to UAV, the question is what to do when UAV' own decision conflicts with the external instruction. As a network node of a geological area, UAV has perfect information of current area, but the instruction sender may know nothing about it. From the point of view of UAV, maybe the instructor is issuing confused orders regardless of the actual situation. On the other side, UAV knows nothing of the global information of the overall network, and the instruct sender is advantageous in that to some extent. From the point of view of the instruct sender, maybe the UAV is selfish departmentalism only seeking for local optimum. What will the result be? Will UAV refuse to accept the command or not?

It seems that to solve the problem, efficient communication, or information interconnection, should be kept between UAV and the overall network, UAV and the operator. But the communication may expose the UAV and the overall network, and thus results in delay for decision-making, lost of abrupt action, the target situation may change or even the target itself may disappear, and then, UAV system may entirely lose its unique advantages.

If all are at the mercy of UAV, will UAV kill the innocent freely, or acts as dog-eat-dog. This is always a nightmare of human being for the application of machines.

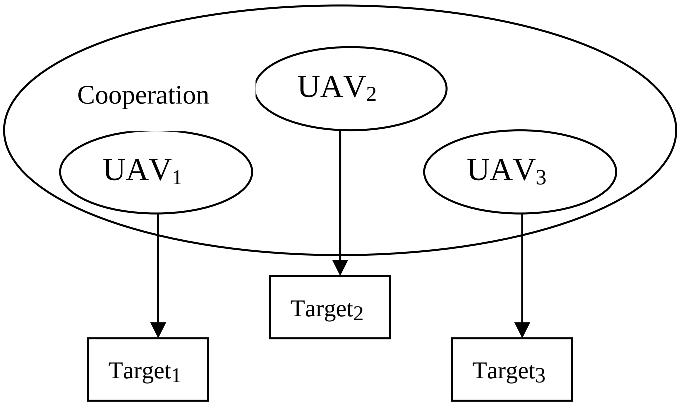
4 Decision Conflicts among Multiple Cooperative UAVs

The conflict that may occur inside a highly autonomous UAV system is presented in the above. Now suppose that this problem has been solved, and we will study UAV on this basis. Multiple UAVs cooperative combat is the main mode for future UAV operation, conflicts may also arise among the multiple UAVs.

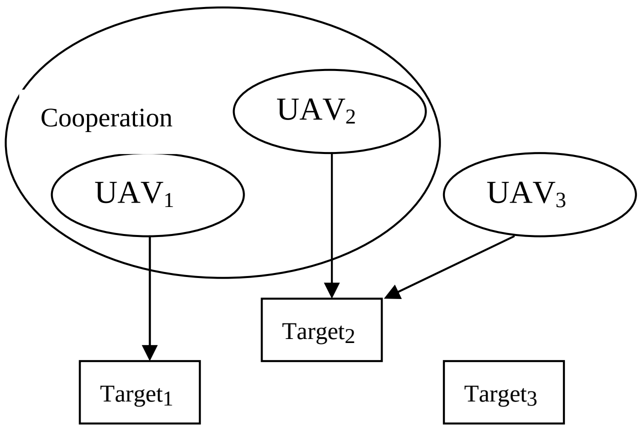
To confirm that the UAVs are operating cooperatively, communication must be kept well. At the same time, the communication must be minimized to prevent them from being detected by the enemy and thus being attacked. Communication is a probabilistic event, which can not ensure that all the members in the formation can be contacted when necessary.

4.1 Decision Conflicts in Team of Multi-UAV

Each member of the team may make different decision because they communicate with different number of the UAVs, thus decision conflict may occur among different member. For example, UAV_1, UAV_2 and UAV_3 form a team for cooperation. UAV_1 make a decision D_a of acting independently because it cannot contact UAV_2 and UAV_3. But, because UAV_2 can communicate with UAV_3, they would make a decision D_b for cooperative action. Then D_a is different from D_b, thus decision conflict occurs. See Fig. 1. The more UAVs in a team, the higher is the probability of decision conflict, and the more decision conflicts. Decision conflict may also occur even with only two UAVs.



1.a Cooperation among Three UAVs



1.b No Cooperation among Three UAVs

Fig.1. Decision Conflicts in Team of Multi-UAV

4.2 Decision Conflict in Team of Two UAVs

While the decision conflict in team of two UAVs is obvious, it is also difficult to solve the problem. Since when the communication is unblocked, paradoxes may exist; and when the communication is blocked, even the real reason of why communication unachieved may not be known by the cooperative sides.

4.2.1 Paradox

Suppose that when the communication of two UAVs is unblocked, UAV1 and UAV2 attack target T cooperatively. If only one UAV attacks, it may be defeated. Therefore, two UAVs must operate together. One UAV will not attack the target unless it receives the information and is sure that the other UAV will attack the target cooperatively with it. Suppose that UAV1 send information to UAV2, hope to attack cooperatively.

