MIT Field Intelligence Lab (FIL)

Green Field Group (Agriculture Systems Productivity)

This report introduces a new research initiative at MIT involving agricultural systems productivity. The name of this effort is the MIT Field Intelligence Lab (FIL). The lab is under the leadership of Sanjay Sarma, associate professor of mechanical engineering and member of the Laboratory for Manufacturing Productivity (LMP).

Organized in outline form, the next sections provide information about the goals, scope, structure, and initial proposed projects for FIL. Concluding the report, several appendices list previous publications related to agriculture, other proposed projects, and the people involved with FIL.

1. The Goal – build an interdisciplinary agricultural research program that utilizes existing and proposed technologies from MIT to create innovations in data integration, sensing, mathematical modeling, supply chain management, marketing science, and the scaling of existing models for specific biological processes. The long-run goal is sustainability, improved competiveness, the understanding of agriculture's role in global climate change, and better positioning of the American agricultural industry as a leader in exports and as a fundamental part of America's energy needs.

   The MIT Field Intelligence Lab seeks to build a partnership involving several governmental agencies (USDA - lead, and perhaps NASA, EPA, and DOE) along with agribusiness and food companies to accelerate research activities and the transfer of technology to industry. The planned organizational structure will be a combination of a federally funded center for fundamental research along with an industrial consortium that will focus on applied research appealing to a group of companies. There will also be the opportunity for research contracts dealing with specific problems.

   The basic assumptions of the MIT Field Intelligence Lab include the following points:

   - There are several possible ways to increase agricultural productivity. Traditionally, improvements in genetics have been a primary focus; however, other non-biological ways to improve productivity also exist. Computers, data, and mathematical models will play an important role in agricultural productivity, offering an alternative to genetic advances.

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- Many technologies developed at MIT in other fields of study have application in agriculture. For example, opportunities exist to apply the principles of manufacturing systems engineering to agricultural as a way of improving productivity. MIT is very good at identifying the cross applications of fundamental technologies.

- It is critical that agriculture respond to global climate change.

- Global competition will prompt the need for higher productivity in U.S. agriculture.

- America's drive for energy independence will include a role for agriculture.

- The study of supply chain management, spanning from the farm to end customer, represents a significant opportunity to increase agricultural productivity.

2. <u>The Scope</u> – with a long tradition of technological advancement and strong ties to industry, MIT has a number of knowledge centers that can contribute to agricultural productivity. Often working at the national and international levels, MIT is also capable of achieving large-scale research in completely new areas through cross-functional teams. These applied and theoretical research efforts frequently result in sustainable contributions to the United States economy through creation of entirely new industries, and to humanity through efforts focused on worldwide problems.

   The specific scope of an agriculture program at MIT will involve the following areas of study:

   a. Data obtained from sensors and other sources will play an increasingly important role in agricultural operations. As a leader in **computer science and electrical engineering**, MIT is at the forefront of Internet applications, the advanced management of data, sensors, and RFID.

   b. Representing a broad field of study, **mechanical engineering** at MIT encompasses many disciplines such as information technology, computer science, and electrical engineering. Basic fields of study such as fluid mechanics, energy, robotics, manufacturing systems engineering, and engineering mathematics have applications in agriculture.

   c. As the birthplace of **operations research**, **management science, and marketing science**, MIT has extensive experience, across many different departments, in the application of models to data for practical decision-making.

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d. Traditionally an area receiving little attention in agriculture, **supply chain management** is emerging in importance as energy costs increase and food safety becomes a high priority issue in the United States. Achieving new levels of supply chain efficiency will reduce costs for farmers, and improve the prospects for exports.

3. Structure – With a strong orientation toward industrial application and new business formation, an integrated program in agriculture at MIT will follow the consortium model with a mix of Federal government funding for fundamental research and industrial consortium membership for applied research. The approach is a proven way to unify research focus across multiple businesses and Federal government agencies. Technology transfer using this form of organization has achieved significant success in many different situations. Other universities might also be members of the consortium.

   The consortium would include a "fellows" program where people from member companies or federal agencies spend between three months and one year in residence at MIT. This approach accelerates technology transfer through a combination of education and participation in ongoing research. When MIT fellows return to their respective companies or governmental departments, they have a much deeper understanding of technology, and what works in practice.

   The MIT Laboratory for Manufacturing and Productivity (LMP) is an Institute wide research center, enabling the formation of multi-disciplinary research projects across all MIT academic departments and programs. This will be the vehicle to operate the consortium and federally funded research center within MIT under the name **MIT Field Intelligence Lab**.

   As a concluding comment, forty percent of the research revenue at MIT involves biology. However, almost all of this work involves human biology. There are great opportunities to expand in the area of agriculture. At the senior levels of MIT, there is an initiative to stimulate research in the biological sciences.

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4. Proposed Projects

The following is a list of projects of interest to FIL. APPENDIX B lists additional projects of lower priority.

- NSF - EMERGING FRONTIERS IN RESEARCH AND INNOVATION

Research Area: Resilient and Sustainable Infrastructures

Title: Agricultural Systems Productivity: Modeling Biological, Logistical, and Information Technology Infrastructure

Sanjay E. Sarma (Principal Investigator) – Associate Professor of Mechanical Engineering
Sensors, spatial analysis, and RFID

Stanley B. Gershwin (Co-Principal Investigator) – Senior Research Scientist, Dept. of Mechanical Engineering
Manufacturing systems, mathematical modeling

Timothy G Gutowski (Co-Principal Investigator) - Professor of Mechanical Engineering
Environmentally Benign Manufacturing

Stephen Ho – Research Scientist, Laboratory for Manufacturing and Productivity
Supply chain management, mathematical modeling

Irvin C. Schick – Research Scientist, Laboratory for Manufacturing and Productivity
Statistics

Edmund W. Schuster – Research Engineer, Laboratory for Manufacturing and Productivity
Agriculture

Abstract

In conjunction with the “gene revolution,” there are significant new opportunities involving sensing, data, and modeling technologies to achieve the next stage of improvement in agricultural output. This emerging era will result in an entirely new way of viewing agriculture as a spatial, data-driven activity in addition to a biological system that depends on genetic advances.

