TOWARDS AUTOMATING THE PRODUCTION OF SOIL SURVEY MAPS
(Extended Abstract)

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ABSTRACT

Soil survey involves the study of soil characteristics in order to predict exploitable properties. For example, predictions may be made as to the most viable crops or the best scheduling of seasonal activities. The results of the detailed soil survey, and of the predictions, are presented as a series of maps. Producing soil survey maps is labour intensive and uses highly skilled soil scientists who sample the soil in the survey region and deduce boundaries between soil types, often sketching these during the survey.

This paper describes a project whose objectives are; firstly, to make the process of map production less reliant on the availability of highly qualified personnel; secondly to remove some error-prone manual processes; and thirdly, to make the results of expensive surveys more widely available.

The approach described attempts to assist the production of maps by automating the analysis of the original survey data. The process uses the Voronoi tessellations of the point survey data as a convenient data structure. An approximation to the detailed soil map is then derived directly by combining this information with the other data for the region. It is the efficient performance of this combination step which is the principle goal of the current phase of the project. The paper concludes by describing the remaining problems and future directions for the work.

Keywords: Soil Survey, Cartography, Computer Aided Mapping, Voronoi Tessellations, Thiessen Polygons, Dirichlet Regions

Background

A soil survey involves the detailed study of the soil types and characteristics over the survey region in order to be able to predict various exploitable properties. For example, results might indicate the most viable crops, the best strategy for soil management (e.g. scheduling of seasonal activities), and the suitability for particular developments (e.g. irrigation). These results are produced as a number of thematic maps showing individual aspects. For example, figure 1 shows a sample from a map displaying the suitability of the ground for irrigation.

The trial survey data used for this project has been derived from a recent survey of part of the Argos plain in Greece, undertaken by the Greek Government as part of a project funded by the Food and Agriculture Organisation of the UN [3]. For this survey maps are produced manually. The soil is first sampled at a large number of points (figure 2) and the findings at these points used to define regions of constant soil type on detailed soil survey maps (figure 3). The raw data for one map sheet consists of approximately 5000 sample points plus those topographic features which will appear on the map. Each sample point is encoded to show the classification of various attributes recorded in the field (e.g. figure 4). As can be seen from the sample in figure 3 the detailed soil map consists essentially of a polygon mosaic where each polygon boundary delimits an area of constant soil type. These polygon boundaries are defined in one of two ways:

(1) The surveyor in the field records point data plotted as shown in figure 2, which the cartographer then analyses, drawing boundaries around regions where all the samples share the same classification.

(2) The surveyor may plot the boundaries directly, as in, for example, recording a boundary where the slope changes.

The final components of the detailed soil map are the topological features such as towns, rivers and roads, which are derived from standard maps and/or aerial photographs.

Thematic maps are produced from the detailed

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soil map by amalgamating adjacent polygons in
the mosaic where the differences between the
detailed soil classifications of the polygons
are not significant within the classifications
of the theme being mapped. The successful
production of a suitable detailed soil survey
map is thus the first stage in any automated
system for thematic map production.

The first phase of this work (reported in [2])
was directed at simulating the way in which
the first category of polygon boundary above
was generated from the detailed point data.
For this category of polygon, each point is
being used to define an area of influence
and, if sample points are of equal signifi-
cance, the areas defined by the points are
given by their Voronoi tessellations. The
pilot system therefore constructed the Voronoi
tessellations and amalgamated adjacent tiles
of the same classification to produce an
approximate detailed soil map for this type
of data. Topological features were then
overlaid and a variety of output formats
considered (e.g. figure 5). Colour output
has also been produced, but is not included
here due to problems of reproduction [2].

Progress in the Project's Second Phase

At the end of the first phase there were still
a number of factors not fully integrated in
the production of the detailed soil map:-

(1) There had been no attempt to combine
polygons not generated from the point
data into a combined polygon mosaic.

(2) The choice of shadings and colours used
for map display were chosen at random,
rather than using an algorithm to reflect
the properties of the soil type.

(3) No attempt had been made to associate the
extra detailed information from soil
profiles, hydraulic conductivity and
water infiltration tests with the rather
cruder soil samples.

By the end of the second phase it is intended
that all of these problems will have been
tackled, but at present the most progress
has been in the first area with some effort
and ideas for the other two areas. The
primary problem is the definition of suitable
algorithms to merge the polygon mosaic defined
by the surveyor in the field (e.g. for hilly
soils) with the mosaic of Voronoi tiles
produced from the point survey results.

Four approaches for this step have been or are
being considered, as follows:-

(1) An adaption of Green and Sibson's method
[6] for computing the Voronoi tessellations
of the point data, so that the
tessellations are computed within an
arbitrary closed polygonal boundary,
which may include holes, rather than
the current implementation which uses a
rectangular outer boundary.

(2) An incremental vector based technique
for amalgamating a complete mosaic
of Voronoi tiles, computed using a
rectangular boundary as at present, with
a polygon mesh digitised from the field
survey.

(3) The use of temporal priority (i.e. the
order of painting the polygons on raster
displays) to produce merged raster
images without ever computing areas of
overlap and positions of intersections.

(4) The most promising method is a develop-
ment of method (3) first proposed by
Earl [7,8]. In this technique the edges
of the two complete polygon mosaics are
first drawn into single bit overlay planes
in a frame buffer. These overlay planes
are then scanned sequentially and points
of intersection detected where the bits
are set in both overlay planes. The
practical problems of implementing this
conceptually simple algorithm will be
discussed.

It is apparent that these techniques can be
applied for all the polygon mosaic work not
covered by the first phase of the project.
In addition to the problem of merging the
polygon mosaics, some experiments are being
carried out using the algorithmic generation
of colour and texture to try and reflect the
various soil types. When applied to detailed
soil maps the number of parameters appears
prohibit a simplistic mapping of properties
to colours, but it is however possible to
invent reasonable algorithms for use with the
thematic maps.

The use of the detailed soil profiles and the
results of other tests is based partly on
proximity to the point of testing and partly
on the soil type of the samples where the
detailed test was made. The incorporation
of this data will therefore use proximity
calculations, aided by the Voronoi tessell-
lation work of the earlier stages of the
project, combined with keyed cross referencing,
via the soil classification, based on more
traditional database techniques.

Further Work

Whilst considerable progress has been made,
it is obvious that there are several topics which must be addressed before these methods could be applied in a production system. Amongst these are:

(1) Efficient handling of the large volumes of data involved in real surveys.
(2) Design of a suitable query language for accessing a database of stored maps and analysis results. Early work has already been done on some aspects of this [5].
(3) Related to (2) is the more generalised problem of the definition of the classification schemes used to define thematic maps and the mapping symbols used to represent them.
(4) Effective and user-friendly interfaces for all aspects of the system, from data entry and checking to map specification and production.

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References

Figure 1  Irrigibility Map for part of the Argos Plain

Figure 2  Sample data for part of the same survey
Figure 3. Detailed Soil Map for the Same Region

Figure 4. Sample of Classification Scheme Used for Soils

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Figure 5(a) Check plot of data points combined with computer generated soil polygons

Figure 5(b) Manually produced detailed soil map for this area

Graphics Interface '84
Figure 5(c) Computer generated soil polygons superimposed on manually generated detailed soil map