SoLIM Workshop

Soil Mapping Using GIS, Expert Knowledge & Fuzzy Logic

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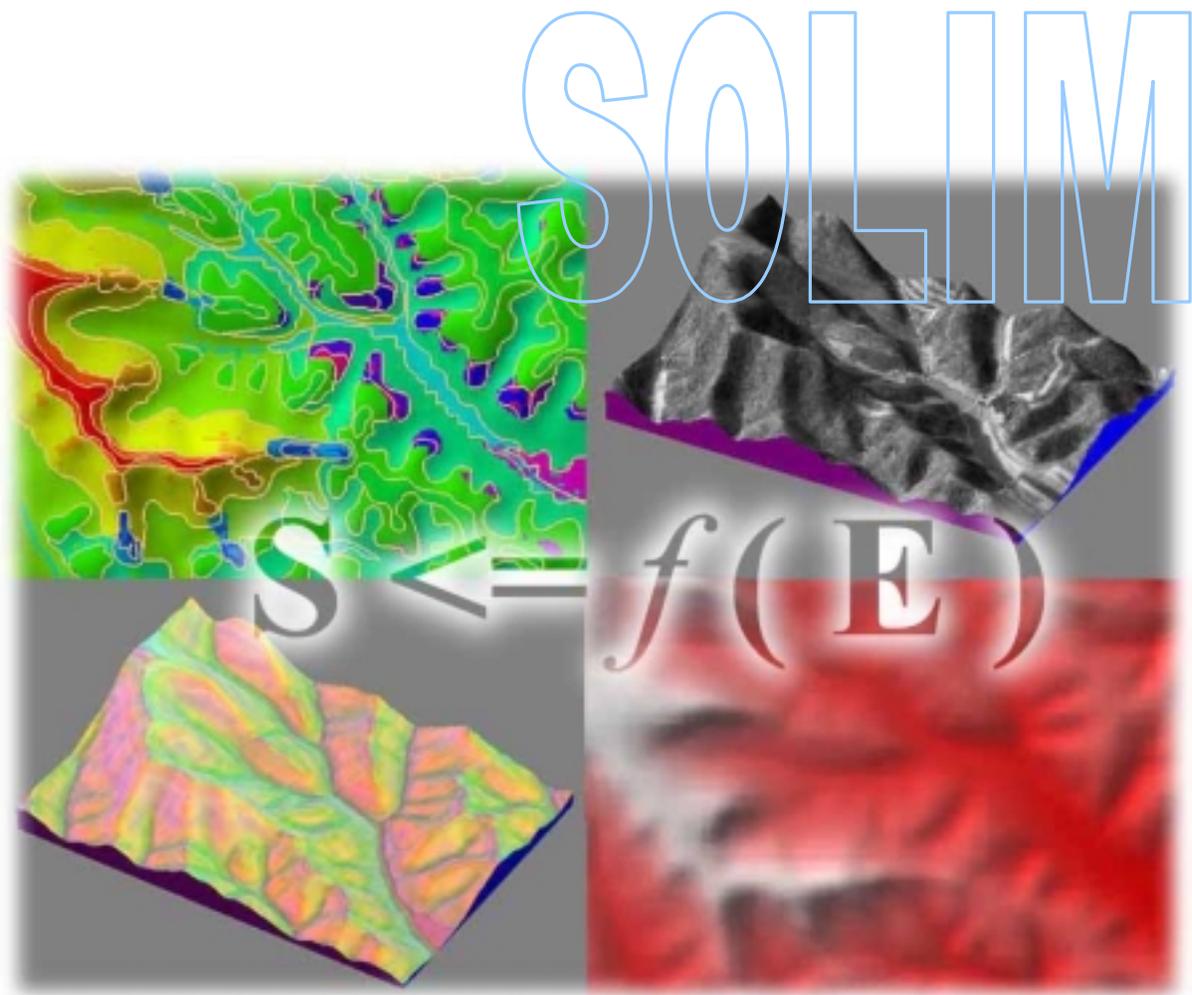
February 16, 2001

University of Wisconsin-Madison

Objective

The purpose of this workshop is to show how the new (SoLIM) approach can contribute to the current soil survey and soil landscape analysis programs. In particular, we hope the workshop will provide some insight as to how this new technique can help expedite soil survey and improve the quality of its products. We would also want to discuss how the fuzzy soil information might be used to assist soil interpretation. Possibilities of future enhancement to the SoLIM approach will also be presented.