The fundamental aspect of this research is a framework for modeling the interdependence between three infrastructures; biological (agricultural) systems,

logistical capacity and cost, and information technology. One area of interest is the capability of the current information technology infrastructure to handle the enormous amounts of data anticipated from sensing technologies, and the corresponding mathematical models needed to understand the data. Of particular interest is development of a process for identifying the types of data needed to increase agricultural output. Another area of importance involves the scaling of existing models for plant growth into a comprehensive agricultural systems model capable of making predictions about the future, including needs for logistical capacity. A final area involves the research and application of drop sensors to gain new types of data for the analysis and modeling of agricultural systems.

Overall, this research effort seeks to model the resiliency, interdependence, and sustainability for three important infrastructures (biological, logistic, and information) under different disruptive conditions, including global competition, rising energy costs, environmental impact, supply and demand for food, urbanization, spatial variability of risk, global warming, and transportation capacity. The outcome will be an understanding of how these infrastructures must adapt and innovate to meet the challenges of the future.

- Drop Sensors and Field Intelligence

Principal Investigator - Prof. Sanjay Sarma

Research Definition: The initial applications of sensors in agriculture commonly involve two deployment approaches 1) fixed where the sensor is mounted in the field and 2) moving where the sensor is attached to a piece of farm machinery such as a harvester. However, a third approach exists where sensors are dropped into areas of interest. This method is a way to optimize the deployment of sensors. To determine drop locations, remote sensing of various types serves an important role in narrowing down the area of interest. Once in place, the sensors can provide detailed information including real-time observations.

Immediate Outcome: This research is in an initial phase with several theses completed. The short-term goal is to apply the technology for an aspect of agricultural sensing with the expectation of understanding the range of uses for this type of technology. A near term objective might be to use dropped sensors to measure pollen concentration at critical times during the development of corn or other crops.

Eventual Outcome: A methodology for deploying sensors in the most economical manner and a firm understanding of the uses of data obtained from the sensor. Data might be used to assess vegetable or fruit quality in the field, “hot spots” of pest or microbiological activity, or conditions of maturity in preparation for the harvest. The identification of hot spots is essential to combating outbreaks of citrus canker and greening, and other diseases that might infect US crops in the field like soybean leaf rust.

Long-term, there are three areas of research:

a. Development of an environmentally friendly sensor that has the required functionality and can be dropped into place using various means. Such a sensor could analyze crop quality or the concentration of pests.

b. Develop a method to identify "hot spots" using sampling theory and a threshold approach where deployment of sensors takes place after reaching some threshold. This also involves the resolution needed for sensing.

c. Visualization of the data gathered by the sensor involving Google maps.

Estimated Resources:

1 Project Leader

2 Ph.D. students (sensor development and identification of hot spots)

1 M.S. student (creation of user-friendly interface)

- Data and Mathematical Modeling Infrastructure

Principal Investigators – Prof. Sanjay Sarma, Dr. Stanley B. Gershwin, and Edmund W. Schuster

Research Definition: One of the biggest issues in agriculture involves the rapid application of mathematical models to data in a way that aids decision-making for practitioners. In situations where data is available, there is often no pre-determined mathematical modeling approach to apply to the data.

If the future of United States agricultural productivity depends on the application of data to make better decisions, then there needs to be a national information technology backbone to make data interoperable with mathematical models. With this idea in mind, it makes sense to build an open system available at little or no cost to users.

Other computer related areas of importance to agriculture include the design of visual interfaces that are simple and intuitive along with answering the question "where does modeling make sense in agriculture?"

An overlooked opportunity in both the data and modeling areas involves the determination of "economic thresholds" for agricultural activities such as spraying or applying fertilizer. In many cases, these models are obsolete because of changing conditions

Immediate Outcome: application of new computer technologies to make threshold models available on the Internet so that these models can be quickly accessed by users and updated rapidly by researchers. The goal is to get growers to use the models and that the models are current thus improving effectiveness.

Eventual Outcome: A rigorous information technology strategy for agriculture that will be implemented during the next 5 years with a lifespan of 20 years.

Resources:

3 Project Leaders

2 M.S. students (IT and modeling)

- Spatial Risk in Agriculture

Principal Investigators – Dr. Stanley B. Gershwin and Edmund W. Schuster and TBD

Research Definition: Building on the work of Allen and Schuster (2004), this research area expands the measurement and mathematical modeling of risk from a point estimate to spatial observations. It also expands the types of risks considered (temperature, wind, and hurricane). This is an especially important issue for specialty crops, which are often very sensitive to frost damage and other risk factors. Beyond modeling risk, the goal is to incorporate a quantitative assessment of risk into supply chain planning and execution. With the prospect of global warming, this area of research is especially important in matching certain types of agricultural products to specific locations. Broadly speaking, this topic area could be considered site selection for both annual and perennial crops.

