跨越虛實：吳毅成教授團隊自動駕駛技術創新

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自動駕駛技術為當今熱門議題，而實現自動駕駛的方法多種多樣，近來有許多運用深度強化式學習 (Deep Reinforcement Learning; DRL) 來進行車輛控制的方法，獲致優異成果。而在自動駕駛技術的研究領域中，陽明交通大學資訊工程學系的吳毅成教授與其團隊的貢獻不容小覷。他們開發的「具動作平滑化之深度強化式學習技術」不僅在自駕模型賽車中取得了突破性進展，更在 2023 年榮獲未來科技獎，顯示了其技術的創新性和實用性。

「具動作平滑化之深度強化式學習技術與運用於自駕模型賽車駕駛應用」是一套基於影像的虛實轉移技術 (sim-to-real transfer)，它可以有效縮減強化學習模型由虛擬環境轉移至真實環境之效能損失，提升純視覺影像神經網路模型在真實環境中的表現。此新技術除了發表於 ICRA 2022 以及 IJCAI 2022 頂尖會議的 Workshop，並於 2022 年底，由 Amazon 公司主辦的 AWS DeepRacer 全球自動駕駛賽車聯盟競賽，獲得包辦全球前三名的殊榮，並獲得總獎金 USD$18,000。

吳毅成教授團隊採用生成對抗模型架構 CycleGAN，將模擬器中之影像從虛擬風格轉換為真實世界風格，並以轉換過後的影像進行訓練，有效縮減純視覺模型的虛實差異 (sim-to-real gap)，大幅提升自駕賽車於實體賽道中的適應性。為了提高自駕車的駕駛穩定度，團隊更進一步研究確認了在實體車控制平滑性方面的重要性，並提出新的平滑化技術。在過去，許多傳統的 DRL 方法著重於最大化累積回報，導致車輛控制動作的不穩定性。因此，吳毅成教授團隊透過損失函數限制神經網路做出劇烈變化之動作，提高時序相鄰動作之連續性，實現 DRL 模型輸出動作的平滑化 (action smoothness)，並大幅提高自駕車的控制穩定度；吳毅成教授團隊的研究也觀察到動作平滑化，同時也會增快賽車的速度。克服以上挑戰，團隊研究出有效且穩定的強化學習策略，能夠有效地提高實體車的完圈率並降低完圈時間。

吳毅成教授團隊提及採用 DRL 之自動駕駛賽車，通常需要透過大量與環境的互動過程，以逐步調整駕駛規則與技巧。由於不易在真實世界中重現數以萬計的精確反饋，訓練過程通常在模擬環境中進行，於真實世界中部署測試。然而，模擬器難以重現複雜多變的真實世界影像，導致未看過真實影像的模型移轉時，容易產生效果不佳的現象。針對這個問題，發展基於影像的虛實轉移技術 (sim-to-real transfer)，為了有效縮減強化學習模型由虛擬環境轉移至真實環境之效能損失，吳毅成教授團隊採用生成對抗模型架構 CycleGAN，將模擬器中影像從虛擬風格轉換為真實風格並進行模型訓練。團隊透過損失函數限制神經網路的動作輸出，提高時序相鄰動作之連續性，結合團隊目前的 muzero 軟體框架，實現 DRL 模型輸出動作的平滑化 (action smoothness)。在吳毅成教授團隊的測試當中，使用此方法的模型，未出界的情況下完成一圈之成功率，從原本得僅僅 42.8% 提升至將近 100%，完圈秒數 也從原本的 22.03 秒降至 19.54 秒，實為全方位的提升。

在這個科技日新月異的時代，我們見證了虛實轉移技術的強大潛力，此虛實轉移技術不只能用於自駕模型賽車，也可以應用於其他基於影像的深度強化式學習模型，幫助解決虛實環境差異的問題，提高深度強化式學習於解決真實問題的可行性並促進強化學習模型在機器人、機器手臂和無人機等領域的實際應用。在此，本院要向吳毅成教授與其團隊表示最深的敬意與感謝。他們的辛勤工作和創新思維為台灣乃至全球的科技發展做出了重大貢獻。我們也期待陽明交通大學的科研團隊能夠繼續以其前瞻性的技術，為世界帶來更多正面的影響，並在自動駕駛技術的道路上，為台灣爭光，並成功為我們的生活帶來更多便利與安全，且為未來的科技創新開啟新的篇章。

