Context Knowledge-Based Decisions for Battlefields

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***Abstract*— Autonomous decision-making in battlefields can be interpreted as a problem of combinatorial RGT (Reproducible Game Trees) class, which allows applying the best knowledge-based RGT solutions.**

This work illuminates the ways for RGT presentation of battlefields, specifies corresponding expert knowledge and situations appropriate for applying TZT (Trajectory Zone Techniques) and PPIT (Personalized Planning Integrated Testing) decision-making RGT algorithms.

***Keywords*—decision making, expert knowledge, battlefield, combinatorial problems.**

I. Introduction

1.1. Involvement of programmatic solutions in various types of battlefield environments is an important and actual problem. Considering the situations of aerial screenings, the scope of the following list may also be included: maps, emergencies, opponents, their positions, etc.

In this space various tasks can be considered, including the tasks of adequate processing of situations, when the program should properly capture and parse the current situation based on retrieved data, mostly from images. Currently, this problem has not been fully solved, however, there are some available solutions for certain types of such tasks, e.g., detecting units of interest, such as emergency areas, e.g., fire sources on images,

Such solutions may require sufficient preliminary inherited knowledge and ongoing data related to the units on the field to be recognized, particularly those to identify the own and opponent units, targeting items, tracking objects, etc., as well as proper training and examining the functionality of target models in performing parsing of situations and recognizing there all valuable units (mistakes might be very costly depending on the problem).

Making valuable decisions in such situations may be divided into the following parts:

- analyze the situations with respect to the goals of the most prospective and simultaneously available ones
- select plans for attaining targeted goals
- analyze the compositions of actions, strategies for perspective plans
- evaluate strategies and apply appropriate strategies to attain goals.

1.2. Advances in Battlefields

In [1], an approach for simulation of UAV-captured images and application for battlefield problems was provided.

Based on open resources dataset for 8 classes of military units as images, a model was created for the detection of specified classes. The model demonstrated positive performance.

For a specific scenario involving a UAV, knowledge for proper selection of a single target from the input situation captured via that UAV was revealed and formalized.

The work discusses the battlefield problem as a combinatorial problem of RGT class and gives basic ways to interpret the battlefield problem as a problem of that class, however, it does not provide sufficient means for the acquisition of various expert knowledge and appropriate decision-making algorithms usage available for RGT problems.

1.3. Defining RGT

Following the approach initiated in [1] we concentrate on RGT achievements to enhance battlefield problem solutions.

RGT problems are the problems where spaces of solutions represent reproducible game trees. They are specified with the following main criteria [2-5]:

- There are interacting actors (players, competitors, etc.,),
- Performing identified types of actions,
- In the specified types of situations,
- There are identified utilities, goals for each actor,
- The scope of solutions at the situations are fully determined by them,
- Actors perform their actions and transform situations trying to achieve the best utilities on that situation (goals) by regularities defining these actions.

For example, a way to interpret the battlefield as an RGT problem is:

a. The battling sides can be considered as interacting actors

b. Military units' movements, attacks can be considered as actions

c. The battlefield areas with the military units involved, can be considered as situations

d. As goals different situations can be considered, such as: capture objects, destroy enemy units, push frontline, hold defense, etc.

We name solvers of RGT problems as RGT Solvers [2, 3, 5, 6].

1.4. Achievements in RGT:

1.4.1. In [4, 8], 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 apply those achievements to any of RGT problem.

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1.4.2. RGT Solvers, following the research lines of Botvinnik, Pitrat, Wilkins and those that have been successfully started since 1957 at the Institute for Informatics and Automation Problems at the Academy of Sciences of the Republic of Armenia approach to the problems by modeling expert approaches involving knowledge bases, knowledge-based algorithms of decision-making and matching situations to classifiers, as well as algorithms for revealing and modifying knowledge, and achieved the following results:

a. Situations transforming solutions for RGT problems, a solution for chess is available. The game “Generals: Command and Conquer” is considered as a sample battlefield problem and positive results were achieved for recognition of military units; later battlefield solutions were enhanced with the results described in [1].

