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A Software Survey of Analytics and Spatial Information Technology

"Get the facts first. You can distort them later."
Mark Twain

This chapter echos the discussion in Chapter 7, in which we laid out the landscape of analytics and its supporting software, with a special focus on spatial information technology. While the purpose of Chapter 7 is to provide the general picture, the current chapter will review solution methodologies and specific software packages. We start with a general-purpose applied mathematics software, such as MATLAB, and progress toward more specialized tools, ending with vehicle-routing software. Many commercial software packages are multi-purpose; they perform more than one function. Oracle Crystal Ball is a good example, being a key spreadsheet-based application suite for predictive modeling, forecasting, simulation, and optimization. The various packages by Vanguard Software are another example. Instead of listing a general purpose software several times, sometimes we chose to list it only once under what we judge to be the most appropriate use.

Much of the information is taken from the commercial software surveys available in the literature, particularly those published in *OR/MS Today*. This is supplemented with a heavy dose of public-domain software surveys gathered from a variety of sources. As with most surveys, the information is solicited from the vendors or the software developers, who may report their own product through "color glasses." Here, we try to do some judgmental screening. As a result, only a small subset of the products available in the market is listed here. Since we are aiming at a general audience, more "proven" and more robust software are favored over overly specialized software. These tend to be the more "popular" packages. Exceptions are made in the public-domain software, many of which are developed in research and academic environments, which by its very nature, is developmental and geared toward a particular niche.

While we include much more specifics in this review chapter than Chapter 7, the evaluation provided here is still quite general in nature, as we stay away from *endorsing* a particular software. The readers are strongly encouraged to visit the references for additional information that would help decide the best

software for his or her application. Here, the author simply lists what he judges to be worth reporting. The criteria include the maturity and versatility of the commercial product, with attention duly placed on public-domain software as well. As always, the users should carefully judge for themselves the applicability of the product to his/her needs. In contrast to its functionality, the details of a software (such as its technical specifications and costs) are best gathered from the supplier's Website. Following our practice in this volume, no Web address is provided—inasmuch as a Web address is subject to change. This should not pose any inconvenience, however, as today's Internet search engine has greatly streamlined the location of Web addresses.

I. GENERAL ANALYTIC SOFTWARE

Echoing the layout in Chapter 7, we will divide software packages into two groups: general analytic software and spatial analytic software.

A. Spreadsheet Modeling

Spreadsheets are gaining popularity not only as a general office tool, but also as a modeling tool. The flexibility and versatility of a spreadsheet to solve a variety of problems are the driving force behind its popularity. There are a number of spreadsheet software available, including MS Excel and Lotus 1-2-3. It is not our intent to show our readers how to use a spreadsheet. Rather, we provide some guidelines to build *quality* spreadsheet models. Hillier and Lieberman (2009) suggest a four-step process to do so:

1. **Plan the spreadsheet model.** Visualize where one wants to finish and then do some calculations by hand to clarify the needed computations. Accordingly, a spreadsheet model is designed with the “feel and look” that one desires. The objective is a clear, logical layout to the overall model.
2. **Build the model.** It is advisable to start by building a small, readily manageable version of the model, mainly for experimentation.
3. **Test the model.** One is advised to test the small version first to get all the logic straightened out, before developing the full scale model.
4. **Analyze the model and its results.** In this final step, one applies the model to evaluate proposed solutions—to see how it performs. For more complex models, one may even use an add-in Solver to find the solution.

By itself, the four-step process is not sufficient. There are additional guidelines for building “good” spreadsheet models. Here are some salient ones (Hillier and Lieberman 2009, Winston and Albright 2007):

- Enter the data first, inasmuch as data really drives a spreadsheet.
- Organize and clearly identify the data.
- Enter each piece of data into one cell only.
- Separate data from formulas, instead of embedding data directly into a formula.

- Keep it simple by avoiding the use of powerful Excel functions when simpler functions are available that are easier to interpret.
- Use range names for easy reference, instead of just leaving the range in the cell.
- Use relative and absolute references to simplify copying formulas. This will save of re-entering the formula at various places in the spreadsheet.
- For readability, use cell comments liberally, use text boxes for assumptions and explanation, and use borders, shading, and colors to distinguish between cell types.
- Separate different parts of a model, possibly across multiple worksheets.
- When a Solver is used, the Solver uses a combination of the spreadsheet and the Solver dialogue box to specify the model to be solved. Therefore, it is possible to include certain elements of the model (such as the right-hand sides of the constraints in a linear program) in the Solver dialogue box without displaying them in the spreadsheet. For effective model dissemination, however, it is advisable to show the entire model on the spreadsheet.

To debug a spreadsheet model, check whether the output cells are giving correct results for various values of the changing cells. Also check whether range names refer to the appropriate cells, and whether formulas have been entered into output cells correctly. Toggle the worksheet between viewing the results in the output cells and the formulas entered into those output cells. Finally, other spreadsheet auditing tools can be used for additional debugging efforts.