Agenda

Morning
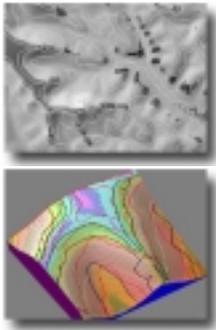
◇ Overview of Challenges to Soil Survey

◇ Products and Accuracy of SoLIM

◇ Process of Using SoLIM in Soil Survey

Afternoon

◇ Current Efforts to Enhance SoLIM

◇ Open Discussion

The Problems SoLIM Addresses

The Current SoLIM

Current soil survey is based on the classic concept of soil-landscape relationship. To conduct a soil survey for a given area, soil scientists first build a soil-landscape relationship model through analyzing the landscape and through extensive fieldwork. Traditionally, the spatial distribution of soil landscape units were identified through photo interpretation and delineated to form soil polygons.

There are three major challenges in this methodology of soil survey. The first is the polygon-based model used in soil maps on which only soil bodies of certain size (scale dependent) are shown and small soil bodies are omitted. Consequently, the level of details is limited by the scale of the map, not by what the soil scientists know. Also, the soils in a given soil polygon are often treated as the same, and changes of soil only occur at the boundaries of polygons.

The second challenge is the manual mapping process which is not only tedious and time consuming, but also error prone and inconsistent. In addition, it is very difficult for soil mappers to identify soil-landscape units using more than three different environmental data layers, due to the limited capability of visually perceiving many variables simultaneously. As a result, the delineation of soil-landscape units may not be as exhaustive as soil-mappers hope. In fact, most soil-mappers base their soil-unit delineation solely on the visual interpretation of stereo photos. Subtle and gradual changes in environmental conditions are often difficult to be discerned via stereoscoping, and so it is easy to misplace the boundaries of soil polygons in the manual delineation process.

The third challenge is the documentation of a soil-landscape model for a given area. The issues are: 1) to what level the soil-landscape model being documented; 2) how much experience (knowledge) for a given area is being passed from one generation of soil mappers to another. In most cases, the knowledge of the soil-landscape model of an area is lost when the soil mapper retires or moves out of the area. The new soil mapper thus has to 'start from scratch'.
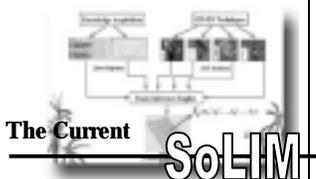
Overview of SoLIM Approach

SoLIM overcomes the polygon map model by employing a similarity model which represents spatial variation of soils by small pixels (dependent on the resolution of environmental data, not the map scale) and the soil at a given pixel as the similarity vector.

It overcomes the manual mapping process through the use of GIS techniques and an automated inference scheme. This inference technique determines the similarity vector for the soil at each pixel position.

The knowledge documentation problem is overcome by explicitly extracting and storing the soil-landscape in a knowledgebase, and is separate from the mapping process.

