A software tool to visualize soil moisture dynamics of an irregular-shaped profile

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ABSTRACT

Software for two dimensional visualization of values that have been automatically measured with in place sensors is difficult to find. Usually these programs assume a regular area and a regular grid of measuring points. In practice, however, both the shape of the area and the position of the sensors are often irregular. This paper describes the program TDRFree, which visualizes the soil moisture content that has been automatically measured with a set of measuring devices distributed over an irregular 2-dimensional soil profile. The output consists of a series of contour-plots which can be easily combined and presented as an animation. It is also possible to generate values for a derived property such as soil water repellency, which depends on moisture content. The program can be applied to any data set that is measured in a 2-dimensional grid.

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1. Introduction

In recent decades a number of computer programs have been developed to simulate two- or three-dimensional flow of groundwater in both unsaturated and saturated soils (Graham and Butts, 2005; Šejna et al., 2011; Šimůnek et al., 2011). These models include a module to graphically visualize the results of the simulations in 2-dimensional contour-plots. To validate the model results and gain more insight into the soil moisture flow processes, moisture contents are measured continuously in the field or laboratory, both in 2 (Worsching et al., 2006) and 3 dimensions (Beff et al., 2013), yielding a lot of data. Nearly all available papers present results in neat contour plots, but they fail to mention how these plots are prepared. Most likely the presentation of the measured data is done using charting features of spreadsheets like Excel (MicroSoft Office, http://www.microsoft.com/) or Calc (http://www.openoffice.org/). These packages can only handle data measured with a regular *x–y* grid and can only present one plot at a time. If irregular grids are to be represented, more sophisticated packages like MathLab (http://www.mathworks.com/) can be applied, or one of the packages from R (http://www.r-project.org/).

Several years ago the program TDRProcessor was developed to create animations from measured soil moisture data (Wesseling et al., 2008; Wesseling, 2009). We used the program to process the measured moisture contents obtained from several experimental fields. The 'movies' generated with that software have been presented at numerous national and international scientific conferences and symposia to show the course of soil moisture changes in time. Researchers and students alike have commented that the movies improve the insight into the dynamics of soil moisture flow. Though the software has been successfully and extensively used, some desirable extensions have also been identified, such as

- capability to visualize data from irregular shaped soil profiles (e.g. potato fields);
- capability to account for sensors installed in an irregular grid;
- option to show a larger number of soil profiles simultaneously;
- visualization of additional moisture related soil properties.

If data is measured in an irregular grid in the horizontal (*xy*-) plane, usually some kind of geo-information tool is applied to generate maps of measured values. These tools are usually commercial products, e.g. ArcView (www.esri.com) or SpecMaps (http://specmaps.com/img/User's%20Guide%20ProTurf.pdf). A good open-source alternative to these packages is Saga, which can be downloaded free at www.saga-gis.org. As these packages are general-purpose software packages and are rather complicated for a non-experienced user, a more dedicated program is preferred. Searching the internet for software and publications on processing continuously measured data in an irregular grid has

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shown that the main development of visualization techniques was presented in the papers of the Institute of Electrical and Electronics Engineers (IEEE) in the early 90's. However, it also revealed that while there are publications available on the processing of data measured on an irregular grid (e.g. Wittenbrink, 1995; Leven et al., 2002), no simple and user-friendly programs are available that can work with this kind of data. Therefore we decided to create our own program and named it TDRFree.

This paper presents the main features of the TDRFree program and shows a few examples of output. For a description of the underlying theory and methods, the program manual (Wesseling and Oostindie, 2012) can be consulted.

2. Materials and methods

2.1. Data collection

In 2009 and 2010 a detailed field experiment was carried out at the 'De Vredepeel' experimental farm of Wageningen University and Research Center (WUR). The aim of the experiments was to investigate the effects of different soil surfactant and irrigation treatments on moisture content and potato growth during the growing season (Oostindie et al., 2012). The soil consists of non-calcareous fine sand with a clay content of $< 3\%$ (w/w) to a depth of > 2 m. The dark colored topsoil is 30–35 cm thick and has an organic matter content of 3–4% (w/w). The subsoil below this plow layer is more yellow in color and contains less than 0.5% organic matter. Potatoes of the variety Fontana were planted on 5th of May 2009 in rows with a distance of 75 cm. Four treatments were used (1) a control with no soil surfactant treatment and no irrigation, (2) irrigation alone, (3) soil surfactant alone, and (4) irrigation plus soil surfactant. To monitor the soil moisture content of the potato ridges, a total of 151 soil moisture-sensors were installed, distributed over the 4 experimental plots. Sensors were located both under ridges and under furrows. The sensors were installed in a rather irregular pattern (Fig. 1). On the basis of time domain reflectometry (TDR) moisture content was measured and recorded automatically every 2 h.