Spreadsheets are appealing in part because it allows many models to be built without requiring computer programming skills on the part of the user. However, programming skills can be developed “on the job.” The use of macros is an example. Beyond building a straightforward spreadsheet model, decision support systems (DSSs) can be developed that builds upon spreadsheets, when assisted by a bit of programming (Albright 2010). A computer language to facilitate this effort is **Visual Basic for Applications (VBA)**. For Microsoft users, VBA comes with MS Office, which make it accessible to a vast audience of potential users. To work properly, one needs to enable macros in the front, since VBA is really a macro to the Excel spreadsheet software. The end result of this effort is a set of spreadsheet applications with front ends and back ends, where inputs are enter in the front and where results are posted at the back.

For our discussions here, VBA works with Excel objects. A few typical Excel objects one would recognize include ranges, worksheets, workbooks, and charts. The goal is to expose a spreadsheet’s object model and functionality to VBA, so that VBA can manipulate it programmatically. As a result, a DSS is built, going well beyond what a single spreadsheet can accomplish. In general, any application software package, such as Access, Word, or even a non-Microsoft software package, can similarly expose its object model and functionality to VBA.

B. Applied Mathematics

Aside from spreadsheets, applied mathematics packages offer a very general modeling environment for all sorts of problems. After all, the basic building block of a mathematical model is, well, mathematics.

1. MATLAB. The MathWorks now offers a very complex array of products to meet professional and scientific needs in both academia and industry. These products are organized around two main components, MATLAB and SIMULINK (Tarrazo 2006). Each of these products can be purchased separately, and a number of “toolboxes” and “blocksets” complement or extend each of them. The MATLAB “family” includes toolboxes in specialized areas and clusters of procedures. The former includes distributed computing, finance, bioinformatics, fuzzy logic, control, signal processing and communications. The latter include optimization, symbolic analysis, partial differential equations, genetic algorithms and direct search, statistics and data analysis, neural networks, splines, curve fitting, GARCH, wavelet, filter design, etc. The MATLAB family also includes a number of utilities, such as links for MS Excel, image acquisition, data acquisition, instrument control, datafeed, database, compiler, and report generator. Modeling needs are addressed by SIMULINK and related products.

Mathematical software is equally focused on both numerical and symbolic analysis. The symbolic toolboxes accompanying MATLAB provide access to MAPLE’s analytical kernel, which has the capability to perform symbolic calculus, transforms, linear algebra, simplification of symbolic expressions, equation solving, specialized mathematical functions, general symbolic operations and variable precision arithmetic. The Extended Symbolic Toolbox also offers C code, Fortran and LaTeX representation of symbolic expressions and full access to the most recent MAPLE kernel (except for graphics). This means support for programming in MAPLE and access to MAPLE specialized mathematics libraries.

According to Tarrazo (2006), the major difficulties stem from the following examples:

- (a) Different versions of the program require different syntax, which limits the usefulness of the older codes. Also, the program itself is evolving. For example, current versions emphasize function handles and anonymous functions and discourage the use of inline functions.
- (b) MATLAB syntax is sometimes hard to understand. Some procedures often seem to work well despite not following the recommended syntax, but this is without guarantees. The error messages sometimes refer to something different from what is going on. Some other items are hard to accustom to. For example, the anonymous function still looks like an odd construct after using it for a while. It is hard to explain the difference between the “abstract” and “symbolic” functions.
- (c) The fact that MATLAB can be used in different ways is both an advantage and a source of perplexing errors. The remedy is to solve (at least at first) the same problem in different ways, until one knows what exactly the program will do.

2. OCTAVE. OCTAVE is a nice free alternative to MATLAB that permits users to process data or to use it as a general purpose (graphic) calculator (Le Reverend 2006). In some cases OCTAVE’s syntax is slightly different from MATLAB’s; but standard functions such as the creation of matrices, concatenation of matrices, two-dimensional and three-dimensional plots, data interpolation and numerical differentiation and integration are exactly the same. OCTAVE can be installed via

Fink or DarwinPorts, where Fink and DarwinPorts are the two major Unix porting alternatives for Mac OS X. Alternatively, the software can also be compiled from the available source code.

In OCTAVE, anyone can develop his/her own toolbox should the need arise. More important, s/he can then share their toolbox with the rest of the OCTAVE community—a prominent feature of an open-source code. An additional benefit of OCTAVE is that the community is very active and that it is very likely that the OCTAVE user group will help if one has problems using the software, from compilation of the source codes to the development of one's own libraries. In fact, the most successful projects are those not only with excellent code bases but thriving communities of users and developers. The social dynamics may lead toward new ways to organize science and heighten the pace of knowledge discovery.