The Current

SoLIM

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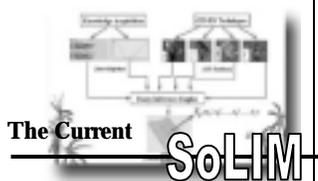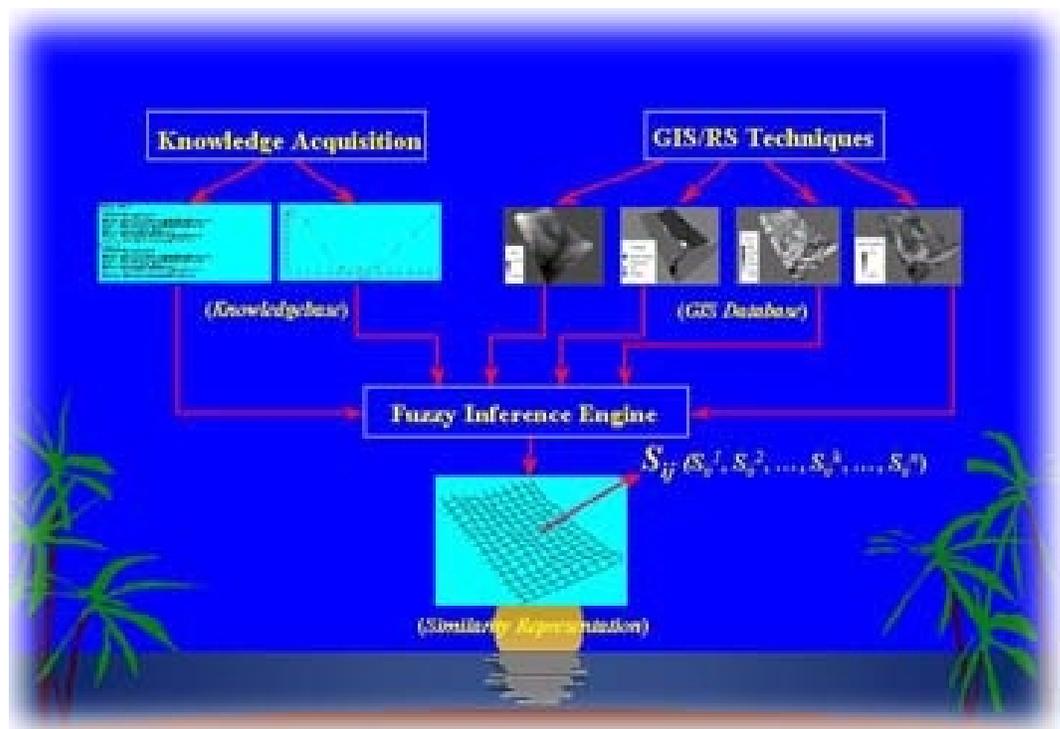
Products and Accuracy 1

The products from SoLIM can be perceived as two major components: the map products (various forms) and the extracted soil-landscape model (various formulations).

Among the map products, there are fuzzy membership maps, raster soil categorical maps, uncertainty maps and conventional soil polygon maps.

Fuzzy membership maps

Fuzzy membership maps show the spatial gradation of soils, and preserve the intermediate nature (between types nature) of soils, thus assisting soil interpretation with more useful information then traditional means.
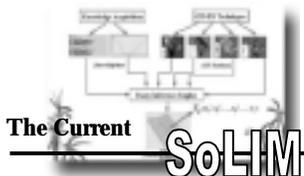

Raster soil categorical maps

Detailed raster soil maps contain soil bodies as small as a single pixel. Not only is the soil map much more detailed, but also uncertainty in creating such a raster map from the fuzzy membership can be produced to assess the validity of assigning local soils to prescribed soil types.

Accuracy

The Current SoLIM
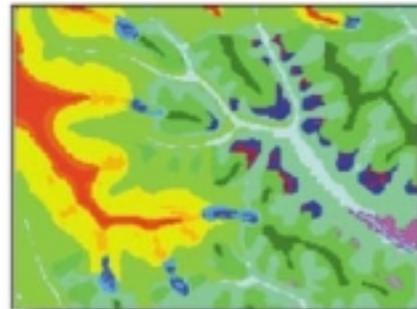
The SoLIM approach has achieved over 80% accuracy when compared with field observations. The accuracy of conventional maps are often between 60% to 70%.

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Conventional soil polygon like maps can also be created from the fuzzy representation. We know that it is inevitable for a soil polygon to include some small soil bodies which are different from what the soil polygon is labeled to be. These inclusions can be reported on a soil polygon basis which is a great improvement over the conventional approach to reporting inclusions (often lumped into a mapping unit).

