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ininflueDeveloping Aerial Unmanned Effective Decision Makers

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Abstract

Unmanned aerial vehicles (UAVs, drones) and similar unmanned units are becoming more and more involved in various spheres, such as agriculture, emergency situations, battles, etc. however, in decision making there are still a lot they can be improved to avoid human direct involvement in those problems.

To advance in the problem we develop tools to make UAV autonomously effective decision makers, particularly, able to analyze properly given situations and then according to assigned goals select appropriate strategies to achieve the goals.

In the following work we aim to provide a solution for a single UAV which is able to discover units of interest, and select the target to track, manipulate or hit based on expert specified knowledge, as well as discuss further steps.

Keywords: Object, detection, Decision making, Combinatorial problems, Expert knowledge.

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1. Introduction

1.1. Problems of Space of UAV Involvements

Involvement of programmatic solutions in various types of UAV-based environments, such as agriculture, emergency situations, battles, and other types of urgent problems, is important and actual problem.

Representation of problems can vary from one to another, while given situation for UAV-based solutions may stay in scope of the following list: maps, emergencies, opponents, their positions, etc.

Overall, it is becoming very important to avoid human involvement in these tasks directly to avoid human causalities, to provide descent support and amount of units involved, thus it is important having decision making modules.

A non-expensive UAV which is able to process the field situation as an image from the top, and make decisions based on the current situation without human involvement is an urgent problem. The advantage of such unit is that it can cost low and has pretty high accuracy and effectiveness.

1.2. Programmatic Improvements of UAV Units

Various tasks can be considered in this space, including:

1.2.1. The tasks of adequate processing of situations. The program has to properly capture and parse the current situation based on retrieved data, mostly from images. This is currently not fully solved, however there are some available solutions for certain types of such tasks, e.g. detecting units of interests, such as emergency areas, e.g. fire sources on the images, etc.

Such solutions require:

a. sufficient preliminary inherited knowledge and ongoing data related to the units on the field to be recognized, particularly the ones to identify the own and opponent units, targeting items, tracking objects, etc.

b. proper training and examining the functionality of target models in performing parsing of situations and recognizing there all valuable units (the mistakes might be very costly depending on the problem).

1.2.2. Making valuable decisions in situations UAV can:

a. analyze them to select with respect to (wrt) the goals the most prospective and simultaneously available ones

b. select plans of attaining those targets

c. analyze compositions of actions, strategies for the perspective plans

d. make evaluation of the strategies and perform appropriate strategies to attain the goals.

1.3. To examine our approach, we concentrate on the topic for a battle field strategy games G, which provide good way to track situation from the top (similar to UAV images).

We consider this as a problem of certain combinatorial RGT class, where the space of solutions is reproducible game trees [1-8].

RGT problems are specified as follows:

• there are (a) interacting actors (players, competitors, etc.) performing (b) identified types of actions in the (c) specified types of situations;

• there are identified utilities, goals for each actor;

• actions for each actor are defined

• the scope of solutions at the situations are fully determined by them (i.e., are identified as games with perfect information)

Actors perform their actions in specified periods of times and do affect situations by actions in time t by transforming them to new situations in time t+1 trying to achieve the best utilities on that situation (goals) by regularities defining these actions.

For example, a way to interpret battle field game G as the RGT problem is:

1. The battling sides can be considered as interacting actors
2. Military units' movements, attacks can be considered as actions
3. The battle field area including military units can be considered as the situations
4. Different situations can be considered as goals: capture objects, destroy enemy units, push frontline.
5. The analysis of given situations are sufficient for selection of proper strategies

1.4. Advances of RGT Solvers

1.4.1. There are certain important advances and achievements in cognizers (RGT Solvers) [7] development:

In it was shown that RGT problems are reducible to each other, particularly, to some standard kernel RGT problem K, say, chess, thus, we get an opportunity to integrate the best-known achievements in solving particular RGT problems into RGT Solvers letting us to apply those achievements to any of RGT problem [1].

In RGT solutions, we follow the research lines of Botvinnik, Pitrat, Wilkins and ones successfully started since 1957 in the Institute for Informatics and Automation Problems at the Academy of Sciences of Armenia and based on modeling of expert approaches involving: knowledge bases, knowledge-based algorithms of decision making and matching situations to classifiers, as well as algorithms of revealing and modifying knowledge.