Of course MATLAB, being a licensed commercial software, is more feature complete. The lack of a SIMULINK equivalent in OCTAVE is a problem for process control engineers. Since MATLAB 6.0, the software is no longer a “**Command Line Interface (CLI)**”-only tool. Some functions are accessible using a graphical user interface (GUI), including graphics and curve fitting. OCTAVE remains a pure CLI application and many value it as a good feature. Like MATLAB, OCTAVE is interpreted and can therefore be quite slow. If one tries to solve big problems, s/he can still use C++ routines directly in OCTAVE to help it run faster, but for small problems, one obtains the solution ten times faster with OCTAVE than the time spent developing the program in C++. OCTAVE also lacks a built-in editor but SCINTILLA will do the job.

Most of these limitations are not found in another MATLAB clone: SCILAB. SCILAB is being developed by a French consortium, but the syntax for SCILAB is quite different from MATLAB's. Therefore if one prefers to maintain as much compatibility as possible with MATLAB, OCTAVE is the more appropriate choice.

3. Mathematica. Mathematica has been known for its symbolic computation. On top of enhancements for symbolic computation and numerical computation, recent versions of Mathematica have gone well beyond these classic capabilities (Sodhi 2009). Included are advanced numerical analysis and linear programming, supporting interior point as well as simplex algorithms. Also included are sparse matrix manipulation with fast algorithms that compete with dedicated numerical software tools. The GUIKit allows a user to create a GUI running on top of Mathematica for other users to do specific tasks. Mathematica 5.1 gave access to Web services offered by other providers (e.g., Amazon) as a Mathematica function. It also allowed better access to spreadsheets (such as MS Excel) and databases.

Mathematica 6 would analyze notebooks files created by older versions to diagnose which function calls need to be modified. New features or enhancements include combinatorial optimization, constrained nonlinear optimization, exploratory data analysis, symbolic statistical computing and extended array operations. Of particular interest is the “manipulate” function, data visualization, and most of all, a variety of datasets including financial datasets. Instead of word processors such as Tex and LaTeX, Mathematica features Publicon's ease-of-use in new versions.

Aside from graphic display and data manipulation extensions, there are features that take advantage of dual-core desktops that are very common today, not to say more specialized desktops (such as Apple) that have eight processors. Last but not least, the Wolfram Alpha search engine performs many search functions in Mathematica as other Internet engines. This shows that Mathematica has every indication and plan to provide desktop software that serves not only mathematics, but also day-to-day office applications.

C. Statistics

Following the criteria set up in Chapter 7 and using our best judgment, we screened the surveyed statistical software (Swain 2009, 2011) and resulted in the list shown below. What remains are some “substantive” statistical packages, including both specialized applications and full feature functionalities. We must admit that there may be bias toward software with full functionalities since we are looking for robustness and popularity. Each software is attributed to a vendor and reviewed with a brief commentary. Since data entry and output portability is a prime concern, we pay particular attention to the input formats and output formats of each software package. Although we exercise best judgment in the following screened list, the reader is advised to consult with the fuller listing by Swain (2009) for more details.

@RISK—Palisade Corporation

@ RISK performs risk analysis using Monte Carlo simulation to show many possible outcomes in Excel. Import formats include anything that can be brought into Excel. The application is an Excel add-in. Export formats include native Excel graphs and .jpg files. The new version, @RISK 5.5, introduced diverse new features and languages.

Autobox 6.0—Automatic Forecasting Systems, Inc.

Autobox will automatically build a customized model for univariate and multivariate time-series data—both in the batch mode and interactive mode. Import and export formats both include ASCII and Excel. The software can detect unusual behaviors such as level shifts, pulses, and seasonal pulses. Local time trends can be detected and adjusted automatically, accounting for intermittent demands while maintaining constancy of parameters and variance. The software was ranked the top Automated Software in the 2008 Daily Time Series Forecasting Competition.

DTREG—Phillip H. Sherrod

DTREG is a predictive modeling software that includes decision trees, neural nets, complete with vector machines support and genetic evolution functions. Import and export formats are in comma-separated values (.csv) files. Twelve predictive modeling methods are integrated into a unified program. The software is very easy to use.

JMP 8—SAS Institute

JMP 8 is an easy-to-use desktop solution, providing dynamic graphing, data visualization, comprehensive statistics and design of experiments. Import formats include JMP, Excel, text, Database via ODBC, SAS, html, First Choice Spreadsheet (FACS file extension), Access and dBASE. Export formats include JMP, Excel, text, SAS and dBASE. Notable features of JMP 8 are SAS integration, its capacity for choice experiments and modeling, and improved reliability/distribution fitting. Simulation can be performed within the design of experiments. JMP Pro Version 9 includes cross validation, Bootstrap Forests, Boosted Trees, 2-layer Neural Networks and more.

MaxDiff—Sawtooth Software, Inc.

