

**PENGEMBANGAN SISTEM DETEKSI POSISI DAN *MONITORING*
PERTUMBUHAN TANAMAN DINAMIS PADA HIDROPONIK BERBASIS
INTEGRASI COMPUTER VISION DAN *COMPUTER NUMERICAL*
CONTROL (CNC)**

INTISARI

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Pemantauan dan pengukuran pertumbuhan tanaman hidroponik, khususnya selada, merupakan komponen penting dalam manajemen budidaya hidroponik pada pertanian presisi. Meskipun telah dirancang sistem monitoring otomatis menggunakan *XY plotter kit* keterbatasan masih ditemui seperti ketidakmampuan mengikuti perubahan posisi tanaman selama pertumbuhan. Penelitian ini bertujuan mengembangkan sistem deteksi berbasis *You Only Look Once* (YOLO) dan monitoring tanaman terintegrasi dengan mekanisme *Computer Numerical Control* (CNC) yang bergerak dinamis mengikuti perubahan posisi tanaman secara *real-time*. Prinsip kerja sistem CNC menggunakan motor *stepper* untuk pergerakan pada sumbu X dan Y dalam rangkaian hidroponik dengan penambahan *limit switch* sebagai pembatas gerakan untuk mengurangi kesalahan program. Sistem menggunakan dua kamera kamera utama berfungsi statis menangkap keseluruhan area budidaya, sementara kamera kedua dipasang pada rangkaian motor untuk analisis detail melalui model *computer vision* YOLOv11 untuk deteksi posisi dan segmentasi tanaman. Validasi model *computer vision* menghasilkan nilai *precision* dan *recall* 0,97189 dan 0,98718. Hasil uji sistem CNC menunjukkan performa sangat baik dengan nilai R^2 mencapai 0,9996 untuk motor X dan 0,9999 untuk motor Y, dengan nilai MAPE terkecil 0,21% dan RMSE terkecil 0,13. Implementasi pada tanaman selada hidroponik selama 21 hari membuktikan sistem mampu mendeteksi posisi tanaman dengan tepat mengikuti perubahan pertumbuhan tanaman dan mengukur pertumbuhan luas kanopi secara otomatis, memberikan solusi efektif untuk pemantauan pertumbuhan tanaman hidroponik.

Kata kunci: *computer numerical control, computer vision, sistem monitoring*

**DEVELOPMENT OF A DYNAMIC PLANT POSITION DETECTION AND
GROWTH MONITORING SYSTEM FOR HYDROPONICS BASED ON
COMPUTER VISION AND COMPUTER NUMERICAL CONTROL (CNC)
INTEGRATION**

ABSTRACT

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Monitoring and measuring the growth of hydroponic plants, particularly lettuce, is a crucial component of precision agriculture hydroponic cultivation management. Although an automated monitoring system using an XY plotter kit has been designed, limitations persist, such as the inability to track plant position changes during growth. This study aims to develop a detection system based on You Only Look Once (YOLO) and an integrated plant monitoring system with a Computer Numerical Control (CNC) mechanism that dynamically follows plant position changes in real time. The CNC system operates using stepper motors for movement along the X and Y axes within the hydroponic setup, with the addition of limit switches to constrain movement and minimize programming errors. The system utilizes two cameras: the primary camera statically captures the entire cultivation area, while the secondary camera is mounted on the motor assembly for detailed analysis using the YOLOv11 computer vision model to detect plant positions and perform segmentation. Validation of the computer vision model resulted in a precision and recall of 0.97189 and 0.98718, respectively. CNC system performance tests demonstrated excellent results, with R^2 values reaching 0.9996 for the X motor and 0.9999 for the Y motor, the smallest MAPE value of 0.21%, and the smallest RMSE value of 0.13. The system's implementation on hydroponic lettuce for 21 days confirmed its ability to accurately detect plant positions following growth changes and automatically measure canopy expansion, providing an effective solution for hydroponic plant growth monitoring.

Keywords: *computer numerical control, computer vision, monitoring system*