GEOREFERENCING AS A BASIS FOR ROBOTS IN HOP GARDENS – A SHORT NOTICE

Hubert LINSEISEN[1], Josef SCHMIDT[2], Martin LINSEISEN[3], Jitka KUMHÁLOVÁ[4]

[1]Agricultural Consultant, Breitenwiese 6, 85283 Wolnzach, Germany; Hubert.Linseisen@web.de
[2]Managing Director of the company digital workbench gmbh, St.-Gangolf-Str.2, 85139 Wettstetten, Germany, info@digital-workbench.de
[3]Graduate Electrical Engineer, Schillerstraße 27, 82223 Eichenau, Germany; martin@linseisen.org
[4]Department of Vehicles and Ground Transport, Faculty of Engineering, Czech University of Life Sciences, 165 21 Prague 6 – Suchdol, Czech Republic; kumhalova@tf.czu.cz

Abstract
The use of GNSS, GIS, and remote sensing data is becoming increasingly economical. This also applies to hop cultivation, which enables very high market yields per hectare. Individual vine or plant-specific treatments in hop cultivation promise significant economic and ecological benefits. This calls for a closer examination of the use of robots. A prerequisite for the use of robots in hop cultivation is the georeferencing of individual hop plants, poles, and anchors in hop gardens. The integration of georeferenced data layers is essential for the targeted treatment of individual hop plants. This article presents initial steps on how to automatically prepare georeferenced information for robotic use in hop cultivation.

Key words: *Robots for hop plants, hop production, GNSS, GIS, remote sensing, data processing*

INTRODUCTION

Georeferenced data are gaining increasing importance in hop production as well *(Kumhalova et al., 2021; Manakos et al., 2025; Linseisen et al., 2025)*. Barriers to implementing site-specific treatments-even down to individual vines-are gradually diminishing, including in hop cultivation. This article presents methods outlining initial steps for the automated preparation of georeferenced information as a basis for the necessary use of robots.

MATERIALS AND METHODS

Hop plants are typically planted at fixed intervals and with relatively consistent angles to one another within the row.
The distance c between two hop plants r_1 and r_2 can be calculated as follows:

$$c = \sqrt{(xr_1 - xr_2)^2 + (yr_1 - yr_2)^2} \tag{1}$$

The angle α, at which the hop plants r1 and r2 are positioned relative to each other, is calculated as follows:

In the first quadrant of a circle *(0°-90°)*: $\alpha = \sin^{-1}[(y_{r2} - y_{r1})/c]$ *(2)*

In the second quadrant of a circle *(90°-180°)*: $\alpha = \pi/2 + \sin^{-1}[(y_{r2} - y_{r1})/c]$ *(3)*

In the third quadrant of a circle *(180°-270°)*: $\alpha = \pi + \sin^{-1}[(y_{r2} - y_{r1})/c]$ *(4)*

In the fourth quadrant of a circle *(270°-360°)*: $\alpha = 3/2*\pi + \sin^{-1}[(y_{r2} - y_{r1})/c]$ *(5)*

X and y are the coordinates of the hop plants r_1 and r_2.
DJI M350 UAV with a high resolution camera *(DJI Zenmuse P1)* was used to scan the experimental hop garden “Viehweide Umbruch” on May 6, 2025.

RESULTS AND DISCUSSION

Fig. 1 shows hop plants of the "Viehweide Umbruch" field on May 6, 2025. As can be seen, some individual hop plants were not captured. Between the rows, hop plants were mistakenly identified. In the initial steps, the distances between the hop plants were determined. The distance in the "Viehweide Umbruch" hop garden, which uses the common German hop variety Herkules, is typically about 1.55 meters. If the calculated distance is clearly too large, a hop plant with its x- and y-coordinates is inserted via interpolation. Additionally, all hop plants identified outside the rows by the drone, which are not within the row's angle, are eliminated. Fig. 2 shows a portion of the "Viehweide Umbruch" hop garden after partial automatic data cleaning. The poles of the hop garden were also georeferenced during the flight. To verify the results, the poles were re-measured using a GNSS S580 receiver from geo-konzept. The desired accuracy of +- 2cm in surveying of the hop garden is achieved using RTK correction signals.