MaxDiff provides “maximum difference scaling,” or best/worst scaling of items such as product attributes, brand features, and position statements. Import and export formats are in .csv files.

Minitab 15—Minitab Inc.

Minitab is arguably a leading statistical software used for analysis and quality improvement worldwide, complete with powerful data and graphical analysis capabilities. Import formats are in Excel, XML, csv, txt, dat, qmd, and .dbf files of the dBase database management system; (Here, the .qmd file extension is primarily associated with the ‘Quicken’ software by Intuit Inc.). Export formats include Excel, XML, csv, txt, htm, html, rtf, etc.

Optimal Scientist Software Package—Transpower Corporation

The software helps to design and analyze optimal experiments. Import and export formats are in ASCII. The package determines the optimal number of predictor (input) variables and the resultant optimal regression equation. It also performs all-ways multiple regression.

SmartForecasts—Smart Software, Inc.

The software is designed for forecasting, sales/demand planning and inventory optimization. Import and export formats include text, spreadsheet files and database Star Schema, where the schema is the simplest style of data warehouse schema, consisting of possibly one “hub” fact table referencing any number of “peripheral” dimension tables—graphically depicted as a “star.” SmartForecasts provides the Bootstrap methodology for intermittent demand, and full-holdout for time-series forecasting.

Smoothie—Demand Works

Smoothie is a sales and operations planning software for manufacturers and distributors, featuring Pivot Forecasting®. Import and export formats include Excel, text or database using ODBC. Smoothie’s Pivot Forecasting enables immediate propagation of aggregate forecasts and adjustments at any level. Modules are now available for consensus demand planning, inventory policy simulations and analysis, and n-tier supply planning.

Stat::Fit—Geer Mountain Software Corp.

The software is popular among users who wish to statistically fit risk, simulation, and modeling distributions to user data. Version 2 includes 32 distributions and enhanced graphics. Import formats include ASCII. The software exports into specific formats for the simulation software of interest. Distribution viewer allows interactive display of distributions. Stat::Fit is complete with a derounding function and diverse data-manipulation options.

STATGRAPHICS—Centurion; STATGRAPHICS Web Services—StatPoint Technologies, Inc.

The powerful software is used for statistical data-analysis and modeling, quality control, design of experiments, forecasting and Six Sigma. Import formats are in Excel and .csv files, while exporting .csv files. StatAdvisor offers instant, easy-to-understand interpretations of one's statistical results. New features include Monte Carlo simulation, random generation of ARIMA time series, multivariate visualization, and sample size determination. The Web Services version is designed to be called from web applications. Web service returns results as html with imbedded images.

Unistat Statistical Package—Unistat Ltd.

Unistat is a comprehensive standalone package that can also work as an MS Excel add-in. Import and export formats include xls, wk!, csv, txt, sdf, slk, dif, mdb, dbf, html. Fully functional demo and/or the PDF manual can be downloaded from the software website.

XLMiner—statistics.com

XLMiner is a data mining add-in for MS Excel. It features classification, prediction, affinity analysis, data reduction, exploration and visualization. Import formats are in.csv files. Exporting data is possible despite the format or location of the data. Should the user choose to export directly, s/he must be willing to devote more resources to do so. XLMiner is equipped with a new time-series analysis, on top of the ability to save models for later review. Subsequently, XLMiner can score saved models to new data.

D. Simulation

A survey was conducted by Swain (2009) to collect information on both specialized and general simulation applications. There were about forty-odd products listed in the survey, taken from twenty odd vendors. This is one of the larger surveys on simulation software. The range and variety of these products continue to grow, reflecting the robustness of the products and the increasing sophistication of the users. The information elicited in the survey is intended to provide a general gauge of the product's capability, special features and usage. Our brief remarks below are meant to be introductory only, identifying the vendor and providing a brief commentary, based on the evaluation criteria set up in Chapter 7 of the text. For more details, the reader is referred to Swain (2009) and the vendor's Website.

@RISK—Palisade Corporation

For this software, RISKOptimizer combines genetic algorithm optimization with Monte Carlo simulation for optimization under uncertainty. @RISK provides a wide range of graphs, data, and statistics on simulation results. Input distribution fitting is based on Komogorov-Smirnov and Anderson-Darling goodness-of-fit tests, including cumulative and discrete distributions. Output analysis supports a wide range of graphs, data, and statistics on simulation results. @RISK Function Swap lets users remove @RISK functions from spreadsheet for non-@RISK use. Major new features include a new interface, new graphs, new functions, and much faster simulations. The version of @RISK, intended for industrial application, provides a fully customizable presentation and quality graphs. Input distribution fitting utilizes over 40 built-in distribution functions. Excel reports on the models can be shared with others who might lack the software to develop their own model. @RISK 5.5 has been fully translated into Spanish, German, French, Portuguese and Japanese.