Conventional soil polygon like maps

The soil polygons produced from the SoLIM approach are consistent with the soil-landscape model due to their ability to accurately discern the subtle and gradual variation of environmental conditions (given that the data is accurate). On the other hand, the soil lines may not follow the landscape variation well due to the difficulty encountered by soil mappers in photo interpretation.
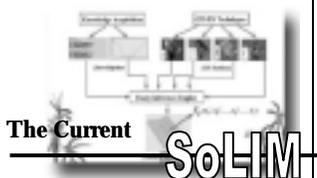
Products and Accuracy 2
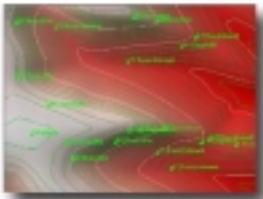
The extracted soil-landscape model knowledge can be documented by several different means:

- ❖ Catenary sequences
- ❖ Dichotomous keys
- ❖ Soil-environment descriptions
- ❖ Tacit points (typical locations for each soil types)
- ❖ Fuzzy membership functions

These separate aspects of knowledge can be studied and updated by current and future soil scientists, and can also be reused in future soil survey updates.

An image of tacit points
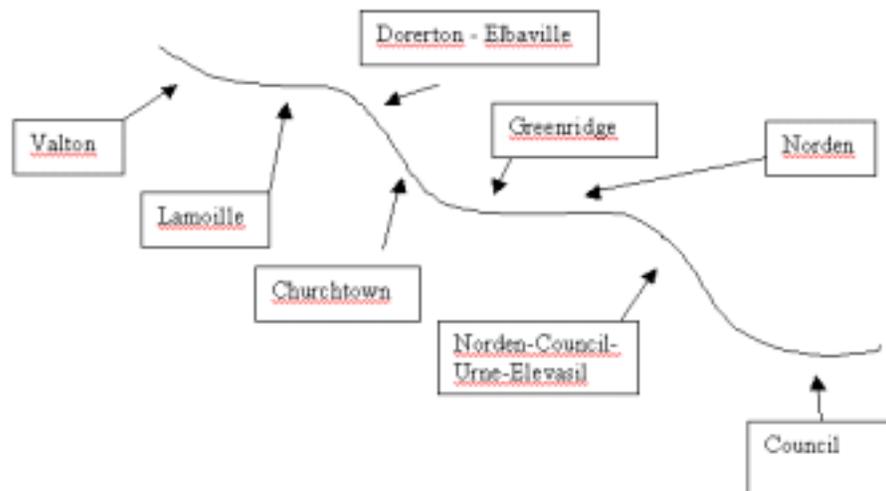

An example of catenary sequence

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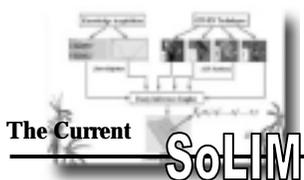
Using SoLIM in Soil Survey 1

Extract the soil-landscape model

The process of applying SoLIM in soil survey can be divided into four steps:

1. Extract the soil-landscape model, which is done by answering the following questions and completing the following tasks:

   ◆ What are the different types of soils in the area?

   ◆ What is their catenary sequence?

   ◆ What are the key environmental variables that are important in distinguishing these different soil types?

   ◆ Use the environmental variables to key out these soil types.

   ◆ Describe the environmental conditions under which each soil type typically occurs.