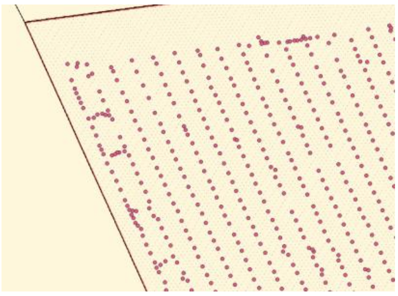

Fig. 1 Hop plants before data processing

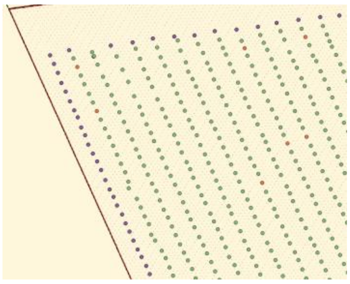

Fig. 2 Result after the data processing

During a second flight on June 17, 2025, the focus was mainly on georeferencing the anchors. The results are not yet satisfactory.
A fertilizer robot capable of addressing individual hop plants has relatively low requirements for the accuracy of the x- and y-coordinates. Deviations of 10 to 15 cm seem to be sufficient. The coordinates determined by the flight are sufficiently accurate for this purpose, as subsequent measurements have shown. GNSS-assisted pruning of hop plants, for example, has much higher accuracy requirements. The transmission of the x- and y-coordinates of the hop plants, poles, and anchors appears to be sufficient for fertilizer robots. Robots in the hop garden itself must work with 3D digital twins *(Gottschalk et al., 2024)*.

CONCLUSIONS

The partially automated calculated coordinates of the hop plants are, according to initial results, sufficiently accurate for applications such as fertilizer robots. Further research is needed into fully automated solutions for the necessary data processing.

ACKNOWLEDGMENT

The authors gratefully acknowledge Mr. Seidl-Schulz of geo-konzept, Adelschlag, and Mr. Granata and Mr. Bezenar of begrar drone solutions, Manching, for their valuable support in data processing and technical assistance throughout the study.

REFERENCES

1. Gottschalk, L., Kastning, K. & Seuß, F. *(2024)*. Hops 24 – Ertragserfassung im Hopfenbau, Praxisprojekt am Kompetenzzentrum für Digitale Agrarwirtschaft an der Hochschule Weihenstephan-Triesdorf, Triesdorf
2. Kumhálová, J., Chyba, J., Krofta, K., Starý, K. & Brant, V. *(2021)*. Evaluation of UAV and Sentinel 2 images to estimate condition of hop *(Humulus lupulus L.)* plants. *Acta horticulturae 1328*: 95-102. https://doi.org/10.17660/ActaHortic.2021.1328.13
3. Linseisen, H., Manakos, I., Delopoulos, A. & Linseisen, M. *(2025)*. Optimizing spatially variable information acquisition for smart hop management. Proceedings of the Scientific-Technical Commission, International Hop Growers' Convention I.H.G.C., Spalt, *(pp. 94-98)*, ISSN 2512-3785
4. Manakos, I., Linseisen, H., Katsikis E. & Delopoulos A. *(2025)*. Hop yield forecast using Sentinel-2 images. In: Dörr J. et al. *(eds)*, Lecture Notes in Informatics *(LNI)* – Proceedings der 45. GIL-Jahrestagung, 25-26. Februar 2025, Wieselburg, Austria *(pp. 309-314)*

Corresponding author:
Dipl.-Ing. *(agr.)* Hubert Linseisen, Ph.D., Agricultural Consultant, Breitenwiese 6, 85283 Wolnzach, Germany, phone: +49 170 52 19 274, e-mail: Hubert.linseisen@web.de