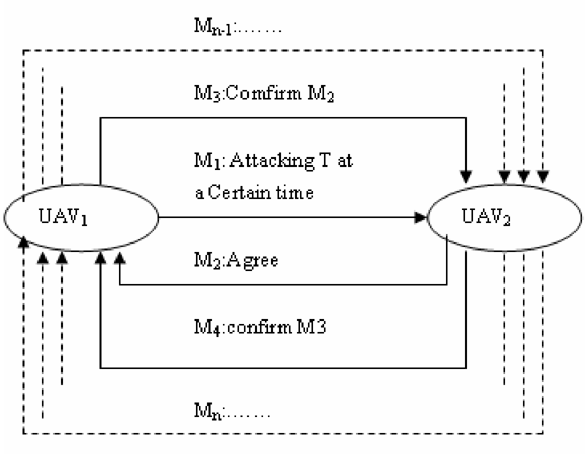


Fig. 2. Communication of Two Attacking Cooperatively UAVs

UAV1 sends a message M_1 to UAV2, "Attacking T at a certain time". Can UAV1 and UAV2 make the attacking successfully? Although the message is sent, UAV1 can't make sure whether it reaches UAV2 or not. Because UAV1 thinks it is possible that UAV2 doesn't receive the message, it will not make the attacking based on the hypothesis that "One UAV may be defeated if it making attacking by itself". Similarly, when UAV2 receives the message, it doesn't know whether UAV1 know it will make the attacking or not, because of the above-mentioned reason, it will not make attacking. In order to make the attacking cooperatively, UAV2 should send a message M_2 back to UAV1, showing "Agree". Thus the first cycle of communication between UAV1 and UAV2 is completed.

When UAV1 receive the information of confirming, can it make the attacking? In fact, UAV1 is now in the similar situation as UAV2 when the later receives M_1. At the same time, UAV2 is not sure whether the message reaches UAV1 or not. Therefore, UAV1 and UAV2 still can not attack the target cooperatively. They may send confirming message continually, but can not make cooperative attacking. The communication procedure is shown in Fig. 2.

4.2.2 Reasons for Failed Cooperation

Even we don't take consideration of paradox above, or suppose that we have solved the problem above by a certain method, some problems still exist in cooperation of two UAVs. Suppose that after receiving the request signal from UAV1, UAV2 sends a signal of confirming the cooperation according to its own situation, the cooperation process is shown in Fig. 3, which consists of 8 steps:

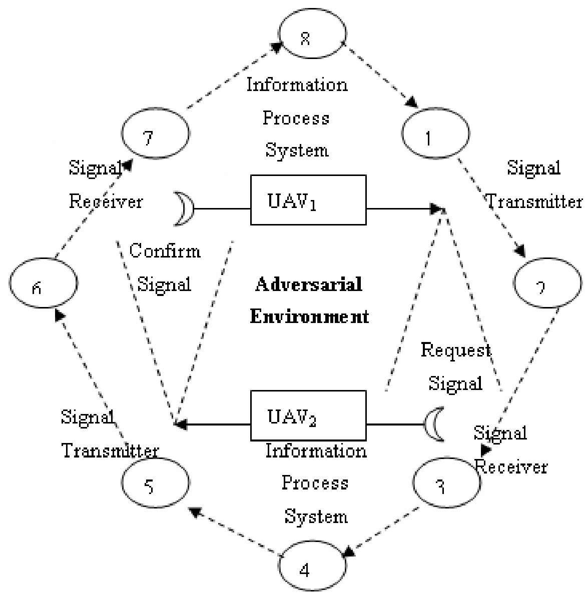


Fig. 3 Cooperative Process of Two UAVs

Step 1: UAV1 sends request signal through transmitter;
Step 2: The signal from UAV1 transmits across the adversarial environment;
Step 3: The signal from UAV1 is received by the receiver of UAV2;
Step 4: Processor of UAV2 processes the signal;

Step 5: Transmitter of UAV2 sends a signal for confirmation;
Step 6: The signal from UAV2 transmits across the adversarial environment;
Step 7: The signal from UAV2 received by the receiver of UAV1;
Step 8: Processor of UAV1 processes the signal.

If any one of the 8 steps fails, the cooperation of two UAVs will be influenced. The failures that may arise are listed in the following:

Case1: Transmitter of UAV1 fails;
Case2: The signal from UAV1 is jamed during transmitting ;
Case3: Receiver of UAV2 fails;
Case4: Information process system of UAV2 fails;
Case5: Transmitter of UAV2 fails;
Case6: The signal from UAV2 is jamed during transmitting;
Case7: Receiver of UAV1 fails;
Case8: Information process system of UAV1 fails.

In the 8 cases above, 2 and 6 case are not controllable by UAV1 and UAV2. UAV1 can do nothing about the case related to UAV2, it can only find that Case 1 or Case 7 is abnormal. Even if it has found the abnormal condition, it is also based on the hypothesis that the information processing system of UAV1 operates normally. In fact, the UAV1 information process system cannot prove that it is in normal operating state. Therefore if UAV1 finds that UAV2 does not cooperate with it, it is impossible for the UAV1 to find the real reason of failed cooperation. Thus decision conflict occurs.

5 Conclusion

There are many reasons for decision conflicts of UAVs:
a. Learning under different information or knowledge exploring mechanics may result in decision conflicts, as discussed in Section 2;
b. Different point of view may result in decision conflict, as discussed in Section 3;
c. Whether the communication is blocked or not may have effect on cooperation of multi-UAV, then result in decision conflict, as discussed in Section 4.1;
d. During the cooperation of multi-UAV, sometimes it is required to confirm in communication, rather than action, and thus may result in paradox and decision conflicts, as discussed in Section 4.2.1. Failure appeared in any step of the communication exchange may result in decision conflict, as discussed in Section 4.2.2.
Decision conflict is the cost that must be paid for developing the autonomous capability of UAVs. The more autonomous a UAV is, the higher the possibility of decision conflict.

References

[1] Leighton Hanon, Robots On The Battlefield – Are We Ready For Them? *AIAA 3rd "Unmanned Unlimited" Technical Conference, Workshop and Exhibit 20-23 September 2004,* Chicago, Illinois. AIAA 2004-6409.