Examples of the value of this research include:

a. The selection of the best location to plant a crop while also optimizing the trade-off between harvesting schedules, quality, and the chance of weather related losses represents a difficult long-term problem for many types of specialty crops.

b. The general area of using geospatial data for making better day-to-day decisions and the development of quality maps is also a very important area for research and application.

c. Using the output from existing long-term weather models to simulate harvest risk changes with the goal of understanding the impact of global warming. Examine the impact on crop insurance.

Note: this topic might combine with *modeling agricultural production systems*

Immediate Outcome: a better method for planning and scheduling of harvest operations for a specific crop such as grapes or oranges. This would allow for better decision-making in the tradeoffs between capital investment and the loss of crop.

Eventual Outcome: A general approach for harvest risk that can be applied to all crops. In addition, this research will examine the establishment of standards for spatial data used in agriculture.

Resources:

2 Project Leaders

1 M.S. student (modeling)

1 Meng student (supply chain)

- Agricultural Supply Chains: Track and Trace for Improved Food Safety

Principal Investigators – Dr. Stanley B. Gershwin and Edmund W. Schuster and TBD

Safety has emerged as an issue for the fresh fruit and vegetable industry with reports of several recent food poisoning outbreaks traced to E. Coli. Although these outbreaks generate a great deal of attention, probably many more fresh food contamination instances go undetected. By one account, 76 million illnesses and 5,000 deaths occur each year in the United States from food contaminated with various pathogens.

While the agricultural supply chain is complex, new technologies are available that hold the promise of better track and trace for fresh foods. This research will examine the trends and applications of RFID and related information technologies as a means of improving the safety for fresh foods in addition to being a platform for other innovations in agriculture. An additional aspect of this research involves the study of “near misses” as a means of better understanding how outbreaks of food contamination occur and spread through the agricultural supply chain.

Immediate Outcome: an identification of the current gaps in technology relating to food safety along with a plan to overcome technological deficiencies.

Eventual Outcome: A fundamental understanding of the causes of food contamination through a comprehensive study of "near misses."

Resources:

2 Project Leaders

1 Ph.D. student

1 M.S. student

5. <u>Conclusion</u> – the MIT Field Intelligence Lab is an innovative effort involving agricultural research, focusing computer science and information technology along with mathematical modeling to improve agricultural productivity. With a core of researchers in place, FIL is prepared to begin executing specific projects, both short- and long term. The goal is to build FIL into a significant research center at MIT that makes major contributions to the advancement of agricultural productivity.

   The following appendices provide additional information on relevant publication history, other projects, and a short bio for each person involved with FIL.

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APPENDIX A – PREVIOUS PUBLISHED MIT RESEARCH RELATING TO AGRICULTURE

Members of FIL have published a number of papers appearing in refereed journals and books that deal with various applications of computer science, information technology, and mathematical modeling to agricultural productivity. Below is a listing of this work along with links to papers available online.

Quantitative Technologies, Modeling, and Data Analysis

a. Sampling through Space

This research involves the *Inverse Sampling Problem* – when and where to *sample* in order to estimate an unknown scalar field within a certain error tolerance. This problem is directly relevant to the placement of static sensors or the motion planning of mobile sensors. The field is modeled as a linear combination of a set of basis functions and the sensor measurements are noisy. Based on the linear estimation theory, the estimation error is a function of the set of sampling locations. The approach involves identifying and characterizing different types of distributions of sampling locations' sets such that the estimation error for any set from such a distribution is always within a tolerance limit. This referred to as *Error Tolerant Distributions* or ETDs for sampling. ETDs not only guarantee tolerable estimation error but may also lead to simplifying the motion-planning problem for sampling using mobile sensors. This research three types of ETDs for fields that are modeled as 2D *trigonometric polynomials* – uniform distributions, delta-dense distributions and adaptively constructed distributions.

Deshpande, A. and S. E. Sarma, "Error Tolerant Distributions for Sampling," submitted to the *2008 American Control Conference*, June 11 - 13, 2008, Seattle, Washington, USA

b. Harvest Risk

Gathering the harvest represents a complex managerial problem for agricultural cooperatives involved in harvesting and processing operations: balancing the risk of overinvestment with the risk of underproduction. The rate to harvest crops and the corresponding capital investment are critical strategic decisions in situations where poor weather conditions present a risk of crop loss. This mathematical model has general application to a wide variety of crops, including grapes, oranges, and vegetables.

Allen, S.J. and E.W. Schuster, "Controlling the risk for an agricultural harvest," *Manufacturing & Service Operations Management* 6, no. 3 (2004): pp 225 – 236.

http://www.ed-w.info/1526-5498-2004-6-3-0225.pdf

Allen, S.J. and E.W. Schuster, “Managing the risk for the grape harvest at Welch’s,” *Production and Inventory Management Journal* 41, no. 3. (2000): pp 31 – 36.

http://www.ed-w.info/P&IMJ%202000%20SJA%20EWS.pdf

c. M Language and Web Machines

This technology involves a means to achieve data interoperability using enhancements to existing XML standards. The technology also provides a framework for building a network of mathematical models using web services and other means. Applications in agriculture include integrating sensor data and making the use of mathematical models practical.