   ◆ Show the geographic locations where each soil type typically occurs.
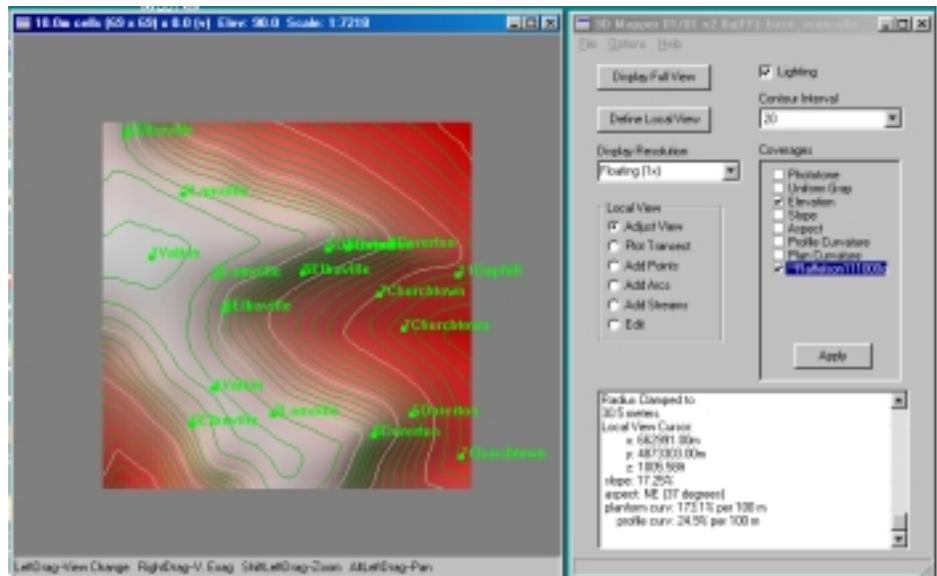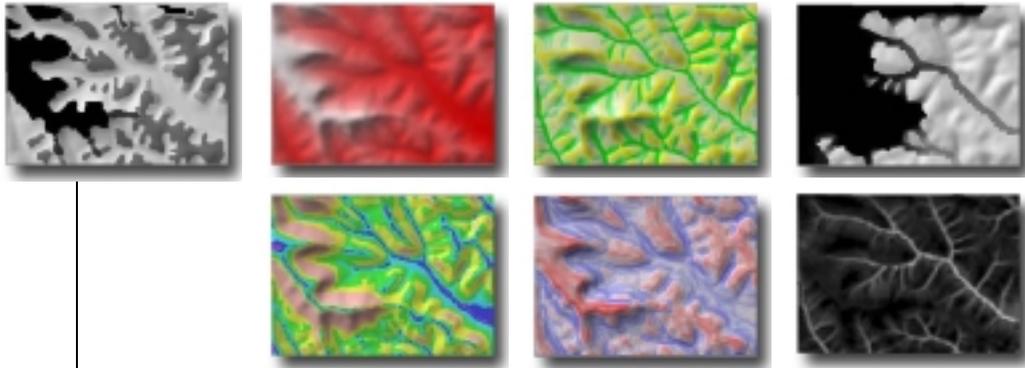
Locating tacit points

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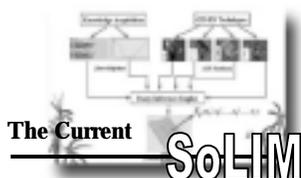
Steps

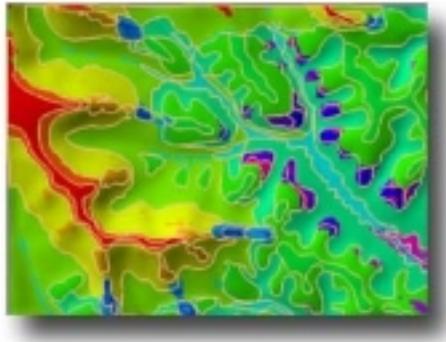**Construct the GIS database**

2. Construct the GIS database:

Based on what we learn from the soil scientists, we derive GIS data on the important environmental variables.


Perform the soil inference

3. Perform the soil inference.

Verification

4. Verification by soil scientists:

Soil scientists examine the inferred result to see if what produced by the inference engine matches what is expected. If not, it is necessary to identify problematic areas and the causes. The products can then be improved by updating the soil-landscape model and/or including additional environmental variables.

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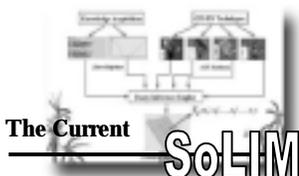
SoLIM

Using SoLIM in Soil Survey 2

The most important requirements of the SoLIM methodology are:

The soil-landscape model and necessary environmental data.

