Research Statement

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Abstract

Over the past 2 years' life in SUSTech as an undergraduate, my learning interest has focused on computer science and engineering (CSE). Inside the classroom, I learned the basics and core knowledge of software engineering, artificial intelligence and mathematics. I gained a solid grasp of computer science and excellent engineering experience through high-quality coursework and critical theoretical thinking on exams and assignments.

Outside the classroom, I was involved in an intelligent robotics research project from September 2020 to September 2022, and since September 2022 I have been working on two projects about artificial intelligence. In this paper, I would like to first introduce you to the intelligent robotics project, together with its purpose, funding, primary works and results. Then, the purpose of the other two AI projects, their funding, comments on related works and unique features of our research and key issues to be addressed will be presented in turn in this paper.

1. Development of Intelligent Robotics System for Robomaster Competition

1.1. Introduction

1.1.1. The Robomaster Competition.

In the RoboMaster University Championship (RMUC) competition, young engineers from different majors work together to build a line-up of intelligent robots from scratch. Robots from various universities are then pitted against each other under an exciting MOBA-like matching rule.

More concretely, robots which conforms to the competition standard are equipped with armor skin and shooting device. They fight each other to gain economy and finally aims to destroy the defense tower and the base of the other team. Seven types of robots can be manufactured to form a diverse fleet with different responsibility as follows:

- Hero: tower toppler which can make tremendous damage to construction units.
- Standard (Infantry) : opponent killer with high shooting rate, also entrusted with the task of activating the buff by attacking the sinusoidal spinning Power Rune.
- Engineer: mining ores to obtain economy advantages and absorbing harm using its high HP.
- Aerial: stable attacking force from the air which can not be killed, also provides a bird-eye view to the team.
- Sentry: autonomous invader crusher serving as the last defense for the base.
- Dart system: automatic guidance dart destroying the tower at surprise.
- Radar: Mapping from camera or LIDAR to provide opponent location information.

For more detailed information, you can see the official website of the competition. [1]

1.1.2. Laboratory and Funding support.

ARTINX Laboratory is the robotics team for Robomaster in behalf of SUSTech. ARTINX has been funded by the School of System Design and Intelligent Manufacturing (SDIM) .

As an engineer in ARTINX's algorithm group, I participated in the 2021 and 2022 competitions. I was in charge of the 2021 aerial agent system and was the main developer of the 2022 automatic firing framework.

1.2. Development and Deployment of Automatic Shooting System

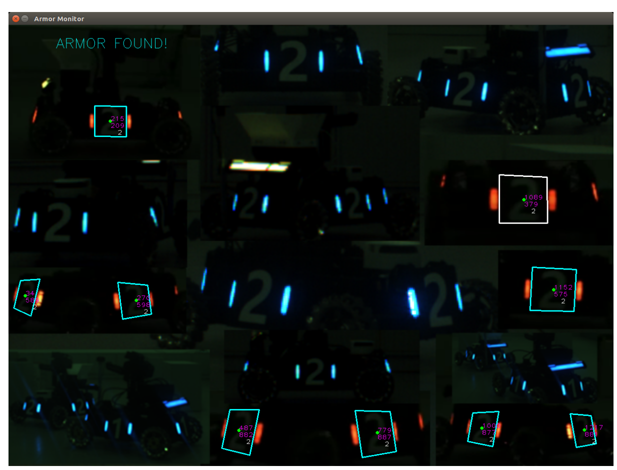

Figure 1. Armor detection algorithm with condition color red and number 2. [2]

Equipped on virtually all types of robot, the Automatic Shooting System (ASS) is vital to the performance of the whole fleet. The development of ASS involved four key issues:

- **Software architecture.** Non-blocking IO with camera and serial port, online performance monitoring, parallel computing and continuous integration/delivery.
- **Image formation and prepossessing.** Camera calibration, color calibration.
- **Computer Vision Algorithms** Object detection (car, armor, ore and number) , angle solving, noise filtering.
- **Decision and control** Attacking strategy (based on the environment) and serial port communication protocol (with the lower computer controlling the firing platform) .

As for deployment, it is worth mentioning that SOTA deep learning methods may not be as applicable and appealing as traditional methods. First, the data size is not sufficient to train a model. Data is collected from real matches, which is difficult when the machinery is not complete. More importantly, the inference speed of deep models is insufficient to perform real-time automatic targeting decisions. The series of YOLO models are known to have decent speed-accuracy trade-off because it simply ”look once”. However, it reaches only 3 fps on the on-robot computer (which is not equipped with a GPU) even boosted by OpenVINO.

1.3. Achievement

My team and I were awarded the 1 Prize on Robomaster 2021 National Super Match and 2 Prize on Robomaster 2022 Provincial Super Match.