Brock, D.L., E.W. Schuster, S.J. Allen, and P. Kar, “An introduction to semantic modeling for logistical systems,“ *Journal of Business Logistics* 26, no. 2 (2005), pp 97 – 117.

http://www.ed-w.info/BrockSchusterAllenKar.pdf

Brock, D.L., Schuster, E.W., and Kutz, Sr., T.J., "An overview of the M Language," *The MIT Data Center*, Cambridge, MA: MIT-DATACENTER-WH-09 (January 2006).

http://www.ed-w.info/MIT-DATACENTER-WH-009.pdf

Brock, D.L., Schuster, E.W., and Thumrattranapruk, C., "Multi-lingual display of business documents," *The MIT Data Center*, Cambridge, MA: MIT-DATACENTER-WH-10 (May 2006).

http://www.ed-w.info/MIT-DATACENTER-WH-010.pdf

Schuster, E.W. and S.J. Allen, "The Data-Driven Economy: Applications of the M Language in Agriculture," University of Florida Citrus Research and Education Center: Lake Alfred, Florida, *MIT-DATACENTER-PR-026*, October 16, 2006.

http://www.ed-w.info/MIT-DATACENTER-PR-026.pdf

Schuster, E.W. and D.L. Brock, "The Data-Driven Economy: Applications of the M Language in Manufacturing and Supply Chain Management," University of Florida - Computer Science Department: Gainesville, Florida, MIT-*DATACENTER-PR-027*, October 17, 2006.

http://www.ed-w.info/MIT-DATACENTER-PR-027.pdf

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Supply Chain as Related to Agriculture

a. *Integrated Capacity Planning for Agricultural Supply Chains*

Optimizing capacity for agricultural supply chains is often difficult because there are a number of processing and transportation steps between the grower and end consumer. This technology uses various types of mathematical optimization to determine the optimal amount of capacity needed for harvesting and production operations.

Schuster, E.W., S.J. Allen and M.P. D'Itri, "Capacitated materials requirements planning and its application in the process industries," *Journal of Business Logistics* 21, no. 1 (2000): pp 169 – 189.

http://www.ed-w.info/JBL2000-CapMRP.pdf

Schuster, E.W. and S.J. Allen, "Raw material management at Welch's," *Interfaces* 28, no. 5 (1998): pp. 13 - 24.

http://www.ed-w.info/Schuster-Allen%201998.pdf

b. *Scheduling Technology*

Given the complexity of agricultural operations, developing schedules by had for various operations is a difficult task. This technology is a family of mathematical models that are capable of producing an optimized schedule in a wide range of real world situations. All of the references below were applied in real-world agricultural situations.

Schuster, E.W., C. Unahabhokha, and S.J. Allen, "Master production schedule stability under conditions of finite capacity," Paper accepted for the poster session of The Proceedings of the 34th Annual Logistics Educators Conference: San Diego, CA (2005).

http://www.ed-w.info/LEC20054-14-05R1.pdf

D'Itri, M.P., S.J. Allen and E.W. Schuster, "Capacitated scheduling of multiple products on a single processor with sequence dependencies," *Production and Inventory Management Journal* 40, no. 4 (1999): pp 27 – 33.

http://www.ed-w.info/ditri[1].pdf

Allen, S.J., J. Martin, and E.W. Schuster, "A simple method for the multi-Item, single level, capacitated scheduling problem with set-up times and costs," *Production and Inventory Management Journal* 38, no. 4 (1997): pp. 39 - 47.

http://www.ed-w.info/P&IMJ%201997%20SJA%20JM%20EWS.pdf

Allen, S.J. and E.W. Schuster, "Practical production scheduling with capacity constraints and dynamic demand: family planning and disaggregation," *Production and Inventory Management Journal* 35, no. 4 (1994): pp. 15 - 21.

http://www.ed-w.info/P&IMJ%201994%20SJA%20EWS.pdf

Schuster, E.W. and B.J. Finch, "A deterministic spreadsheet simulation model for production scheduling in a lumpy demand environment," *Production and Inventory Management Journal* 31, no. 1 (1990): pp. 39 - 42.

http://www.ed-w.info/P&IMJ%201990%20EWS%20BJF.pdf

c. RFID and Supply Chain - Track and Trace

A new technology, Radio Frequency Identification (RFID) holds great promise as a replacement for the bar code. Already applied in the agriculture industries, RFID is an effective means of improving operations. There are also substantial applications in tracking and tracing agricultural produces moving through complex supply chains.

Schuster, E.W., S.J. Allen, and D.L. Brock (2007), *GLOBAL RFID: The Value of the EPCglobal Network for Supply Chain Management*, Berlin and New York: Spriger-Verlag.

http://www.ed-w.info/EWSwebpageGLOBALRFID.htm

Koh, R., E.W. Schuster, I. Chackrabarti, and A. Bellman, "Securing the pharmaceutical supply chain," *MIT Auto-ID Center*, Cambridge, MA (2003).

http://www.ed-w.info/MIT-AUTOID-WH021.pdf

d. Simulating Warehousing Cost

Many specialty crops must undergo refrigeration prior to distribution to retailers. While warehousing fulfills important temporal and spatial functions within supply chains, it also represents a significant cost that must be minimized. This technology uses a computer simulation to determine the lowest cost billing system for refrigerated warehousing.

Canella, T and E.W. Schuster, “Simulating warehousing costs: a spreadsheet application,” *Production and Inventory Management Journal* 28, no. 4 (1987): pp. 1 - 5.

http://www.ed-w.info/P&IMJ%201987%20TC%20EWS.pdf

e. Fresh Food Supply Chain

Increasingly, American consumers are demanding fresh foods as a part of everyday life. This requires a complex supply chain to ensure a high percentage of availability. The technologies and organization involved to accomplish this task requires a high degree of sophistication. In case study format, this research explores current issues in Japan relating to the Sushi supply chain. Through study of this case, readers will gain greater insight into distributing fresh foods in the United States.

