A25-042

應用大型語言模型 實現個人化智慧停車場自駕系統

Personalized Smart Parking Autonomous Driving System Based on Large Language Models

隊伍名稱｜昱鬱寡歡 SAD YU LITTLE HAPPY !!!

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研究領域

自動控制、智慧型車輛、行動機器人與人工智慧應用。

作品摘要

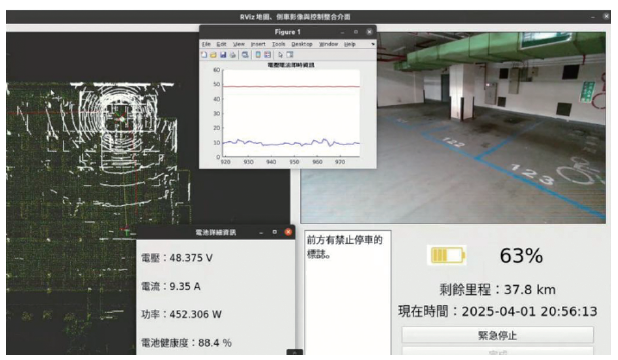
本作品針對大型停車場動線複雜、尋位不便與行人安全隱憂，提出一套結合大型語言模型(LLM)、視覺語言模型(VLM)、行人軌跡預測、自動駕駛與智慧電池管理的個人化智慧停車系統，車體配置以下圖一所示，前方搭載螢幕顯示資訊給使用者、方向盤驅動馬達處理角度的控制、麥克風收集音訊，光達負責定位以及深度攝影機處理VLM和行人意圖預測，車體後方配置電腦即時運算資訊，光學編碼器負責速度量測、網路攝影機偵測車格線位置，最後資料收集器量測及時電壓、電流資訊。

系統整題流程為乘客透過語音輸入傳達偏好(如靠近電梯或需要停邊一點)，LLM解析指令後決策最佳車位並規劃路徑，並以3D光達建置停車場點雲地圖，採Hybrid A*進行路徑規劃，接著以簡化腳踏車模型的MPC演算法實時控制車輛，而停車輔助部分為攝影機結合Canny+霍夫轉換偵測車格線，PD控制器控制方向盤，並利用LLM解析車內乘客體型或物品大小，微調停車位置以提供足夠空間。

路途中的詳細情形，如下圖二所示，此畫面為顯示給使用者參考之介面，左邊的路徑以及即時位置圖為使用者透過LLM所得出之理想停車位之路徑，即時位置為光達定位結果，右上方為VLM搭配行人意圖預測之結果，利用OpenPose偵測骨架後，將座標輸入Conditional VAE模型預測行人未來軌跡，當預測軌跡與車輛路徑重疊且達到Euro NCAP規範門檻時自動減速刹車。VLM部分則可以辨識環境以及物件偵測，在停車場的情境下分別辨識障礙物、行人與停車場標誌，再由環境判斷LLM綜合回饋予決策核心，提高場景理解能力，最後右下方電池管理系統利用HIOKI LR8450收集電壓電流資料，透過線性回歸估算SOC與Coulomb計算法計算SOH，並即時顯示在使用者介面，實際測試下手動與自動駕駛時電壓保持穩定。

結合VLM+LLM架構能正確辨識場景關鍵資訊，整合後的系統不僅大幅縮短尋車時間、降低迷路焦慮，還能提供客製化停車方案與高精度自動駕駛，並兼顧行人安全與電動車電池健康管理。

圖一 車體配置圖。



圖二 系統介面圖。

Abstract

This study tackles the challenges of complex traffic conditions, difficulty in locating suitable parking spaces, and pedestrian safety in large-scale parking lots by proposing a comprehensive, personalized intelligent parking system. The system integrates Large Language Models (LLMs), Vision-Language Models (VLMs), pedestrian trajectory prediction, autonomous driving, and intelligent battery management to create a seamless and adaptive parking experience.

The workflow begins when a passenger provides voice input indicating specific preferences—such as proximity to elevators or requiring extra space for cargo or passenger access. These commands are parsed by the LLM, which identifies the optimal parking location and generates a navigation plan. Simultaneously, a 3D LiDAR sensor constructs a point-cloud map of the environment. Hybrid A* path planning is applied to determine a safe and efficient route to the designated spot. The vehicle is controlled using a simplified bicycle model paired with a Model Predictive Control (MPC) algorithm, which adjusts steering and speed in real time.

For precise parking, on-board cameras use Canny edge detection and Hough transform to identify parking space lines. A Proportional-Derivative (PD) controller then fine-tunes the steering angle to align the vehicle accurately, taking into account any personalized spacing preferences based on the passenger's physical size or cargo dimensions as interpreted by the LLM.

The driver interface offers a real-time, intuitive visualization of the system. We use the driving perspective to present our system, as shown in Figure 3 below. On the left, a top-down view shows the planned path and the vehicle's real-time position as determined by LiDAR localization. On the top right, the VLM collaborates with a pedestrian intent prediction module. It uses OpenPose to extract human skeletal keypoints and feeds them into a conditional variational autoencoder (cVAE) to predict pedestrian movement. If a pedestrian's future path is likely to intersect with the vehicle's trajectory and violates Euro NCAP safety standards, the system automatically decelerates or applies brakes to prevent collisions. The VLM also detects objects like obstacles, signage, and structural boundaries, and the LLM uses this contextual information to improve scene understanding and high-level decision-making. The system also accounts for environmental variables such as lighting conditions, weather, and dynamic objects to adapt driving behavior robustly.

In the bottom-right corner of the interface, a real-time Battery Management System (BMS) display provides insights into vehicle power conditions. A HIOKI LR8450 logger records voltage and current, which are used by a linear regression model to estimate State of Charge (SOC) and a Coulomb-counting algorithm to assess State of Health (SOH). Users can view live SOC and SOH values, and the system issues predictive maintenance alerts if battery degradation is detected, extending battery life and preventing unexpected failures.

By leveraging the synergy between LLMs and VLMs, this system delivers a highly intelligent and user-centric solution that reduces the time and stress associated with parking, enhances pedestrian safety through real-time behavior prediction, and ensures consistent electric vehicle performance. The architecture is scalable to multi-level parking structures, commercial complexes, and smart cities. It also prioritizes data privacy by encrypting voice commands and LiDAR data, storing only anonymized metadata for continual model improvement. Future expansions may include in-app payment integration, parking reservations, and multimodal mobility support (e.g., bike or scooter sharing). As the system learns from user history and traffic patterns, it will offer increasingly refined and context-aware parking recommendations.

Fig. 3 Driver's-seat view of autonomous golf cart dashboard.