Introduction to Decision Support Systems

- A Decision Support System (DSS) integrates and organizes all types of information required for production decisions.
- DSS tools vary in complexity:
  - Data component, e.g., automated weather stations or site-specific weather products
  - Tools for processing data: rules, schedules of management, equations
  - Combinations of decision aids
  - Complex computerized expert systems

Computerized disease forecasting systems

- Stand-alone forecasters: in-field electronic forecasting systems
  - Example: Spectrum Technologies Inc. [http://www.specmeters.com/home_usa.html]
  - Example: Weather Innovations Inc. with 'Beetcast' [http://www.michiganbeets.com/contact.cfm]
- Interactive on-line forecasting systems
- Spatial trajectory systems
- Expert systems
- Neural networks

Summary

Overview

- Introduction to Decision Support Systems
- Computerized disease forecasting systems:
  - Stand-alone forecasters
  - Interactive on-line forecasting systems
  - Spatial trajectory systems
  - Expert systems
  - Neural networks
- Summary
Computerized disease forecasting systems

- Electronic units commercially available for forecasting several different diseases on the following crops:
  - Apple/pear, grapes, cherries
  - Turf grass, potatoes, tomatoes, onions etc.
- Advantages of in-field forecasting units:
  - potential to provide more accurate, site-specific information
- Disadvantages:
  - units are relatively expensive ($1000-$3000) and easily damaged (by lightning, field equipment, etc.)
  - require periodic maintenance, sensor calibration, frequent data acquisition

Lettuce production in California

Controlled environment studies – Temp. & LWD

Example: downy mildew of lettuce

Gompertz model
\[ Y(t) = Y_{\text{max}} \exp \left(-\exp(k \cdot t)\right) \]
\[ Y_{\text{max}} = \text{asymptote parameter} \]
\[ k = \text{rate parameter} \]

Modified Gompertz model
\[ Y(t, \text{LWD}) = Y_{\text{max}}(T) \exp \left(-\exp(k(T) \cdot \text{LWD})\right) \]
\[ Y_{\text{max}}(T) = a \cdot e^b \cdot T \cdot e^{-c(T)} \]
\[ k(T) = b \cdot e^d \cdot T \cdot e^{-e(T)} \]

Simple deterministic model

- constant vs varying temps

Standardized growth rate of constant temperature

Organism A

Standardized growth rate of fluctuating temperature

Organism B
Field studies – microloggers & spore trap

Field studies – Temp, RH, LW

Field studies – weather variables -> infection

Field studies – weather and disease forecasts

Field studies – spatial analysis

Results of cluster analysis in GIS
Computerized disease forecasting systems

Online forecasting systems – Examples:
- Enviro-weather - Michigan State University
  [http://www.enviroweather.msu.edu/home_map.asp](http://www.enviroweather.msu.edu/home_map.asp)
- AU-PNUT for early and late leaf spot of peanut – Auburn University, AU-PECAN for pecan scale – University of Georgia
  [http://www.awis.com](http://www.awis.com)
- UC IPM Online: Statewide integrated pest management program – University of California, Davis

Interactive forecasting systems
- Example: EPIPRE (epidemiology, prediction, prevention) since 1980s for pest control in winter wheat (Zadoks, 1981)
  - Information about at least 6 diseases & insect pests
  - Crop, soil and weather taken into account.
  - Participation fee, enter own field monitoring, received forecast info from centralized location where info was processed.
  - A pesticide application recommended when predicted severity was above chosen threshold for a specific disease or pest.
  - EPIPRE now replaced by CERDIS predicting fungal diseases and making management recommendations for wheat and barley (from Opticrop)
  - Recently: EPIWHEAT for leaf rust and Septoria leaf spot by S. Savary

Example: Plant-Plus by Dacom company since 1990s for disease control on potato (Raatjes et al., 2003)
- Interactive, spatial DSS for management of late and early blight and irrigation management
- Communication of data and info between farmer, consultant, and processor
- Choice of interface and output (SMS, Fax or Email)
- Five day weather forecast -> predictive risk assessment
- Disease models require on-farm, automatic, weather data
- Uses a biological model based on the lifecycle of the fungus
- Combines infection events with unprotected tissue area
- Recommends when to apply a new spray and what type of chemical to use: contact, translaminar or systemic.
Computerized disease forecasting systems

- **Example**: Plant-Plus by Dacom company
- **Now in 10 countries**
- **Results**:
  - Netherlands: potato late blight model tested at many locations since 1994, 10,000 participating farmers in 2001
  - on average 28% reduction in sprays (no difference in disease/yield)
  - USA: Phytophthora model tested 7 States at 14 locations in 2003, 2004, 2005
  - on average 4 fungicide applications recommended versus 7.4 in standard practice (46% reduction, no significant difference in protection or yield).
  - Canada: Alternaria in potatoes, one test site in 2005
  - Dacom advised 2 sprays, WISDOM and TOMCAST recommended 4 sprays (no difference in disease or yield)