Schuster, E.W. and K. Watanabe, "The impact of e-commerce on the Japanese raw fish supply chain," Proceedings of the 32nd Annual Logistics Educators Conference (2003).

http://www.ed-w.info/Watanabe%20-%20Schuster,%20eCommerce,%203-22-03%20(final%20draft).pdf

Presentation

http://ed-w.info/LEC%202003%20pres..pdf

f. Marketing Science

The integration of marketing science, engineering technology, and supply chain management represents the next big innovation in business. Although this is a future technology, there are currently examples of applications in the consumer goods industries that use a wide range of computer science techniques.

Schuster, E.W., S.J. Allen, and D.L. Brock, “Marketing Science and Technology: Unique Identification and Spatial Diffusion” Executive Update (April 2007). (Published by the Cutter Consortium: Arlington, MA)

http://www.ed-w.info/CutterSpatialDiffusion.pdf

Schuster, E.W., Tsou, C., and Williams, J.R., "Improved new product forecasting though visualization of spatial diffusion," The MIT Data Center, Cambridge, MA: MIT-DATACENTER-WH-006 (July 2005).

http://www.ed-w.info/MIT-DATACENTER-WH-006.pdf

g. The Organic Supply Chain

Though it is at an early stage of development, organic food in the United States represents a growing business. Not much is understood concerning the characteristics of organic food supply chains. This study represents early survey research to gain understanding.

Chang, M.W. and E.W. Schuster, "Understanding the Organic Foods Supply Chain – Challenges and Opportunities from Farm Gate to End Consumer," Unpublished Manuscript (2002).

http://www.ed-w.info/Agribusiness,%206-7-02.pdf

h. Production Planning for Vegetables

Innovative companies are experimenting with taking the role of integrator within agricultural supply chains. This results in the need for new decision-making capabilities. A specific problem involves deciding how many acres to plant, and where to plant, to maintain a steady flow of vegetables to retailers year-round. This technology involves a two-stage production planning model that trades-off transportation cost and planting windows to arrive at the optimal pattern of planing within Eastern United States.

Merrill, J.M.,"Managing Risk in Premium Fruit and Vegetable Supply Chains," unpublished Master of Engineering Thesis, *Massachusetts Institute of Technology* (2007).

Thesis Advisor: Edmund W. Schuster

i. Crop Yield Distributions and Crop Insurance

Agriculture is a business fraught with risk. Crop production depends on climatic, geographical, biological, political and economic factors, which introduce risks that are quantifiable given the appropiate mathematical and statistical methodologies. Accurate information about crop yields helps farmers, agribusinesses, and governmentental policy making bodies and is an important modeling input to managing risk. Estimating yield is an important part of crop size estimation. Historically, crop yields are assumed to exhibit normal distribution for a statistical population and for a sample within a crop year. This thesis examined the assumption of normality of crop yields with data collected from India. Country yield data for India and state level yield data from Madhya Pradesh, Maharashtra states of India was collected for Sugarcane and Soybean crops. The null hypothesis of normality of yields was tested using Lilliefors test and results conclusively rejected the null hypothesis. This thesis concludes that crop yields of sugarcane and soybean exhibit non-normal and skewed distribution. The impact of skewed distribution of yields on crop insurance was analyzed and discussed. Strategies for effective risk management are suggested.

Gayam, N.R., "Risk in Agriculture - A Study of Crop Yield Distributions and Crop Insurance," unpublished Master of Engineering Thesis, *Massachusetts Institute of Technology* (2006).

Thesis Advisor: Edmund W. Schuster

Future Publications

a. *The Three Risk Problem*

This prospective model extends harvest risk to include supply and demand variability. The formulation of the model is consistent, however, after a great deal of searching it appears there is no analytics solution. We plan to solve this problem either through numeric methods or by reformulation. the difficulty in using numerical methods for this type of problem is that the solution might be different each time the model is run. Therefore, all that might be possible would be a bounded solution.

http://www.ed-w.info/AnalysisofThreeCropRisks%20(SJA%208-1-04).pdf

If solved, this is a very important problem in establishing the optimal size of an agricultural cooperative. There are many opportunities in the agricultural supply chain to put this technology into operational practice.

Stuart J. Allen and Edmund W. Schuster

b. *The Jones Problem*

The idea of risk in agriculture has a foundation in the work of Jones et al. The group worked with Syngenta to establish a two-stage model for dealing with hemispheric specialization of the production of seed corn in the US and S. America. The goal is to establish the number of acres to plant in each hemisphere to minimize the year-round risk of over or under supply.

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More details can be found at the following link:

http://www.ed-w.info/Jones.pdf

We feel that more detailed analysis of hemispheric risk is an important first step in establishing optimal land use.

Stuart J. Allen and Edmund W. Schuster

APPENDIX B – OTHER TOPICS

Besides the topics listed above, FIL has developed an additional list of topics that involve the application of computer science, information technology, and mathematical modeling to agriculture. All of these projects are opportunities to increase agricultural productivity. This list includes:

- Water Flow Management for Optimal Agricultural Production

Principal Investigators: Dr. Stanley B. Gershwin and Edmund W. Schuster

Research Definition: At the April 24-25 Specialty Crop meeting, it was noted that much of the modeling in agriculture involves empirical approaches based on past macro observations such as the estimated total irrigation load per day for a vineyard. While these specific models add value in managing water flow, there is a constant need for updating. The consensus is that models of actual biological processes are required to refine agricultural management activities such as irrigation management. This might include a daily forecast of water uptake per plant based on weather conditions, or, in another case, the mechanics of pollen transfer between plants. Diffusion models combined with inputs that account for weather conditions might also apply in this area.