AnyLogic—XJ Technologies

OptQuest by OpTek Systems Inc. provides optimization functionality to this simulation software. Input distribution fitting utilizes the Stat::Fit software. Simulation output provides dataset statistics, distributions, regular and two-dimensional histograms, various charts, etc. AnyLogic models can be exported as standalone Java applets or Java applications. Major new features include templates for agent based and other methods, the rail yard library, pedestrian dynamics modeling, and three-dimensional animation.

DecisionTools Suite—Palisade Corporation

The software features genetic algorithm for optimization under uncertainty, which is applied toward Monte Carlo simulation. Similar to another Palisade simulation package @RISK, input distribution fitting is based on Komolgorov-Smirnov and Anderson-Darling goodness-of-fits tests, including continuous and discrete distributions. The output includes a wide variety of graphs, data, and reports from simulation, utilizing decision trees and optimization analyses. @RISK Function Swap lets users remove @RISK functions from spreadsheet for non-@RISK use. Recent innovations include new graphs; new interfaces; new functions; faster simulations; and common interface conventions across Palisade products.

Emergency Department (ED) Simulator—ProModel Corporation

This medical-application software provides customized ED-specific data-output charts and graphs such as level-of-service, census by patient status and time-of-day and more. Input distribution fitting is based on user-defined distributions, or 15 predefined distributions, plus distribution fitting using Stat::Fit and/or Data Analyzer Software (at additional cost). Trial Version of Simulator can be shared. Solutions are driven by the ProModel VAO Technology, where VAO stands for Visualize, Analyze, Optimize. The software developer suggests that VAO can lead to better decisions faster.

Enterprise Portfolio—ProModel Corporation

Input distribution fitting is based on 15 predefined distributions. Distribution fitting can also be performed using Stat::Fit software (at additional cost). The software output analysis includes reports and charts, and documents in MS Excel format. A trial version of Portfolio Simulator can be shared among users. New products include web-browser version of the software, which runs on Microsoft (MS) Silverlight. It integrates with MS Project Server, including automatic updates. Solutions are driven by ProModel VAO Technology.

ExtendSim AT, ExtendSim OR, and ExtendSim Suite—Imagine That Inc.

An open-source evolutionary optimizer is included in all versions of ExtendSim. Input distribution fitting uses the Stat::Fit software, which is included in the package. For output, confidence intervals for output statistics are calculated at the click of a button. Free download Demo-Player version is available from the Imagine That! Website. The downloaded version opens, previews and runs the models of interest. Recent innovations include integrated database, built-in LP solver, revised and updated modeling components, variable connector arrays, and more scalable modeling. ExtendSim AT has broad functionality that supports modeling across both discrete-event and batch-process modes.

Flexsim and Flexsim CT—Flexsim Software Products, Inc.

For this simulation software, OptQuest by OpTek Systems Inc. provides the optimization functionality. Input distribution fitting is based on ExpertFit. Output is displayed as Flexsim Charts. Industry-specific and application-specific modeling objects and libraries or model-building objects can be shared. Flexsim Runtime allows completed models to be shared with others who might lack the software to develop their own model. Flexsim is easy to learn and it builds true three-dimensional models. New features include a complete library of model-building objects, consisting of container-terminal resources. Flexsim CT is the only commercial simulator designed specifically for managers and engineers to model container terminals. Meanwhile, Flexsim HC is a completely new simulation software product created specifically and solely to model healthcare patient-flow processes. Patient Trackú is the key to making healthcare modeling building both easy to do and extremely realistic and accurate.

GoldSim—GoldSim Technology Group

GoldSim includes a feature that provides global optimization of dynamic, uncertain systems, complete with sensitivity and uncertainty analysis. Model sharing is built into the software. New features include 64-bit support, new dashboard controls, enhanced reliability engineering and risk analysis, and enhanced distributed processing. A hybrid version combines system dynamics with aspects of discrete-event simulation, embedded within a Monte Carlo framework.

Micro Saint Sharp—Alion Science and Technology

The software can be linked with OptQuest optimization. Micro Saint Sharp automatically collects data to better understand the modeling process, in which data on utilization, queues, resources, and tasks are collected automatically. At the

same time, users can customize data collection to see whatever results are desired. For model sharing, users just need to select the Export Model to Runtime option under the Utilities menu. There s/he would select a folder, and Micro Saint Sharp will then create runtime version of the model that can be distributed. New features include three-dimensional animation, custom object types, communications module, VISIO import/export, and experiment definition.

Portfolio Simulator and Project Simulator—ProModel Corporation

Mathematical optimization capability is built into this stimulation tool. Input distribution fitting uses 15 predefined distributions, or the Stat::Fit software at additional cost. Output analysis includes reports and charts, with option in the MS Excel format. Trial Version of Portfolio Simulator can be shared among users. New features include direct imports from MS Project Server and Excel. Solutions are driven by ProModel's VAO Technology.