The soil-landscape model

The participating soil scientists should already have a satisfactory soil-landscape model for the area under concern. If not, the soil scientists should build such a model before applying the SoLIM approach. We are developing techniques to assist soil scientists to quickly develop satisfactory soil-landscape models.

Environmental Data

The necessary environmental data are generally DEMs and geology information. Orthophotos are useful if available.

Role of soil scientists

Clearly, the role of soil scientists in making SoLIM function is paramount since it is their soil-landscape model which the SoLIM approach relies on.

Cost effective

The modular design allows each component to be updated independently of the others. This design makes the initial investment reusable and cost effective. In addition, it will speed up future updates.
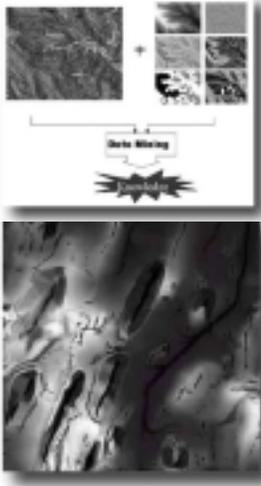
Training

Although the SoLIM methodology is in place, training is needed to make the process more efficient. The training is necessary because:
1. Experts need to be comfortable with the approach
2. GIS personnel need to be proficient in the SoLIM methodology

The Current

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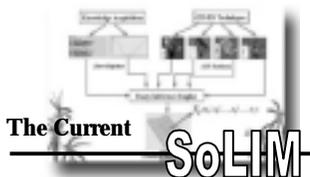
Current and Future Efforts

There are a number of extensions to the current methodology to be pursued. The following three are the priorities:

1. Helping to implement SoLIM in soil survey
2. Exploring the use and interpretation of fuzzy soil information from SoLIM
3. Enhancing SoLIM

With regards to the enhancement of SoLIM, we currently focus our efforts on building and extracting the soil-landscape model. Specially, we are examining the utility of data mining techniques for extracting soil-landscape model from non-human sources (such as maps). We are also exploring the use of fuzzy classification techniques to assist soil scientists in initially building soil-landscape models. In addition, we continue to enhance the 3dMapper to facilitate knowledge acquisition (extraction of soil-landscape model).

Extracting Knowledge

Feng Qi

❖ Through years of soil surveys, soil scientists have accumulated their understanding of the local soil-environment relationship. And this understanding is embedded in paper maps. It is hypothesized that the knowledge embedded in conventional soil maps could be extracted using data mining approach. The knowledge could then be applied to soil mapping under the SoLIM framework. This research makes SoLIM applicable in regions lack of experienced soil experts yet with soil maps available.

Building soil-landscape model

Edward English

❖ Because the SoLIM methodology is driven by expert knowledge, it would be of considerable importance to clarify soil-landscape relationships in situations of limited expert experience, with the goal of improving the accuracy of inferred soil information. The purpose of this study was to demonstrate how an unsupervised fuzzy classification scheme, known as 'fuzzy c-means', could be employed to provide preliminary soil-landscape models for study areas.

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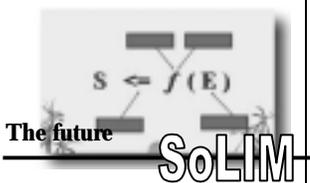
Improving Inference Engine

Xun Shi

❖ Another research avenue currently under way is to explore a more integral method to incorporate the two types of soil scientists' knowledge. The goal of such integration is to build a 'user-friendly' interface for the CBR inference engine, in order to give soil scientists more flexibility when expressing their knowledge. In addition, this new method can consider the spatial similarity when running CBR (currently only the parametric similarity is considered).

Enhancing 3dMapper

James Burt

❖ 3dMapper has been played an important role in knowledge acquisitions for the SoLIM approach. It can also be used to examine and improve conventional soil maps. The usage of this tool will be demonstrated. We are also soliciting suggestions on enhancements to 3dMapper.