Immediate Outcome: Based on existing physiological understanding, develop a working model for water uptake for grapes or other perennials. This model would forecast daily demand for water.

Eventual Outcome: Integrate the model for water uptake into current irrigation control systems. A good area of focus might be the Yakima Valley area of Washington State or locations in California.

Resources:

2 Project Leaders

1 M.S. student from the Biological Engineering Division

1 M.S. student from Mechanical Engineering

- The Capacity of Agricultural Production Systems

Principal Investigators – Dr. Stanley B. Gershwin and Edmund W. Schuster

Research Definition: The question to be answered, "what is the biological capacity to produce food, fiber, and materials for ethanol given the land resources available? The question also includes an appraisal of how the rural/urban boundary will change as the United States grows in population, thus determining the number of cultivatable acres. A final question involves the amount of export capacity for food and fiber.

Note: this topic might combine with *spatial risk in agriculture*

Immediate Outcome: an assessment of the difficulties involved in calculating agricultural capacity for the United States. A framework for performing the calculation, including data required and analytical approaches employed.

Eventual Outcome: ongoing calculation of near-term and long-term agricultural capacity based on population increases, the amount of available land, changes in climate, and the cost of transportation. This information would be used for policy making at the Federal level for such topics as immigration policy and population growth, land use, water management, and agricultural price monitoring.

Resources:

While this would most likely be a very large project, an initial analysis would require the following resources:

2 Project Leaders

1 Ph.D. Student (method to calculate variable capacity)

1 M.S. student (data analysis)

- Optimal Size of an Agricultural Cooperative - The Three Risk Problem

This prospective model extends harvest risk to include supply and demand variability. The formulation of the model is consistent, however, after a great deal of searching it appears there is no analytical solution. We plan to solve this problem either through numeric methods or by reformulation. The difficulty in using numerical methods for this type of problem is that the solution might be different each time the model is run. Therefore, all that might be possible would be a bounded solution.

http://www.ed-w.info/AnalysisofThreeCropRisks%20(SJA%208-1-04).pdf

If solved, this is a very important problem in establishing the optimal size of an agricultural cooperative. There are many opportunities in the agricultural supply chain to put this technology into operational practice.

- Hemispheric Specialization - The Jones Problem

The idea of risk in agriculture has a foundation in the work of Jones et al. The group worked with Syngentia to establish a two-stage model for dealing with hemispheric specialization of the production of seed corn in the US and S. America. The goal is to establish the number of acres to plant in each hemisphere to minimize the year-round risk of over or under supply.

More details can be found at the following link:

http://www.ed-w.info/Jones.pdf

We feel that more detailed analysis of hemispheric risk is an important first step in establishing optimal land use.

- Agricultural Planning Under Demand, Yield, and Harvest Uncertainty: An Application in Tomato Farming

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Ed Schuster assisting

Deadline June 2007 (draft)

Target for *Manufacturing and Service Operations Management* published by the Institute for Operations Research and Management Science (INFORMS)

Motivated by farming of specialty tomato, we consider a multi-period planning problem for multiple farms. A decision maker evaluates a number of farms located in different regions for farming of a single crop during a planning period. The planning problem is complicated due to three sources of risk. First, the demand during each week of the planning period is random that yields *demand risk*. Furthermore, each farm has a different *yield* that is defined as the production obtained per acre. The yield at each farm is also uncertain that is referred as the *yield risk*. Finally, the length of the farming period at each farm is also uncertain. The uncertainty of the length of the farming period is referred as the *harvest risk*.

The objective of this study is to develop a method that matches the total supply and the total demand such that the total cost of underestimating and overestimating the demand is minimized. The decision variables are the location and area of each farm and the seeding times of this crop at these farms.

- Integration of Weather and Pest Data (Ecostat)

Project Team: Steve Rogers and Ed Schuster (plus student MIT - UROP)

Deadline – September 1.

This project uses the M Language as a means of integrating weather data with data about insect concentrations that are gathered by a field scouting system and recorded on the Internet.

The plan is to use the M dictionary to provide a semantic tag for data in both systems. More advanced applications will use spatial data standards developed as part of the M Language and possibly Google Maps.

- Managing Risk In Premium Fruit And Vegetable Supply Chains

Project Team: Joshua Merrill, Master of Engineering in Logistics

Thesis Supervisor: Ed Schuster

Deadline – (thesis is complete)

Completed Paper - October 1, target Agribusiness or Interfaces

This research deals with formulating a mathematical model to determine the optimal location to plant a specialty vegetable crop so that constant supply can be guaranteed year round.

As part of this project, several other research topics were identified relating to forecasting, execution in the field during harvest, and the use of sensors to calculate weather risk. These topics are candidates for MLog thesis projects in 2007-08 with the same company.

- Overview of the Application of the M Language in Agriculture

Project Team: Reza Ehsani, Raghav, and Ed Schuster

Deadline – October 2007

- The M Language and Agricultural Sensors

Project Team: Reza Ehsani (University of Florida), Ed Schuster, Student (UF) and student (MIT – UROP)

Deadline – October 2007

The goal of this work is to use the M Language for data from a new field sensor produced by Matsushita. The M Language will allow the data to be interoperable. A secondary goal is the application of the change point method to agricultural data along with the use of edge models for translation between data sets.

- Integrating the M Dictionary into ERP Systems for Agricultural Companies

Project Team: Ed Schuster, Keith Launchbury, and a MIT-UROP

Deadline: October 2007

The idea is to integrate parts of the APICS dictionary, SAP terminology, and company terminology into an M interface for ERP systems.

