"Optimizing Agriculture with Robotics and Artificial Intelligence, A Focus on Autonomous Weeding and Vineyard Phenotyping"

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"The agricultural sector faces global challenges such as a growing population, limited farmland availability, and the pressing threat of climate change. Responding to these challenges, the Digital Agriculture Revolution (DAR) emerges as a beacon of progress, employing technologies like AI, Robotics, and IoT to support farmers and promote sustainable agriculture. However, Digital Agriculture encounters significant hurdles, with one of the most critical being the generalization of AI and robotics systems' performance. Models trained with limited and specific data struggle to adapt to new conditions. This thesis explores the variability in agricultural environments, influenced by local weather and soil characteristics, and investigates domain generalization methods to effectively address this diversity in two key use-cases: autonomous weeding and vineyard phenotyping. Autonomous weeding, an appealing solution to challenges like labor scarcity and environmental pollution, utilizes technologies such as machine vision and AI. The METRICS-ACRE project is introduced to assess and develop these technologies, tackling complexities such as different weed species and varying environmental conditions. Domain adaptation techniques are explored to improve the generalization of weed detection models on new domains, such as different acquisition platforms or years. Vineyard applications are also explored, focusing on plant phenotyping. This involves observing and measuring grapevine characteristics like growth patterns, yield potential, disease resistance, and reactions to environmental factors. The VINEPICs dataset supports the development of grape bunch detection and tracking, providing valuable data for yield estimation and vineyard management. Surgical Fine-Tuning (SFT) is presented as an innovative transfer learning technique to enhance the accuracy of instance segmentation models in various viticultural scenarios. Furthermore, the thesis delves into autonomous navigation within vineyards using LiDAR sensing. Unlike methods relying on pre-mapped routes, our approach utilizes real-time data to autonomously navigate vineyards, adapting to changes in the environment. This research contributes to digital agriculture, showcasing how innovative technologies can transform traditional practices, promising increased efficiency, and fostering sustainable farming. Nevertheless, the high variability of agricultural environments poses a generalization problem, which this thesis addresses by capturing the field's variability through real-world datasets and enhancing the generalization capabilities of models for real-world deployment."