b. Knowledge presentation [2, 5] and matching algorithms [5] were developed generally for RGT problems and adequacy was experimented for chess, marketing, defense problem of ships from various types of missile attacks, problem of protection of systems from hacker intrusions and other RGT problems [5, 9].

c. Decision-making algorithms were developed, initially starting with IGAF [9], which is based on common knowledge planning, gave remarkable improvements compared to brute force algorithms for the RGT problem of network intrusion protection. In [3], PPIT personalized knowledge-based strategy elaboration algorithms were proposed and implemented in RGT Solvers [5], The adequacy of PPIT algorithms was demonstrated on chess etudes suggested by Botvinnik as tests for such decision-making frameworks. PPIT utilizes TZT algorithms for goal searching, initially proposed by Botvinnik as a goal searching algorithm in chess [10], and later integrated with RGT Solvers [9]. The developed algorithms were successfully experimented with chess, program testing and other RGT problems [5, 11]. TZT algorithms consist of: a. Generation of the tree starting from a given situation for a specified horizon consisting only of trajectories of attack, i.e., actions leading to the goal achievement, b. expansion of the tree by inclusion of possible actions by the opponents within zones of counteractions, c. Processing the generated tree to check if the goal is achievable [11] and proposing appropriate actions.

1.5. The Aim

Following the achievements in battlefield processing and RGT problems, we aim to enhance them by addressing the mentioned open questions, particularly knowledge filtering, acquisition from both experts of the domain and the books with transferring it into RGT Solvers, followed by the presentation of battlefield situations in RGT Solvers. As a result, we get the ability to apply the best achievements discussed above to battlefield problem solutions.

For this purpose, we limit the domain to only a certain subtype of battlefield, where a squad in its enhancement needs to defend it from the attacking enemy.

II. Takeaways from Battlefield Expert Knowledge

UAV-based battlefield solvers [1] combine the following achievements:

a. Processing of image-based situations and detection of military units from the mentioned 8 classes.

b. Presentation of basic classifiers describing each of the detected units with its specified type and position, it is worth mentioning that these classifiers are defined in the programs and fixed.

c. At each step, a list of instances of these classifiers are retrieved, which we can consider as a situation.

d. The developed algorithm selects the most perspective unit on the situation as a target.

e. Object tracking is applied to track the target, and the movement direction is provided to properly follow it.

f. Experiments demonstrate close to real-time performance of programs on low-power devices.

In acquiring expert knowledge from books [14] and domain experts, models of RGT knowledge presentation are used [2, 5]. Although the provided military regulations [14] are not modern, we consider them sufficient to demonstrate the validity of the approach, while the up-to-date regulations and knowledge pieces are supposed to be updated and integrated into the frame of the work accordingly.

2.1. Formalization of Battlefield Knowledge

The provided in [1] presentations are enhanced, particularly by the acquisition of specific action types, goals and plans.

Assuming that we have described a specific small field and limited goals only for defense (defending the given area/enhancement), we specify the knowledge as follows:

a. We define the lowest level of classifiers (nuclears): positions x, y, z cords (including altitude, supposed to be an important factor in future and deeper analysis), types of military units, limited to the following classes [tanks, infantry, machine gun, armored vehicles, grenade launcher, anti-tank weapon], unit side as [own, enemy].

b. The basic classifiers, accordingly, appear with a combination of nuclears as for other RGT problems [5], e.g., own infantry at a given x/y/z position.

c. We consider limited actions according to the goal of defense: 1. fire (from predefined positions, as in battlefield, initially all the defensive positions are supposed to be initially defined and all the acting units are supposed to know their exact positions), where they need the aim to throw back the enemy, 2. all-round defense, 3. retreat, while the enemy side is supposed to attack the given positions.

d. In RGT Solvers, strategy execution relies on PPIT and TZT algorithms [3, 11, 12, 13], as mentioned before. So, next, we define plans with structures defined in [5]. We define the following plan: 1. Protect positions (fire if a specific condition is met, e.g., if the distance between own units and the enemy is shorter than the given value), 2. If the enemy attempts to bypass positions, then all-round defense is taken, 3. If casualties are higher than a given number, then retreat from the positions.