Process Simulator—ProModel Corporation

A notable feature of this simulation software is that output analysis reports and charts are included, with options in MS Excel and Access format for further analysis. In addition, model information can be modified in MS Excel and imported back into Process Simulator for additional runs. Model sharing can be accomplished through Process Simulator Lite. Recent additions include directly displaying simulated results via data graphics, and Minitab Integration. Solutions are driven by ProModel's VAO Technology.

ProModel Optimization Suite, ServiceModel Optimization Suite, MedModel In this software package, optimization Suite—ProModel Corporation

Optimization is available using OptQuest and/or SimRunner. Input distribution fitting uses user-defined distributions and 15 predefined distributions, plus distribution fitting using Stat::Fit that is included in the package. The software outputs analysis reports and charts, including documents in MS Excel and Access for further analysis. Model packaging is available within software view using free ProModel Play. The suites model separate areas of a broader model independently. Then it brings them together for overall simulation, complete with Minitab connectivity. Solutions are driven by ProModel's VAO Technology. The MedModel suite is a simulation-based software tool for evaluating, planning or re-designing healthcare systems.

Risk Solver, Risk Solver Platform, Risk Solver Premium—Frontline Systems Inc.

In this simulation package, input distribution fitting is available, matching against scores of continuous and discrete distributions. Risk Solver outputs charts, probability distribution function (PDF), cumulative density function (CDF), tornado and scatter plots, plus 30 statistics and risk measures. The Risk Solver Engine supports the sharing and distribution of models to others. New features include ultra-fast interactive simulation, probability management with **Statistically Improbable Phrases (SIPs)** or distributions, and multiple parameterized simulations. (Here, SIP is a search string likely to generate meaningful results from a search engine.) Notice the software is from developers of Excel Solver and Premium Solver, which are

among the notable products in spreadsheet solvers. Finally, Risk Solver is ungradable to Risk Solver Platform for powerful stochastic optimization. The Platform provides simulation and optimization, stochastic programming, and robust optimization with up to 12 powerful solvers. New features include everything in Risk Solver and Premium Solver Platform and more. The Premium software provides simulation and optimization with GRG Multistart¹ and Evolutionary Solvers. New features include everything in Risk Solver, everything in Premium Solver, plus Simulation Optimization.

Simcad Pro-Patented Dynamic Process Simulator—CreateASoft, Inc.

The software features built-in Dynamic Optimizer tool, on-the-fly user interaction, integrated work-order/schedule optimization, value stream maps, Gantt chart, scenario analysis and lean reports. Here, value stream mapping is a lean manufacturing technique used to analyze the flow of materials and information currently required to bring a product or service to a consumer. An input distribution is auto-fit to a database encoded in .csv file, and Excel files, etc. Model sharing can be accomplished through Simcad Viewer or Simcad Online. Recent advances include Multi-core Processor, Dynamic Optimizer, linkage with Radio Frequency Identification or Real-Time Locating System, Simcad Online, and Excel Import/Export Wizards.

SIMUL8 Standard, SIMUL8 Web, SIMUL8 Professional—SIMUL8 Corporation

This simulation software includes OptQuest optimization by OpTek Systems Inc. It provides automatic confidence interval calculation with no coding required. Input distribution fitting is accomplished through the Stat::Fit software. Outputs include results and charts for all simulation objects, dynamic on-screen reporting as the simulation executes, and export to external applications such as MS Excel, V.I.S.A., and Minitab. Here, V.I.S.A. is a Web based multi-criteria decision-making software. By linking SIMUL8 to V.I.S.A., one can assess the impact of weighing the importance of each of these performance measures, and assess which scenario best meets the analysis goals. SIMUL8 boasts being a pioneer on the use of trial calculators, which determines the number of simulation runs to get accurate confidence intervals. According to the software developer, SIMUL8 is easy to use, powerful, and among the fastest in the field. The web version allows hosting on the vendor's Website, user's Website or user's corporate network. There is an option for animation. No end-client install is required. The Professional version has all the features of the Standard version. On top, it has the SIMUL8 Results Manager, which provides centralized results database, scenario and run comparison reports, and customizable charting and reporting capabilities. Model sharing can be achieved through SIMUL8 Viewer. Among recent advances is a 30%-faster run execution speed, the SIMUL8 Results Manager, predictive text, multidimensional arrays, customizable runtime charts, and extended ease-of-use, and power to link to any application or data source with SQL and Component Object Model (COM).

