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Intellectual Control Systems for Aviation: Enhancing Autonomy and Safety

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This paper presents an innovative approach to the implementation of intellectual control systems in aviation, focusing on their applications to both manned and unmanned aerial vehicles (UAVs). These systems are developed using advanced neural network architectures and deep reinforcement learning (DRL) techniques to enable dynamic decision-making, real-time adaptation, and increased automation in complex and unpredictable flight environments. This approach offers new possibilities for improving safety, autonomy, and operational efficiency in aviation.

The increasing complexity of modern aviation systems necessitates the development of more intelligent and autonomous control mechanisms. Traditional control frameworks, though effective in certain scenarios, struggle to cope with dynamic environments and unexpected changes. In recent years, neural network-based control systems have emerged as powerful tools for addressing these challenges by enabling adaptive, real-time decision-making.

In this paper, we explore the potential of deep reinforcement learning (DRL) integrated into neural networks for developing intellectual control systems. The focus is placed on controlling both individual and groups of UAVs, which are becoming indispensable in various sectors, including agriculture, logistics, defense, and disaster management.

Previous research on control mechanisms for UAVs and other aerial vehicles has demonstrated the limitations of traditional methods such as manual control and pre-programmed autopilots. Neural networks, particularly deep learning models, have shown promise in overcoming these limitations by providing greater flexibility and learning from environmental interactions. Recurrent neural networks (RNNs), convolutional neural networks (CNNs), and DRL techniques have been successfully applied in similar contexts to manage control tasks, from obstacle avoidance to formation flying and target tracking.

This paper proposes a DRL-based intellectual control system for aviation, designed to enhance both autonomy and operational safety. Our framework integrates neural networks that learn and adapt to environmental changes by analyzing real-time data from sensors and onboard systems. The architecture consists of:

1. Actor-Critic Network Architecture A dual-network system where the actor network predicts the optimal control action, and the critic network evaluates the predicted action by estimating the reward outcome.
2. Multi-Agent Coordination Framework: Specifically designed for groups of UAVs, the system enables them to work together to achieve

shared objectives, such as search and rescue operations or coordinated surveillance.

The proposed system not only enhances the individual decision-making capabilities of each UAV but also facilitates inter-agent communication and collaboration, even in conditions of limited or delayed information sharing.

To validate the proposed control system, we conducted a series of simulations in a disaster response scenario. In these simulations, a group of UAVs was tasked with locating and tracking multiple targets in a dynamically changing environment, while simultaneously avoiding obstacles and potential hazards. Each UAV was equipped with sensors providing real-time data on its surroundings, which were processed by the neural network to generate optimal control actions.

The experimental results showed that the DRL-based intellectual control system significantly outperformed traditional autopilot systems in terms of coordination, adaptability, and overall mission success. The system demonstrated robust performance across varying environmental conditions and was able to dynamically adapt to changes, such as the appearance of new obstacles or targets.

The results of our experiments indicate that neural network-based intellectual control systems hold great potential for advancing aviation technologies, particularly in enhancing the autonomy of UAVs. These systems offer a high degree of scalability, enabling the coordination of large teams of UAVs, each with unique capabilities and characteristics.

Key challenges remain, such as improving the interpretability of the decision-making process and ensuring the robustness of the system in more complex real-world scenarios. Furthermore, additional research is needed to optimize the training processes and minimize the computational resources required for large-scale deployments.

The development of intellectual control systems using neural networks and DRL marks a significant advancement in aviation technology. By enhancing the autonomy and adaptability of UAVs and other aerial vehicles, these systems have the potential to revolutionize various applications, from routine commercial flights to emergency response operations.

Future research will focus on expanding the capabilities of these systems to handle more complex and dynamic scenarios, improving their safety and reliability, and scaling their application to larger, more diverse fleets of aircraft.

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