The advances in RGT [1-10] include the following:

1. Solutions for transforming situations for RGT problems, a solution for chess is available. “Generals: Command and Conquer” game is considered as a sample battlefield problem and positive results were achieved for recognition of military units.
2. Knowledge presentation and matching algorithms were developed generally for RGT problems and adequacy was experimented for chess, marketing and other RGT problems.
3. Planning and decision-making algorithms, IGAF and PPIT (including TZT) based on Botvinnik’s ideas were developed and tested for network intrusion protection problems and chess problems. Additionally, partial implementation of PPIT algorithms were integrated in general RGT Solver and experimented for chess and other RGT problems.

Various urgent combinatorial problems were investigated as RGT problems including network protection from hacker intrusions [1], single ship defense from various types of attacks [6, 7], chess [2, 4], etc.

1.5. We aim to resolve some of above-mentioned tasks by providing programs for UAV, i.e., autonomously effective decision makers, or agents, particularly for type of games G that will allow to process properly situations of G, then according to assigned goals select appropriate strategies for achieving the goals.

In the current work we concentrate on the following problems:

a. From the input images from UAVs detect and classify units of the game G influential for attaining the goals

b. From the input situation including already classified influential units select target to hit.

2. Units’ detection, classification

Classification of influential units is performed via the recorded images. Popular object detection and image classification methods are now widely based on machine learning solutions, particularly deep convolutional neural networks, e.g. in the following an approach for vehicle detection from aerial images is discussed [11].

In the following we also rely on ML solutions to train a model for influential units’ detection and classification.

2.1. Creation of Classification Dataset

Based on analysis of available data, we collected influential unit images and videos. From the collected data images were revealed to describe influential units for training the model. We made

a grouping of some classes of influential for game G units into one class, later to be classified as the same. This allows to have much less classes and possibly higher detection rate. The created dataset mostly consists of aerial photos, because UAVs mostly take pictures that way.
We have selected 8 groups of influential for game G classes, then created dataset consisting of their aerial images.

2.2. Preparation of Detection Model

Once we have the images as discussed in above section, we prepare it for training models. In the case of the game G unit's detection, the model needs both accuracy and speed, but it is more essential to draw accurate detection conclusions. Some of the studies reveal that YOLO provides better detection and speed combination over other models in various problems, providing real time detection ability [11-16]. Based on the available results we use YOLOv5 as a model to be used for our dataset training and detection.
The trained model gave results of accuracy with the values as follows: detection precision about 80%, recall is close to 60-70% and mAp about 60. The summary is in Fig. 1.

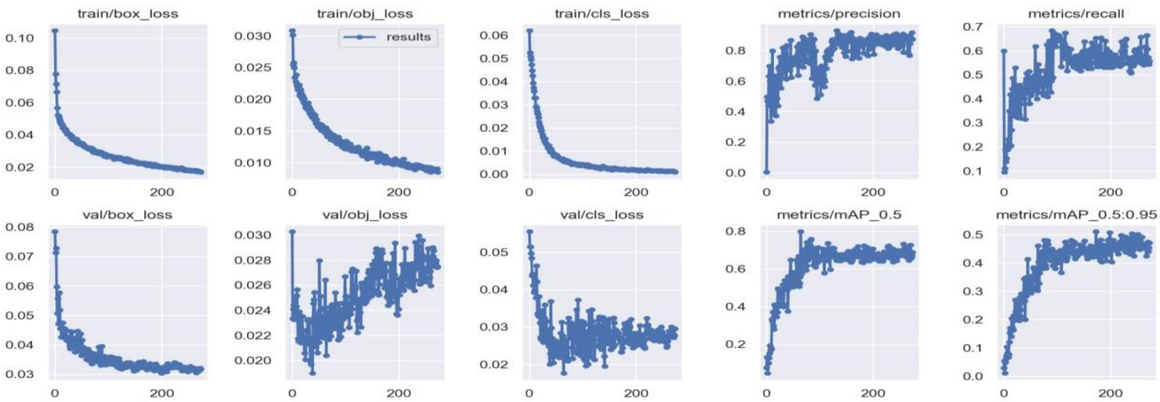

Fig. 1 Metrics of Training Results.

3. Selection of The Target

As described in Introduction chapter we are relying on the achievements of RGT to provide decision making solutions in such problems, particularly the solutions rely on expert knowledge. Here it comes to finding out the knowledge pieces needed in decision making in the game G and specifically for selection a target for UAV managing as we concentrate our attention to that specific game G in the current work.
The experts' analysis and descriptions the following nuclear types [2] of knowledge for game G were revealed.
For the targeting influential units:

1. The class of the G units as classified in section 2, can be reduced to a value in range of {1-8} for each class having a specific value.