2.2. Decision-Making in RGT

The situations in RGT Solvers meet specific conditions so that they can be easily processed and decision-making algorithms are applied effectively. This approach utilizes PPIT algorithms processing for the given situations.

III. Bringing Battlefield Situations into RGT Solvers

3.1. Presentation of Situations

Following the RGT Solver results in the presentation of situations, similar to [5, 13] for battlefield situations, we generate a specific simulation environment, where the territory is fixed, and positions are fixed, however, military units still can move and change their positions in situations.

For instance, in RGT Solvers, chess situations are described by defining each chess field as a composition of the following classifiers: figure type (which defines the type of figure on that field, or 0 if no figure is there), figure color (which defines the color of the figure, either white or black, or 0 if no figure is there), x and y cords.

3.2. Defining Battlefield Situation Constituents

Similarly, for sufficient simulation of battlefield situations and enhancing the available knowledge pieces defined in [1, 5], we define the situation pieces in battlefield in the following way: a. x and y cords of the position on the absolute space (since we limit our situation to a specific area, we can assume having absolute positions without referring to location information, such as GPS positions), b. altitude of the position, since it may be very important in some scenarios (e.g., taking the peak could be a goal), as for this specific squad defense scenario, it still may be not obviously needed, c. military unit type, if available, as specified in [1] also and extended above to cover minimal participation d. actor side in the case a unit exists there, i.e., if its own unit or an opponent. The battlefield situation will be a composition of instances of the given basic classifiers, which composes the mentioned nuclear classifiers.


```
{
  { "x": 0, "y" : 0,  "z" : "1800", "unit": "tank", "side": "own" },
  { "x": 1, "y" : 0,  "z" : "1800", "unit": "0", "side": “0" },
  { "x": 2, "y" : 0,  "z" : "1802", "unit": "machine gun", "side":
"own" },
...
}
```


Fig. 1 Example presentation of situation

3.3. Processing of Battlefield Situations

The provided presentation of situations combined with classifiers defined above lets us process battlefield situations with generic RGT Solvers, where the PPIT planning algorithm, including the TZT goal searching algorithms, gives results adequate to experts in different RGT problems.

Plan execution for the given battlefield situation matches to defined knowledge. The matching result is used to check if the first priority goal of the selected plan can be achieved with the required preconditions, and if not, then the next priority goals are checked respectively in a similar way. For the selected goal an appropriate action is recommended.

The work will continue to experiment execution of the mentioned decision-making algorithms for their adequacy achievement.

IV. Conclusions

We have discussed the presentation of the battlefield as RGT problems and the ways to apply RGT Solvers.

The UAV-based version of the battlefield solver provided the following:

1. Processing of aerial images to detect 8 military unit classes based on the constructed model. The training dataset of the model represents 8 classes of military unit groups defined by experts.
2. Certain expert-defined classifiers were integrated for proper processing of target selection algorithms.
3. Algorithms were developed to select the target based on input images, objects classified according to them and the knowledge of the field.
4. Experiments on low-power computing devices demonstrated close to real time processing efficiency.

The solution effectively covers aerial image-based decision-making for a single UAV. Current work extends it to the point where RGT achievements are utilized for better results, particularly:

1. Expert knowledge acquisition allows using enhanced classifiers, including actions, plans, goals. Definitions start with nuclear, basic classifiers and actions.
2. Situations for battlefield presentation is enhanced and specified for RGT Solvers representing a certain composition of battlefield essential nuclear classifier instances.
3. The planning and decision-making algorithms available in RGT Solvers are applied to propose actions for the given situations, which effectively enhances the solutions by available knowledge-based TZT and PPIT algorithms.

In continuation of the work, experiments on the adequacy of the acquired knowledge, and situation-processing algorithms for battlefield problems will be conducted.

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