A26-019

具備全場域導航之智慧型撿網球機器人

An Intelligent Tennis Robot with Full-Court Navigation and Ball Collection



隊伍名稱｜球求你別跑 Catch Me If You Can

隊　　長｜陳冠仲 / 中央大學電機工程研究所

隊　　員｜袁子婷 / 中央大學電機工程研究所

指導教授 ADVISOR



王文俊 | 中央大學電機工程學系

交通大學電子博士，現為中央大學講座教授。曾任中央大學教務長及院長、臺北科技大學研發長，並曾於美國喬治亞理工及路易維爾大學訪問研究。曾獲IEEE Fellow、國科會傑出研究獎、教育部學術獎。

研究領域

模糊控制與系統、神經網路、機器人、影像處理。

作品摘要

本作品「具備全場域導航之智慧型撿網球機器人」旨在解決網球多球訓練後大量人工撿球所造成的時間浪費與體力負擔。傳統撿球工具多仰賴人工推行，部分自走式撿球裝置也多半只能處理攝影機視野內已出現的目標，難以主動判斷球場中是否仍有遺漏網球。因此，本作品以「主動搜尋遺漏網球」與「完成全場域清理」為核心特色，進一步建立一套可主動搜尋、分區確認、跨場移動並完成全場清理的智慧型撿球系統。

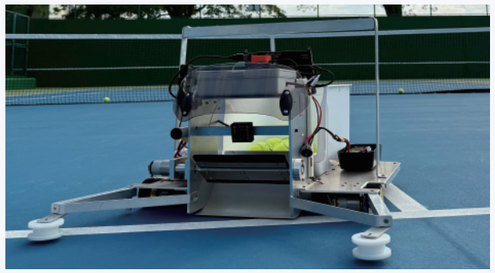
本系統整合車載影像辨識、無基站定位導航、分區搜尋策略與自製撿球機構。硬體方面，機器人採用客製化車體架構，前方配置V型導流軌道與具彈性接觸特性的EVA旋轉葉片，使網球能被導引至中央撿拾口並穩定送入後方儲球籃。此設計可降低多顆網球同時進入時的卡球風險，提升連續撿拾效率，並使機器人能應付實際訓練後網球密集散落的情境。

在視覺辨識與控制方面，本作品以NVIDIA Jetson AGX Xavier作為邊緣運算平台，搭配YOLOv8深度學習模型進行即時網球偵測。當攝影機偵測到網球後，系統會依據目標於影像中的位置進行視覺伺服控制，使機器人自動撿拾。底層則由Arduino Mega微控制器負責馬達控制與機構作動，將影像辨識結果即時轉換為車體移動與撿球動作。

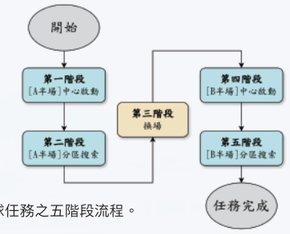
在全場導航方面，本作品採用編碼器里程計結合IMU航向資訊之定位方式，不需額外架設外部定位基站，即可估測機器人於網球場座標系中的位置與方向。系統將任務規劃為A半場中心啟動、A半場分區搜尋、換場、B半場中心啟動與B半場分區搜尋等階段。

機器人會先於半場中心進行搜尋與撿拾，若視野內未再發現網球，則前往各分區定位點檢查可能遺漏的球；完成單側半場確認後，再沿預設路徑繞過網柱前往另一半場，繼續執行搜尋與撿拾任務。

整體而言，本作品結合視覺辨識、無基站導航、主動搜尋策略與實體撿球機構，突破過去撿球機器人難以自行確認遺漏球的限制。系統不僅能追蹤並撿拾視野內的網球，也能依據場地分區主動巡查殘留目標，展現應用於網球訓練場域自動化清理之實用價值與發展潛力。



圖一 智慧型撿網球機器人之外觀。



圖二 全場撿球任務之五階段流程。

Abstract

This project, "An Intelligent Tennis Robot with Full-Court Navigation and Ball Collection," aims to reduce the time and physical effort required for manual ball collection after multi-ball tennis training. Conventional ball-collecting tools often rely on manual operation, while some self-propelled devices can only handle targets already visible within the camera's field of view. They are generally unable to actively determine whether any tennis balls remain on the court. Therefore, this project focuses on two core features: active searching for missed tennis balls and full-court cleaning capability. It establishes an intelligent ball-collecting system capable of active searching, partition-based confirmation, cross-court movement, and full-court cleaning.

The system integrates onboard visual recognition, base-station-free navigation, partition-based search strategy, and a custom-designed collecting mechanism. In terms of hardware, the robot adopts a customized chassis structure equipped with a V-shaped guiding rail and flexible EVA rotary blades at the front. This mechanism guides tennis balls toward the central collecting inlet and transfers them steadily into the rear storage basket. The design reduces the risk of jamming when multiple balls enter the mechanism simultaneously, improves continuous collection efficiency, and enables the robot to handle densely scattered tennis balls after actual training sessions.

For visual recognition and control, the robot uses an NVIDIA Jetson AGX Xavier as the edge computing platform and adopts the YOLOv8 deep learning model for real-time tennis ball detection. Once a tennis ball is detected by the camera, the system performs visual servo control according to the target position in the image, allowing the robot to collect the ball automatically. At the lower control level, an Arduino Mega microcontroller is responsible for motor control and mechanical actuation, converting visual recognition results into real-time robot movement and ball-collecting actions.

For full-court navigation, the system adopts encoder odometry combined with IMU heading information. Without installing external positioning base stations, the robot can estimate its position and orientation within the tennis court coordinate system. The overall task is divided into five stages. The robot first searches and collects balls from the center of one half-court.

If no more balls are detected within the field of view, it moves to partition points to check for possible missed balls. After completing one half-court, the robot follows a predefined path around the net post to reach the other half-court and continues the search and collection process.

Overall, this project combines visual recognition, base-station-free navigation, active search strategy, and a physical collecting mechanism. It overcomes the limitation of previous ball-collecting robots that could not independently confirm whether balls were left on the court. The system can not only track and collect visible tennis balls, but also actively inspect remaining areas based on court partitioning, demonstrating practical value and development potential for automated cleaning in tennis training environments.

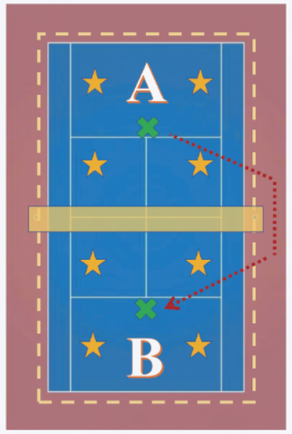


Fig. 3 The green crosses indicate the center starting positions of courts A and B, while the yellow stars represent partition search points. The light-yellow area denotes the net isolation zone, and the outer dashed boundary indicates the ball-collecting operation area. The red dashed arrow shows the cross-court path from court A to court B around the net post.