2. Multi-task recommendation system running on multi-scene

2.1. Introduction

To solve the problem of Information overload coming up with the Information Age, Information Retrieval Systems such as search engines and personalised recommendation systems have been proposed. [3] Recommendation systems can benefit multiple parties at the same time. [4]

Recommendation systems are now widely used in numerous domains, and one of the most typical and promising areas of development and application is e-commerce. [3] While the information needs of users in different scenarios are different, the traditional recommendation system research tends to focus on the accurate prediction of a single recommendation metric in a single business domain (scenario). [5] The solution to effectively serve the information needs of users in different scenarios has then become a hot problem for enterprise application of recommendation systems.

Since building and maintaining multiple independent recommender systems at the same time is costly in terms of manpower and computational resources [5], and since it is suboptimal ignoring commonalities in the training data [6], Multi-Task Learning (MTL) paradigm is applied to recommendation system to improve its generalization performance and maintenance cost.

2.2. Comments on Related Work

The existing multi-task learning recommendation system solution has worked well and provided a baseline for this project, but there is still much room for improvement. For example,

1) The MMoE and STAR models simply distinguish between different tasks by a shared parameter part and a task-specific parameter part, but do not take into account the impact on model training caused by differences in data distribution and optimisation directions across tasks, resulting in insufficient training for each task and less than optimal overall performance. [5]
2) To address the problem of unbalanced optimization steps on shared parameters, MetaBalance dynamically adjusts the gradient size of the scaled-down auxiliary tasks during the training phase. However, forcing multiple tasks to have the same gradient size results in a model that is often not optimal for the target task. [7] Although MetaBalance also provides a hyperparameter r to alleviate this problem, this is not a permanent solution.

2.3. Key issue to be addressed

This project plans to propose a multi-task learning paradigm with high generalisation performance to build a deep recommendation system based on multi-task learning. The research in this project needs to address the following main issues.

1) Addresses the impact of differences in data distribution and optimisation direction between datasets on model training, and builds models to deal with such differences, allowing models to be fully trained for each task or scenario.
2) The problem of the model falling into a local optimum due to the introduction of the gradient dynamic adjustment method is addressed by improving the method of rational decomposition of the gradient over the shared parameters so that the overall result converges to the optimum solution.
3) Addresses the problem that the current model does not have the ability to generalise to new recommendation tasks, and improves the usefulness of the model by modelling the addition of new recommendation tasks through a migration learning approach.

3. Intelligent identification and origin tracing of ancient jade based on near-infrared spectral data

3.1. Introduction

Jade is an important part of traditional Chinese culture. Since ancient times, jade has been given a special meaning that transcends ordinary ornamentation, belonging to a class of ceremonial objects (as in Figure 2) that signify the rank, power, etiquette, morality and wealth of the wearer. Chinese ancient jade is mainly composed of nephrite, which belongs to the tremolite-actinolite series of the hornblende group of calcium hornblende [$Ca_2(Mg, Fe^{2+})_5 Si_8 O_{22} (OH)_2$] mineral aggregates with interwoven fiber microstructures. [8]

Figure 2. Jade pipe excavated from M54 [9]

There are two main textures of nephrite, magnesian marble and serpentinized ultramafic rocks. Generally speaking, these two types come from different origins (see Figure 2), with the former mainly including Xinjiang Kunlun, Liaoning Kuandian, Sichuan Wenchuan, and Korea Chuncheon, and the latter mainly including Xinjiang Tianshan, Henan Xichuan, and Taiwan Hualien, with the former dominating in mainland China and the latter in the rest of the world. This leads to a question about the traceability of ancient jade, i.e., what type of nephrite it is and from which specific origin.

3.2. Uniqueness of this project

In previous work, experts in archaeological research have often used mid-infrared absorption spectroscopy to determine the composition of artifacts, but this analysis requires destructive sampling of the artifacts, and the sampling sites are often unrepresentative. In contrast, the mineralogical identification of excavated jade objects in this project relies on NIR spectroscopy. This technique is a rapidly developing non-destructive analysis technique in recent years, and has been widely used in many fields due to its low cost and easy sampling. There are few precedents for using NIR spectroscopy to systematically analyze excavated ancient jade; and there is no precedent for combining NIR spectroscopy data with cutting-edge artificial intelligence machine learning techniques. Therefore, this project is pretty cutting-edge.

Machine learning methods are still not commonly used in archaeology, which is less favored by capital, and archaeology requires a great deal of study and empirical knowledge to identify the type and age of jade in fieldwork, a task that is more complex and requires more a priori knowledge. In addition, the machine learning model for recovering the chemical structure of jade in our work closely integrates the disciplines of archaeology, chemistry, and data analysis, providing archaeologists and chemists with a large amount of information quickly and accurately. In summary, our work can transfer machine learning as an efficient method into the field of archaeology, helping to obtain better and more accurate results in archaeology and ancient culture analysis.

3.3. Key issue to be addressed

In summary, this project needs to solve the technical problems of identifying jade types in NIR and analyzing jade artifacts. At the same time, we need to build a database and apply machine learning methods to deal with the application problems such as dating of jade artifacts and identification of excavation areas according to the existing geoarchaeological data.

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