2. The price of the unit. This is not the actual cost of the unit, but the price of the unit in the battle, describing how much can its damage be. So we assign this a rule of {1-8} range depending on the type of target.
3. Other types of expert knowledge also participate in decision making, based on which the decision becomes more accurate.

For own UAV:

1. It also contains specific types of knowledge, in this case this is related to the managing abilities, the decision realization instruments type and power, which determine the target to be resolved.

Based on the following nuclear classifiers we construct classes of units that appear as possible

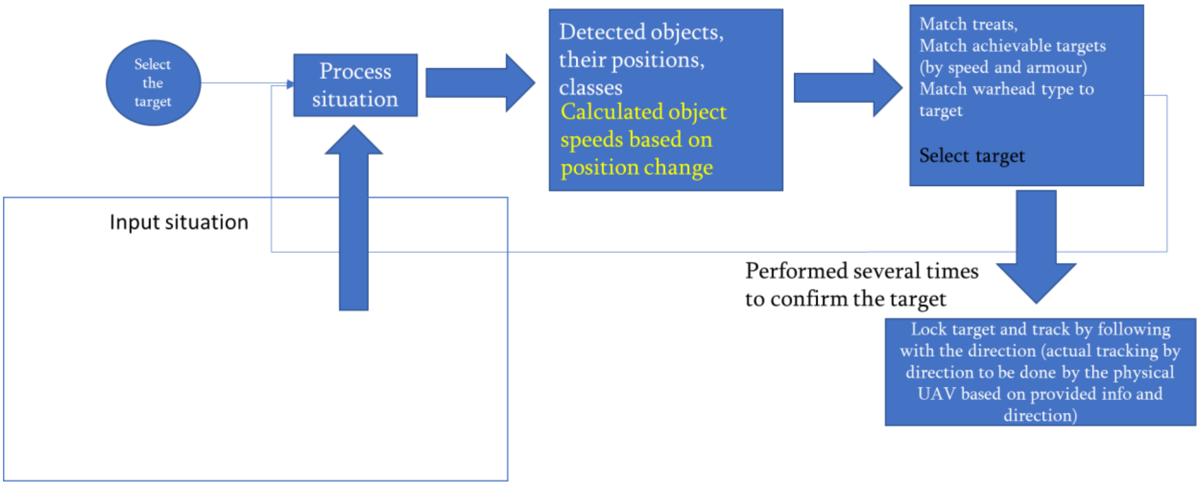

Fig. 2. The Flow of Target Selection Algorithm.

targets [2, 9]. In the tasks we only consider decisions relevant to the game G by the UAV as our own action. So, the simplified version of goal searching algorithms [2, 10] is applied here. First non-perspective targets are filtered out in the situation. Then by unit price the prioritization is applied and, with some additional corrections the target is selected.

Because the situation is changing, the selected target on each situation can be different.

To increase the confidence of correct selection of the targets, in sequential situations the same logic of target selection is applied several times.

If examined target is confirmed, the confidence is increasing. With attaining certain confidence in certain time period, the target is locked on.

3. Above we discussed the basic approach and some of applied knowledge descriptions for the selection of the targets.

The model of detection of influential units and its metrics were provided in section 2.

Knowledge-based approach adequacy has been discussed in [2, 8, 9].

The performance and the efficiency of programs realizing our UAV approach are attributed as follows:

a. The program is developed in python programming language to provide easy and fast transitions between various experimenting environments.
b. To improve efficiency of the program, when the target is selected, it is only tracked without its recurring detection and matching.

c. Once target is locked on, the program calculates and provides the direction for hitting it.
d. The efficiency of the program is experimented with various video inputs with different frame update rate: frames per second (FPS), resolution, the program provides close to real time results: for HD and FullHD videos with 20-25 fps the program is able to achieve close to real time performance.
e. The prepared program and its performance were tested low power-consuming and GPU enhanced devices, which may be a good fit for UAV setup.

4. Future Works

The current solutions demonstrate the positive results of the work, as well as provide background for the future steps.
The next steps of the current works are:

1. The accuracy of the detection of game G units affects the whole flow of target selection and situation processing, decision making, thus improvement of detection is one of essential topics, also due to possible fatal problems in actual application mistakes. For this step we go on the following direction: 1.1. Enhancement of the dataset with new images, 1.2. Enhancement of dataset by machine learning solutions, such as data augmentation, 1.3. Applying machine learning techniques to improve quality of the input 1.4. If the amount of data is sufficient, then classify exact types of units instead of grouping them.
2. Enlarging the scope of considered situation. This assumes enhancing the knowledge for matching situations, which can help in properly selection targets, provide more than one type of actions for involved other than the given single UAV own units, specifying separate targets for own units and the sequence for targets to be hit. The enhancement of knowledge of the experts is an essential part in making decisions and improvement of decision with the increase of expert knowledge is demonstrated in [9], while integration of knowledge-based decision-making algorithms provided in [2, 10] also demonstrated their adequacy.