Interactive forecasting systems: Strawberry Advisory System (University of Florida) (Pavan et al., 2011)

- **Disease models**: anthracnose and Botrytis fruit rot
- **Agroclimate data base and FAWN**
- **Interface with user**
- **Controller (model management and view requests**

Simulation models in R

- **Anthracnose**: temp > 18°C, wetness
- **Botrytis rot**: temp 15-22°C, wetness > 4 hr (RH > 95%)

**Results**:
- Tested in 3 farms (weather not conducive; 2009/10)
- Fungicide applications reduced by 50%

Forecasting by trajectory analysis

- **Example**: Forecasting blue mold of tobacco (NC State Univ.)
- Tobacco blue mold (Peronospora tabacina) forecast is based on mean temperature for January. If mean temperature is < 45°F, light occurrence of blue mold is predicted. If mean temperature is > 62°F, severe epidemics are predicted. Reason: temperature affects the survival (overwintering) of the oospores or fungal colonies on a weed host.

  - http://www.ces.ncsu.edu/depts/pp/bluemold/

- Based on trajectory analysis of airborne inoculum and probability of favorable weather conditions for spore production and spread, and weather conditions

Forecasting of tobacco blue mold (NC State Univ.)

- Multi-level trajectories from western Cuba for February 20, 2008
Computerized forecasting systems - spatial

Forecasting by trajectory analysis
- Example: Soybean rust (Univ. Florida / NC State Univ.)
- Soybean rust (*Phakopsora pachyrhizi*) forecast is based on availability of inoculum (spore release from 8 AM through 1 PM; trajectory start at 10 AM)
- Survival on kudzu in winter
  - http://www.ces.ncsu.edu/depts/php/soybeanrust/
  - http://sbr.ipmpipe.org/cgi-bin/sbr/public.cgi
- Based on trajectory analysis of airborne inoculum and probability of favorable weather conditions for spore production and spread, and weather conditions for infection (6-7 hours of leaf wetness at a dew temperature between 18 - 26.5°C; no infection 27.5°C).

Forecasting systems – expert systems

- Expert systems are computer programs that use logic and problem-solving of a human expert, using concepts developed in the field of artificial intelligence (AI)
  - can employ heuristics, a problem-solving technique that uses "rules-of-thumb" based on experience to make management decisions.
  - not subject to the constraints of conventional computer programming, encountered with simulation or optimization analysis.
- Expert systems have the ability to:
  - make decisions based on incomplete or uncertain information
  - provide the user with an explanation of how its conclusion was derived
- Development of ES
  - interview of human expert by a knowledge engineer, trained in AI and ES.
  - Knowledge engineer organizes info from expert into interconnected rules
  - ES building tool "shell" used rather than a programming language
  - Example: Penn State Apple Orchard Consultant (PSAOC) (Travis, et al. 1992)

Computerized forecasting systems - spatial

- Soybean rust (USDA and NC State Univ.)
- Surviving on kudzu in Florida
- Trajectories from Florida going North-East

Forecasting systems – expert systems

- Figure 1: Diagram of expert system architecture.
- Figure 2: An example of a rule for recommending a control action for powdery mildew of tomato.

Artificial Neural Networks

- Sophisticated pattern recognition systems that mathematically mimic the biological human learning process and are capable of learning the relationships between system inputs and responses.
- A typical artificial neural network consists of
  - a set of input variables
  - a "hidden layer"
  - a set of output variables
- A training data set is used to adjust the weights of the nodes of the hidden layer to optimize the accuracy of the output

Forecasting systems – neural networks

- Example: Penn State Apple Orchard Consultant (PSAOC) (Travis, et al. 1992)
Forecasting systems – neural networks

Example: Regression and artificial neural network modeling to predict gray leaf spot of maize (Paul and Munkvold, 2005)

Regression was used to identify sets of most important input variables:

- LON: longitude
- GLSR: gray leaf spot resistance rating
- SR: maize residue on soil surface
- PD: planting date
- CDT4: cumulative hours of daily temperature, period 4 (45-15 days before silking)
- AVNT2: average night temperature, period 2 (15 before until 15 days after silking)
- NRH904: cumulative hours of nightly RH >=90%, period 4

Evaluation with independent data set
- Model underestimated high levels of disease severity and overestimated low levels of disease severity. \( R^2 = 0.75 \)

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