2.2. The applied methodology

As in the previous version of the program, the input data for this new tool is read from three Excel files. The user defines the boundaries of the area under consideration and the location of the moisture sensors. The program generates a grid of triangular and/or quadrilateral elements as defined by the user. The corners of these elements (called nodes) coincide with the positions of the sensors.

This approach is based upon the well-known finite-element technique that has been applied regularly in hydrology and mechanics (Hughes, 1987).
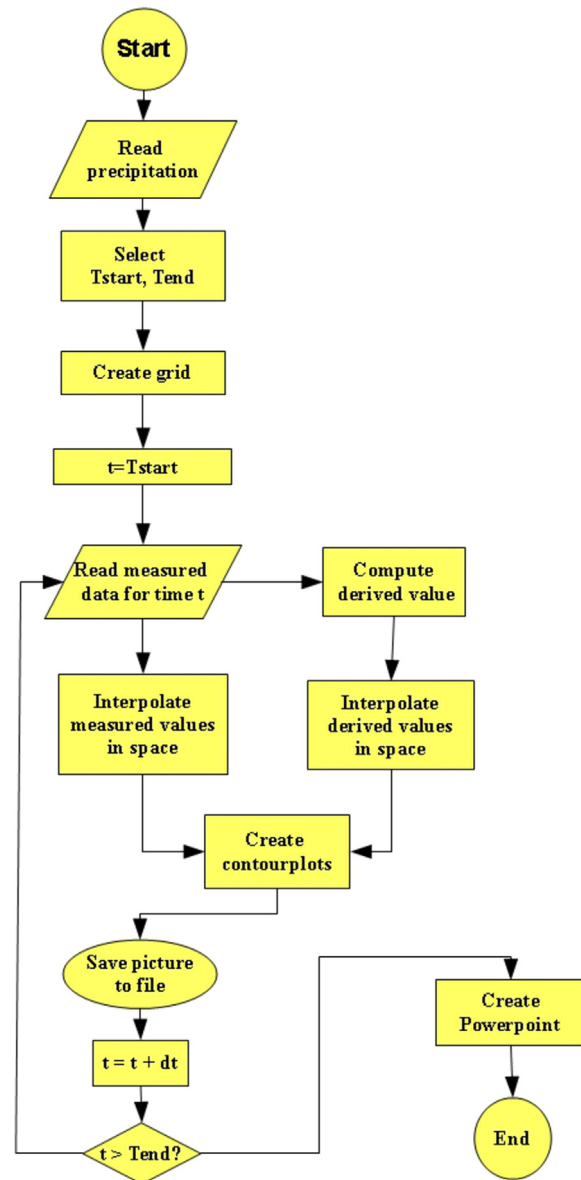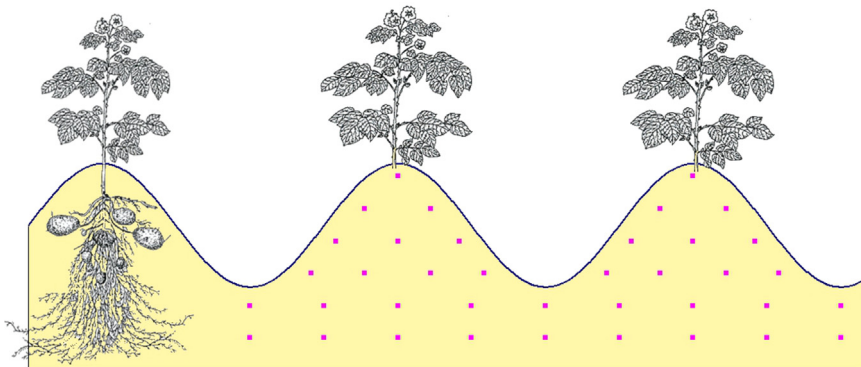

Fig. 2. The flowchart of the TDRFree program.

Fig. 1. The measuring setup with TDR sensors installed in the ridges and under the furrows of a potato field. The purple squares indicate the locations of the sensors. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this article.)