Dr. I-Chen Wu's Team: Sim-to-Real Transfer - Innovations in Autonomous Driving Technology

Autonomous driving technology is a hot topic today, and various approaches are explored to achieve it. One method that has gained popularity is Deep Reinforcement Learning (DRL), which has shown impressive results for vehicle control. Notably, Professor I-Chen Wu and his team at the Department of Computer Science at Yang Ming Chiao Tung University have made significant contributions to autonomous driving technology. Their innovation, "Deep Reinforcement Learning with Action Smoothness," has not only made breakthrough progress in autonomous miniature car racing but also won the prestigious Future Technology Award in 2023, highlighting the ingenuity and practicality of its technology.

"Deep Reinforcement Learning with Action Smoothness and Its Application to Autonomous Miniature Car Racing" is a system that utilizes image-based sim-to-real transfer technology. This system effectively reduces the performance degradation of reinforcement learning models during the transfer from virtual to natural environments, improving the performance of pure visual image neural network models in real-world settings. This innovative approach gained attention at workshops of the ICRA 2022 and IJCAI 2022 conferences and achieved notable success in the AWS DeepRacer League competition hosted by Amazon at the end of 2022. It secured the top three positions worldwide and earned a total prize of USD 18,000.

Professor Wu's team adopts the CycleGAN architecture, a generative adversarial model, to convert images from the simulator's virtual style to the real-world style. Training the models with these transformed images effectively narrowed the gap between simulation and reality for pure visual models, significantly enhancing the adaptability of autonomous miniature cars on physical tracks. Furthermore, to improve autonomous miniature car stability, the team focused on the importance of smoothness in physical car control and proposed novel smoothing techniques. Unlike traditional DRL methods prioritizing maximizing cumulative rewards, which may lead to unstable vehicle control, Professor Wu's team utilized loss functions to constrain neural networks from making drastic changes. This approach enhanced the continuity of sequential actions, achieving smoother outputs in DRL models and greatly enhancing autonomous miniature car stability. Additionally, the team observed that smoother actions also accelerated racing car speed. Tackling these challenges head-on, the team developed effective and stable reinforcement learning strategies to boost the completion rate of physical cars and reduce lap times.

Professor Wu's team mentions that employing Deep Reinforcement Learning (DRL) in autonomous miniature racing cars typically involves extensive environmental interaction to refine driving strategies over time. Due to the difficulty of replicating precise real-world feedback, training usually takes place in a simulated environment before testing in the real world. However, simulators struggle to accurately replicate the complex visual landscapes of reality, which leads to performance degradation when models are transferred from virtual to natural environments without exposure to real-world imagery. To address this issue, the team developed an image-based sim-to-real transfer technique to mitigate performance losses during this transition. Using the CycleGAN architecture, a generative adversarial model, Professor Wu's team transformed simulated images from a virtual style to a real-world style for model training. They design loss functions to regulate the neural network's action outputs, enhancing the continuity of actions over consecutive time steps. This approach facilitated the smoothing of DRL model output actions. According to their tests, the success rate of completing a lap without going off-track increased from a mere 42.8% to nearly 100%, and lap times decreased from 22.03 seconds to 19.54 seconds, representing a comprehensive enhancement.

In this era of technological advancement, we have witnessed the potential of sim-to-real transfer technology. This innovation not only improves autonomous miniature car racing but also extends to various image-based deep reinforcement learning models. By bridging the gap between virtual and real worlds, this technology enhances the viability of deep reinforcement learning in addressing real-world challenges. Moreover, it facilitates the practical deployment of reinforcement learning models across domains such as robotics, robotic arms, and drones. Our college would like to express profound appreciation to Professor I-Chen Wu and his team for their diligent efforts and innovative thinking, which have significantly contributed to the technological development of Taiwan and the world. We eagerly anticipate the research teams at Yang Ming Chiao Tung University persisting in leveraging their forward-looking technology to generate further positive outcomes worldwide. May they illuminate Taiwan's path in autonomous driving technology, enhancing convenience and safety in our lives, while pioneering new frontiers in technology and innovation.