This provides a good background for using the solutions in real UAVs.

5. Conclusions

In the following work an approach to describe battle field problem is discussed, where a way to formalize the problem is given. The following results were achieved:

1. From open sources many photo and video data were analyzed, and images were revealed to create a dataset of G units. The dataset consists of 8 classes, each of them containing a group of units functionally equal to the ones defined by experts, to achieve an acceptable accuracy in detection.
2. YOLOv5 model was used for training a model to detect the selected classes, and the results of model performance were demonstrated.
3. By close cooperation with experts of that field certain types of knowledge to properly select the target to be hit were revealed.
4. Algorithms to select the target based on input images, classified objects on that and the knowledge of the field are developed.
5. Experiments were conducted for low power computing units and close to real time processing efficiency is achieved.

Relying on the results achieved in this work and achievements described in the field of RGT problems, we plan the next steps of the work as follows:

1. Collect more data from available sources, enhance the existing dataset by machine learning tools. This allows to achieve better detection and classification accuracy, as well as makes it possible later to more detailed classification instead of grouping them.
2. Enlarge the scope of included problems to consider also agricultural, emergency and other urgent applications, to provide certain types of actions based on decisions it makes using algorithms developed for RGT Solvers [2, 9, 10].
3. Enhance knowledge base for the problems based on expert knowledge to enable various types of actions, including ways of more appropriate target selections, target managing sequence selections, etc.

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Անօդաչու արդյունավետ որոշումների կայացման ծրագրերի մշակում

Սեդրակ Վ. Գրիգորյան և Էդվարդ Մ. Պողոսյան

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Ամփոփում

Անօդաչու թռչող սարքերը (ԱԹՍ, դրոն), եւ այլ անօդաչու միավորները լայն կիրառում են ստանում են տարատեսակ կարեւոր ոլորտներում, ինչպիսիք են՝ գյուղատնտեսությունը, արտակարգ իրավիճակները, ռազմական խնդիրները եւ այլն, չնայած դրանց որոշումների կայացման եղանակներում դեռ կան լավարկման հնարավորություններ՝ խուսափելու համար մարդկային գործոնի ուղղակի ներգրավվածությունից:

Այսպիսի խնդիրներում առաջադիմելու նպատակով մենք մշակում ենք գործիքներ, որոնք հնարավորություն կտան ԱԹՍների կողմից ինքնուրույն արդյունավետ որոշումներ կայացնել, մասնավորապես՝ վերլուծելով ստեղծված իրավիճակը, ըստ հասցեագրված նպատակների մշակել ռազմավարություն՝ այդ նպատակներին հասնելու համար:

Այս աշխատանքում մենք ձգտում ենք տալ մի լուծում միայնակ ԱԹՍի համար լուծում, որը կհայտնաբերի իրավիճակում հետաքրքրություն ներկայացնող միավորները, դրանցից կընտրի թիրախ հետեւելու, խոցելու կամ այլ նպատակի

համար՝ հիմնված փորձագիտական գիտելիքների վրա: Հաջորդիվ նաեւ բերվում են լուծման հետագա զարգացման քայլերը:

Բանալի բառեր՝ օբյեկտների հայտնաբերում, որոշումների կայացում, կոմբինատոր խնդիրներ, փորձագիտական գիտելիքներ:

Разработка программ принятия эффективных беспилотных решений

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Аннотация

Беспилотные летательные аппараты (БПЛА, дроны) и подобные беспилотные устройства наряду с возрастающим числом приложений в сельском хозяйстве, управлении при чрезвычайных ситуациях, например боевых и т.д., требуют значительного усовершенствования эффективного принятия решений.

Нами разрабатывается програмы, позволяющие, в частности, анализировать ситуации, а затем в соответствии с поставленными целями выбирать подходящие стратегии для достижения целей.

В работе представлены описание процедуры анализа ситуации для обнаружения целевых обьектов и их отслеживания, анализа версий решений с использованием наличных знаний эксперта, выбора конкретной цели и принятия окончательного решения.

Ключевые слова: обнаружение объектов, принятие решений, комбинаторные задачи, экспертные знания.