Evaluation of plant spatial placement by TF POLYM Software

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Abstract. Food production intensity is a key issue in the modern world. Due to the development of the possibility of increasing the production area, the technology is constantly being improved and supplemented to increase their efficiency. The basis of any cultivation is sowing, which should provide everyone with a suitable living space. It allows the plant to effectively use the applied fertilization, chemical protection or mechanical treatments. The article develops the options for determining the living space of plants. The computational algorithm uses the Voronoi diagram belonging to the computational geometry technique, and then the Delphi software, the TfPolyM computer application, which was developed at the Faculty of Engineering of the Slovak University of Agriculture in Nitra. Based on the digitization of photos, the software is able to calculate the living space of the plant, and also allows for a precise assessment of the uniformity and quality of planting.

1. Introduction
Under the term quality of seeding placement we understand horizontal and vertical seeding placement in the soil at its minimal damage. Most of crops is raising in rows, so the area distribution of crops depends on spacing between rows and on horizontal placement between seeds in row. This is the main evaluative criteria at evaluation area distribution of crops in the soil [Griepentrog 1995, 1998, 1999, Hermann, Heege 1970, Müller, Köller 2000]. SANDER-Schlinker [2002] contend the harvest is influenced by seed germination and by seeds spacing in the row. According to Weil [1990], Buchler, Köller [1990], Schmitz [2001], Szparaga et al. [2019] irregular stand and density stand have huge significance to crop weed competition. Irregular stand has negative impact on harvest and on internal quality of crops Findura [2017], Kocira et al. [2018]. Maga et al. [2017] successfully assessed the quality of sowing using the TfPolyM program, using in the experiment different driving speeds of the sowing unit in relation to the biomass yield. It is difficult to seed placement evaluation is more complicated for human labour. Living-space around crops may take the shape of polygons.

2. Materials and methods
When determining a polygon, it is essential which plants that are close to the reference plant are considered to be adjacent and that they are essential for forming the polygon. Polygonal layout solutions are known for many applications in various fields. Delaunay triangulation and Thiessen or Voronoi polygons are used (QUEST, D. - BRUNOTTE, J., 1997). Using Delaunay triangulation, which, according to ISO 19100 standards, constitutes such a mesh of triangles for which a circle passing through the vertices of any triangle does not contain any other triangle in its interior. According to Delaunay three adjacent points are those, which are sets on a common circle (k1), that doesn’t contains another point, in studied case crop (figure 1).

According to Voronoi points are adjacent, when polygons in consequence of polygons placement show common side-chain (create common side edges-walls). Fig. 2 and equation 1-2 shown, that points A and B doesn’t influence shape of polygon created around point S. Ideal field should has been circle, but it is not possible to reach ideal field by seeding machine, which we have. Circle shows for a given area smallest circuit. Its ratio, formed by the ideal and real circumference, should be used as a criterion for describing the shape deviation of the actual area from the ideal specific area (living space). For the shape evaluation of the area was introduced so-called shape factor.

\[ T_k = \frac{1}{n} \sum_{i=1}^{n} \frac{O_{\text{ideal}}}{O_{\text{real}}} \]  

(1)

\( O_{\text{ideal}} \) - the ideal circumference of a hexagon polygon,  
\( O_{\text{real}} \) - the actual perimeter of the polygon,  
\( S_i \) - the area of the actual polygon

The ideal circumference is determined by the actual size of the polygon area and according to:

\[ O_{\text{ideal}} = 3.7224\sqrt{S_i} \]  

(2)

The actual area of the polygon \( S_i \) is obtained by summary of triangles forming the polygon (Figure 2).
Figure 2 Voronoi polygon decomposition: 1 to 7, A, B, S- represent individual adjacent points (plants); k1- the circle on which the neighboring Denaunay points lie; a2´, a6´- lengths of perpendicular projections of nodes (2´, 6´) of the polygon for the sections SB and SA; b2´, b6´- half lengths of sections SB and SA.

Seeing that the identification of the coordinates of individual seeds respectively, plant in field conditions is a laborious matter, we have replaced it by digitizing the stand. We took a picture of the growth after emergence and we evaluated it to a scale using TiPolyM software.

3. Results

By using the software, the photos had to be converted from “jpeg” to “bmp” and adjusted to the size of the photo frame. The reason for this re-formatting is that the program can only work with the "bmp" format of a photo (Figure 3).

The software allows to evaluate different methods of seeding. The same seed quantities result in the same average area size. Polygons with the same area size can be distinguished in the shape of the area per plant. The ideal area should be in the shape of a circle, but we are not able to achieve it with current seed drills. In that the circle has the smallest circumference for a given area, the ratio formed from the ideal to the real circumference should be used as a criterion for describing the deviation of the shape of the actual area from the ideal specific area (living space). Figure 4 shows a block diagram of the software algorithm according to which the operation of recognizing seedlings and determining the optimal real living space of the plant and the resulting quality of sowing is carried out.
The software interface visualizes the plant's living space in a real photo (Figure 5), which allows the software to be used by unqualified personnel and ensures its universality.

Figure 5 Detail of Plant Living Space Evaluation

The activity of the program consists in designation of plants respectively, points and finding their neighboring plants. After that, the living space around the individual plants is designated and the living
space area of the plants is subsequently determined. The programme can be also used to determine the proper place to set the probes for soil resistivity measurement [15].

4. Conclusion

The results that I present in the paper were required by the needs of practice, which was not always able to accurately orientate in the selection of suitable seed drill equipment. Producers offer different types of seeders that create living space around plants of different shapes. The evaluation criterion is usually the longitudinal misalignment of the sowing, but it cannot be used for track sowing. The evaluation criterion for characterizing the living area around a plant is a shape factor. The shape factor values vary depending on the seed drill speed. Created TfPolyM software allows to compare and evaluate different methods of sowing, which is original. The contribution was solved within the project VEGA 1/0642/18 "Analysis of the impact of structural parts of forestry mechanisms in the forest environment from the point of view of energy and ecology".

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