- Risk in Agriculture - A Study of Crop Yield Distributions and Crop Insurance

Project Team: Narsi Reddy Gayam (thesis completed in 2006)

Thesis Supervisor: Ed Schuster

Deadline – December 2007 (edited paper)

Agriculture is a business fraught with risk. Crop production depends on climatic, geographical, biological, political, and economic factors, which introduce risks that are quantifiable given the appropriate mathematical and statistical methodologies. Accurate information about the nature of historical crop yields is an important modeling input that helps farmers, agribusinesses, and governmental bodies in managing risk and establishing the proper policies for such things as crop insurance. Explicitly or implicitly, nearly all farm decisions relate in some way to the expectation of crop yield.

Historically, crop yields are assumed to be normally distributed for a statistical population and for a sample within a crop year. This thesis examines the assumption of normality of crop yields using data collected from India involving sugarcane and soybeans. The null hypothesis (crop yields are normally distributed) was tested using the Lilliefors method combined with intensive qualitative analysis of the data. Results show that in all cases considered in this thesis, crop yields are not normally distributed.

This result has important implications for managing risk involving sugarcane and soybeans grown in India. The last section of this thesis examines the impact of crop yield non normality on various insurance programs, which typically assume that all crop yields are normally distributed and that the probability of crop failure can be calculated given available data.

- Information Kiosk for Agricultural Products

Project Team: Ed Schuster, Peter Bostwick, and a master degree student

Deadline – Summer 2007

There has been research and application in placing an informational kiosk near the wine section in a store as a means of stimulating sales. The issue has been the "many-to-many" problem in moving data from manufacturers to retailers. The goal is to use the M Language to solve this issue.

- Application of the Boeing TR System to Agricultural Machinery

Project Team: Ed Schuster and Dave Brock, master degree student

Deadline – January 2007

The M Language system being proposed to Boeing has potential to be applied in the agricultural machinery business. This project will explore the application potential for a company like John Deere.

- **Tracking Rainfall and Crops Affected**

Project Team: Ed Schuster, Dave Brock and master degree student

Deadline - June 2008

Using the spatial data capabilities of the M Language in combination with mapping technologies such as Google Earth, this research project will develop a method to match rainfall to the exact number of acres for particular crops. The approach will use satellite imagery.

- **Semantic T-BOM (Semantic Web of Things) for Track and Trace of Agricultural Products**

Project Team: Ed Schuster, Peter Bostwick, and a master degree student

Deadline- TBD

Tracking and tracing is an important issue in agriculture. The T-BOM approach has potential to solve this important problem. This project will explore how to integrate the M Language into the T-BOM in order to create a semantic web of things.

- **Use the M Dictionary for Proper Nouns Relating to the Output of Agricultural Models**

Project Team: Ed Schuster, Reza Ehsani, Steve Rogers

Deadline – TBD

The goal of this project is to enter proper nouns for agricultural products into the M Dictionary and to use various models to calculate requirements for such things as fertilizer. The outputs of the model will be described using proper nouns.

- **Harvest Risk for the Orange Crop in Florida**

Project Team: Ed Schuster, Stuart Allen, Steve Rogers, Reza Ehsani, and David Brock

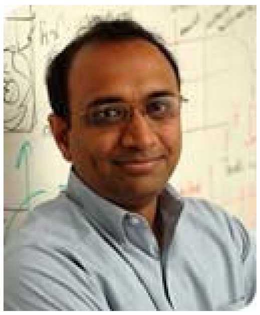
Deadline – TBD

Application of harvest risk approaches developed for grapes, along with the M Language, to the orange crop in Florida.

APPENDIX C – PEOPLE

The MIT Field Intelligence Lab has a core of MIT employees committed to research in various aspects of agriculture. Under the leadership of Prof. Sanjay Sarma, FIL has a mixture of senior faculty and staff researchers representing a broad range of skills an interests. Below is a listing of the initial staff of FIL.

Sanjay E. Sarma – Associate Professor of Mechanical Engineering (Director of FIL)



Dr. Sarma is an Associate Professor in the Mechanical Engineering Department. He graduated from the Indian Institute of Technology Kanpur with his B Tech in 1989 and received his Masters from Carnegie Mellon University in 1992. He earned his Ph. D. from the University of California, Berkeley in 1995. Dr. Sarma began his career at Massachusetts Institute of Technology in 1996, after working for Schlumberger, Inc. and Lawrence Berkeley Laboratories.

In 1999, along with Dr. David Brock and Professor Sunny Siu, he co-founded The Auto-ID Center at MIT, which developed many of the technical concepts and standards prevalent in the RFID industry today. The center has now grown to 5 labs worldwide, including the University of Cambridge, Adelaide University, Keio University and Fudan University.

Dr. Sarma currently serves on the Boards of Governors for EPCglobal. He is a board member for OATSystems, a software company he helped found during his leave of absence from MIT 2004-2006. Dr. Sarma is also a trustee of the Massachusetts Technology Leadership Council.

He is a recipient of the National Science Foundation Career Initiation Grant, the Cecil and Ida Green Career Development Chair at MIT, the Den Hartog Teaching Excellence Award, and the Joseph H. Keenan Award for Innovation in Undergraduate Education.

Stanley B. Gershwin – Senior Research Scientist, Dept. of Mechanical Engineering

Stanley B. Gershwin is a Senior Research Scientist at the MIT Department of Mechanical Engineering. He is affiliated with MIT's Laboratory for Manufacturing and Productivity, Leaders for Manufacturing Program, and Operations Research Center.