Tecnomatix Plant Simulation—Siemens PLM Software

Tecnomatix Plant Simulation is a discrete-event simulation tool that creates digital models of logistic systems, so that one can explore the system's characteristics and

optimize its performance. The Integrated Optimizer features layout optimizer plus neural networks and bottleneck analyzer. Input distribution fitting is accomplished through the Data::fit module; Outputs include Sankey chart, html result report, and Gantt chart. A Sankey chart is a flow diagram, in which the width of the arrows is shown proportionally to the flow quantity. They are typically used to visualize material transfers between processes. Tecnomatix has integrated Pay and Go functionality, and fee-charge viewer for licences. For applications, Tecnomatix provides Virtual Commissioning, plant design and optimization solution, and Teamcenter Interface for product-lifecycle-management solution. Virtual commissioning is the use of a virtual model that represents an accurate and realistic three-dimensional simulation of mechanical, electrical, and control systems in order to validate the physical functions of a production system prior to actual physical implementation. In Tecnomatix, the user is provided with real object-orientation, inheritance², openness to import SAP, Excel, Oracle data, and ease-of-use through real Windows standards.

Vanguard Business Analytics Suite, Vanguard Strategic Forecasting Suite, Vanguard System—Vanguard Software

Features include simulation statistics, sensitivity analysis, and graphical presentations. Input distribution fitting is performed through the Distribution gallery, Auto-fit wizard, user-defined distributions, and SIP/SLURP search support. Here, SLURP is a web crawler from Yahoo! that obtains content for the Yahoo! Search engine. Outputs integrate with Microsoft Office, rendering them available as Web reports and Interactive Web-based models (without any Web programming). Modelers can take advantage of grid computing, collaborative modeling, and linkable models. Analytics Suite provides scalable, high performance simulations. Vanguard Strategic Forecasting Suite features a new stochastic optimizer and grid computing for higher performance. The Vanguard System is designed for large-scale enterprise modeling, including invariant branch optimization in compiler operations.³ It includes Multi-Objective Decision Analysis (MODA)/MAUT, AHP, and decision tree analysis.

E. Optimization

While the review here is mainly on LP and MIP software, a number of the following products can handle more general nonlinear problems as well (Fourer 2009). Some of the available software packages for nonlinear programming are described in a survey by Nash (1998). Note that this latter survey was restricted to “full feature” nonlinear programming packages, meaning packages that accept a full range of non-linearities (i.e., nonlinear objective function, and nonlinear equality and inequality constraints). This omits many worthwhile pieces of software that only handle more restricted models.

For more specialized applications, there is a recent movement toward open-source optimization software. A prominent example is the COmputational INfrastructure for Operations Research, or COIN-OR for short. The project is managed by a non-profit foundation. Irrespective, the number of available commercial and public-domain optimization products is large. Accordingly, we have done a judgmental quality screening, resulting in the following short list.

ADBASE—University of Georgia

ADBASE is an MPS-based PC software that operates under DOS. It is built upon the revised simplex algorithm, as extended to multiple criteria. It generates all non-dominated multicriteria-LP solutions. Interval criterion weights can be specified to find a subset of the non-dominated solutions. Lexicographic ordering of criterion vectors is included as a feature in the software. An I-file is used to input the cost vectors for the criteria, the constraint matrix, and the right-hand-side vector. A G-file is used to specify the problem-specific options. ADBASE is among the very few software available to solve a multicriteria LP. While not totally user-friendly, it is a free software for the non-profit academic community. To obtain a copy of the executable code and a User's Manual, please contact Dr. Ralph Steuer at the University of Georgia.

AIMMS, the modeling system—Paragon Decision Technology Inc.

AIMMS is an integrated modeling tool built upon the use of large-scale optimization models. It is an integrated development, complete with end-user GUI, point-and-click database and XML integration, advanced developer-support tools, multi-language and unit support, internal data-management facilities, batch run options; multi-agent technology, API/COM interface and Web posting. Of particular interest is the outer approximation algorithm, an open source algorithm for generating the set of all efficient extreme points in the outcome set of a multicriteria LP. AIMMS provides a modeling environment for CPLEX, XPRESS, XA, CONOPT, KNITRO, LGO, BARON and more through their Open Solver Interface. New features include parallel solver sessions, stochastic programming support, new syntax editor, case differencing, web services, GIS support, pivot table, multi-developer support, non-linear math program inspector, solution pooling, lazy constraints,⁴ Benders' decomposition algorithm, nonlinear pre-solve, multistart solve, GUROBI,⁵ MOSEK,⁶ Dynamic database functions, MS Virtual Earth link, Yahoo Maps, ESRI Shape files, geocoding functionality, free viewer license, and free student license.

AMPL—AMPL Optimization LLC

AMPL is a general nonlinear solver that supports second derivatives, detailed solver-specific directives and results, user-defined functions and MATLAB interfaces. Noted for its modeling environment, it supports at least 35 solvers, as listed on the vendor's Website. Flexible handling of sets and indexing for handling complex models naturally and large models efficiently. AMPL includes a scripting language for iterative optimization schemes. Free experimentation is available through the NEOS Server.⁷ New features include Solver support for multiple solutions, parameter tuning, local search, mixed-integer programming with non-linearities.

BendX Stochastic Solver—Maximal Software, Inc.