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The future
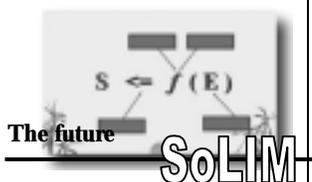
SoLIM

Appendix: SoLIM Tools

We have developed a set of software for the implementation of SoLIM approach to soil survey practice, including the 3D visualization tool (3dMapper), the case-based reasoning inference engine, the integrated SoLIM interface, and a series of other useful utility programs.

3dMapper

❖ **The 3dMapper Software**
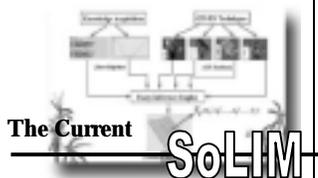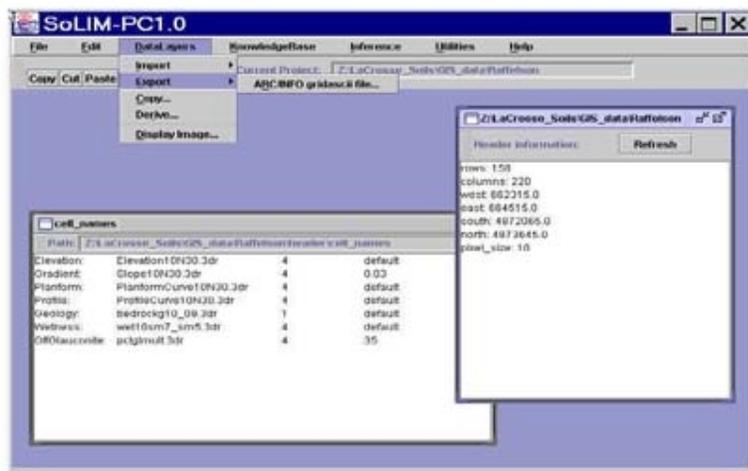---- developed by Professor Jim Burt, UW-Madison.
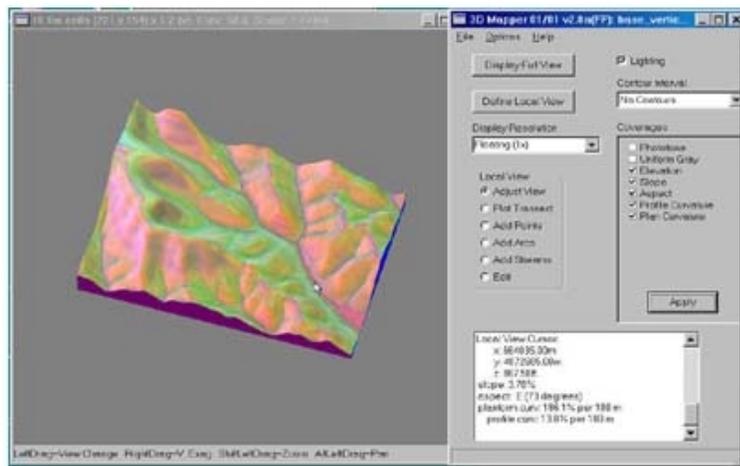
Case-based reasoning

❖ **The Case-based Reasoning Inference Engine**
---- developed by Xun Shi, A-Xing Zhu, Feng Qi, UW-Madison.

❖ **The SoLIM Interface**
---- developed by Feng Qi, UW-Madison

SoLIM Interface

Appendix: Contact Information

A-Xing Zhu
550 N. Park Street
Dept. of Geography, UW-Madison
Madison, WI 53706

Tel: (608) 262-0272
Fax: (608) 265-3991
Email: axing@geography.wisc.edu

James Burt
550 N. Park Street
Dept. of Geography, UW-Madison
Madison, WI 53706

Tel: (608) 263-4460
Fax: (608) 265-3991
Email: jburt@geography.wisc.edu

Xun Shi
Tel: (608) 262-1857
xunshi@students.wisc.edu

Edward English
Tel: (608) 262-1857
emenglish@students.wisc.edu

Feng Qi
Tel: (608) 262-1857
qif@geography.wisc.edu

SoLIM Homepage:
http://solim.geography.wisc.edu

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