He received the B.S. degree from Columbia University (1966); and the M.A. and Ph.D. in Applied Mathematics from Harvard University (1967 and 1971).

He studied telephone systems at Bell Laboratories (1970-71) and manufacturing and transportation systems at the Draper Laboratory (1971-75) and at the MIT Laboratory for

Information and Decision Systems (1975-87). He was Professor of Manufacturing Engineering at Boston University in 1986-87.

Dr. Gershwin has published "Manufacturing Systems Engineering" and numerous papers in international journals. Two of his papers received the Best Paper Award for the IIE Transactions issues on Design and Manufacturing, and one earned the Outstanding IIE Publication Award for 2000-2001. He has been an editor of two books and an associate editor of several international journals.

He and his students have done research or consulted for Boeing, General Motors, Hewlett Packard, Johnson & Johnson, Peugeot, and others.

Dr. Gershwin is a member of INFORMS, the Institute of Industrial Engineers, and the Society of Manufacturing Engineers. He is a Fellow of the IEEE.

Stephen Ho – Research Scientist, Laboratory for Manufacturing and Productivity

Dr. Ho is a Research Scientist at the Laboratory for Manufacturing and Productivity. He obtained his Bachelor of Science in Mechanical Engineering in 1996 from Cornell University and his Master of Science (1999) and Doctor of Philosophy (2004) from the Massachusetts Institute of Technology in Mechanical Engineering. He has extensive experience with modeling and simulation development and research including his Ph.D. work with The Auto-ID Center at MIT in warehouse operations optimization and the impact of information on optimal material storage and retrieval. Dr. Ho also has experience with artificial intelligence and decision- making technologies including the application of AI and knowledge engineering technology solutions to Department of Defense research issues as a Senior Scientist at Charles River Analytics, Inc., in Cambridge, Massachusetts (2004-2007). Dr. Ho returned to MIT in 2007 to continue his research on optimal material storage as well as explore the impact of information on other fields of operations, industry, and planning.

Irvin C. Schick – Research Scientist, Laboratory for Manufacturing and Productivity

Irvin C. Schick received his B.S. (Electrical Engineering, 1976), M.S. (Chemical Engineering, 1978), and Ph.D. (Applied Mathematics/Statistics, 1989) from the Massachusetts Institute of Technology. He has taught at Harvard University, Boston University, and MIT. During 1979/1987, he was with Scientific Systems, Inc., where he performed and directed research in statistical signal processing, pattern recognition, estimation, model identification, stochastic processes, and optimal control, focusing in particular on the analysis of bioelectric signals, consumer level electric load shapes, and econometric time series. During 1987/1992 and 1995/2003, he was with BBN Communications (later Genuity), where he performed and directed work on the analysis and design of data networks, specializing in performance and trend analysis, fault detection and diagnosis, root-cause analysis, quality of service monitoring, and network management across different product lines. During 1992/1995, he was with the Laboratory for Information and Decision Systems of M.I.T., where he conducted research in robust estimation, nonlinear and infinitedimensional filtering, multiscale signal analysis, stochastic processes, and automatic handwritten character recognition. Since 2004, he has been with the Laboratory for Manufacturing and Productivity of MIT, where he has conducted research on the modeling and analysis of quality/quantity interactions in manufacturing systems, analyzing the influence of different inspection strategies, quality control schemes, and production system design parameters on system performance.

Edmund W. Schuster – Research Engineer, Laboratory for Manufacturing and Productivity

Mr. Schuster is a research engineer at the Laboratory for Manufacturing and Productivity. He is currently working to develop new approaches for connecting data and mathematical models in a machine understandable way along with several projects in agriculture.

Previously, Mr. Schuster held the appointment of Director of the Affiliates Program in Logistics at the MIT Center for Transportation and Logistics and worked for a time at MIT Auto-ID Center and Labs. Before MIT, Ed worked as corporate manager of operations planning at Welch Foods (Concord, MA) and for Oscar Mayer. His business career has concentrated in the field of logistics with responsibilities including the management of corporate raw materials and operations.

Mr. Schuster has published over 100 articles on the application of management science to solve real world problems. His research interests include the application of models to logistical and planning problems experienced by industry. In January 2007, Ed's book titled *GLOBAL RFID: The Value of the EPCglobal Network for Supply Chain Management* was published in the US by Springer Verlag (New York and Berlin).

Ajay Deshpande – Ph.D. Student and Research Assistant, Dept. of Mechanical Engineering

Ajay Deshpande is a doctoral candidate in the Mechanical Engineering Department at the Massachusetts Institute of Technology. He graduated from the Indian Institute of Technology Bombay in 2001 with his B.Tech and M.Tech in Mechanical Engineering with the specialization in Computer Integrated Manufacturing. He earned his double Masters in Mechanical Engineering, and Electrical Engineering and Computer Science from MIT. His PhD thesis topic is coverage problems in mobile sensing. His research interests include sensor networks, signal processing, estimation and computational geometry. He is also a recipient of the MIT Presidential Fellowship.

Stuart J. Allen – Professor Emeritus, Penn State Erie – The Behrend College (Special Advisor to the group for all projects)

Dr. Allen works on design of decision aids for application in agriculture. During his academic career, Dr. Allen has published over 50 referred journal articles in engineering and management science. His educational background includes a BS in mechanical engineering from the University of Wisconsin, master of mechanical engineering from Seattle University and Ph.D. in engineering mechanics from the University of Minnesota. Dr. Allen began his research career in the field of non-Newtonian fluid mechanics. Besides academics, he has owned and operated three businesses in New York and Wisconsin.