BendX is a standard C Application-Programming-Interface (C-API) callable-library stochastic solver. It supports solving both scenario-based and independent-variable models with Deterministic Equivalent (DEQ) and Benders' algorithms.⁸ BendX solves both DEQ and Benders decomposition problems, using CPLEX, GUROBI and CoinMP as the underlying LP solvers. In addition to the C-API callable library interface, BendX supports both SMPS⁹ and XML files. With optimization projects, there is often a need to store model instances, e.g., for building model libraries, providing

technical support, and optimization services over the Internet. OptML facilitates a new portable, non-solver specific standard, based on XML, which supports multiple problem types, including linear, mixed-integer, quadratic, nonlinear, and stochastic programs. At the same time, there is also a need to convert raw data in XML format into problem instances that conform to the optimization services instance language (OSiL) standard. BendX can be an add-in to the MPL Modeling System, CPLEX, GUROBI, and CoinMP. Recently, BendX offers unique object-oriented library stochastic interface for Visual Basic, C#, and Java.

CoinMP—Maximal Software, Inc.

CoinMP is an open source C-API interface library that includes Coin LP (CLP), Coin Branch-and-Cut (CBC), and Cut Generation Library (CGL) projects. Pre-compiled ready-to-use CoinMP.dll is available for download. When source is compiled for Windows it generates a CoinMP.dll library that can be readily used in projects. When compiled for Unix/Linux it generates a CoinMP.so library. CoinMP serves as an add-in to MPL Modeling System and others. New release of the software offers object-oriented library interfaces for Visual Basic, C#, and Java. Linux/Unix versions are available with automake/configure support.¹⁰ IPOPT¹¹ and Storage Management Initiative support are coming soon.

GAMS—GAMS Development Corporation

GAMS is arguably a classic algebraic modeling language. A GAMS system includes all components with size restrictions removed for those that are purchased. Solvers/modeling environments that link to the product include ALPHAECF, BARON, CONOPT, CPLEX, DECIS, DICOPT, GUROBI, KNITRO, LGO, LINOGLOBAL, MINOS, MOSEK, MPSGE, MSNLP, OQNLP, OSL, PATH, SBB, SNOPT, XA, and XPRESS.

IBM ILOG CPLEX—ILOG, an IBM Company

ILOG CPLEX has been one of the front runners in solving LPs, exploiting the speed of network algorithms. With call backs and goals, users can customize MIP branch-and-cut, such as branching strategies and cutting planes. IBM ILOG ODM is an application and cutting-planes development tool. It builds and deploy custom planning and scheduling applications based on IBM ILOG CPLEX. OPL Development Studio has multi-model algorithms, featuring warm-start, external calls to Java, decision expressions, performance profiler, automatic tuning, constraint detection and conflict resolution. Solvers/modeling environments that link to the product include IBM ILOG OPL-CPLEX Development System, AIMMS, AMPL, GAMS, MPL, MATLAB, and Microsoft Solver Foundation.¹² New features include dynamic search, MIP solution pools, deterministic parallel MIP, tuning tool; multiple MIP starts, solution polishing API, multi-model algorithms, warm-start, external calls to Java, decision expressions, performance profiler, automatic tuning, constraint detection and conflict resolution.

LINDO API, LINGO—LINDO Systems, Inc.

LINDO API is a popular suite of fast callable solvers for creating customized linear, integer, nonlinear, quadratic, stochastic and global optimization applications. Solvers/modeling environments that link to the product include MATLAB, GAMS, LINGO and What'sBest. LINGO is a popular suite of fast linear, integer, nonlinear,

quadratic, stochastic and global solvers. It includes a comprehensive modeling language with convenient data options. LINGO's solvers and interactive modeling environment make it a comprehensive tool for operations research professionals. The modeling language and mathematical functions allow quick, concise problem expression. Data can be stored separately in text. Solvers/modeling environments that link to the product include LINDO API and Excel. New features include Stochastic programming capabilities, statistical sampling, and K-best MIP solver.

MPL Modeling System, OptiMax Component Library—Maximal Software, Inc.

With the OptiMax Component Library which is listed separately below, MPL models can be embedded into end-user applications using Visual Basic, VBA, C#, C/C++, Java, and Web-scripting languages. OptiMax is an object-oriented component library, specifically designed to help embedding optimization models into end-user applications. Solvers/modeling environments that link to the product include CPLEX, GUROBI, Xpress, OS, XA, MOPS, LINDO, FORTMP, C-WHIZ, CoinMP, GLPK, LPSOLVE, CONOPT, KNITRO, LGO, PATH, and EXCEL. Latest releases feature increased speed and scalability. New solver versions include CPLEX 12, GUROBI 1.1, Xpress 2008, MOPS, CoinMP, GLPK, LPSOLVE, KNITRO, CONOPT, LGO, PATH, stochastic programming, and new data sources. New release of OptiMax offers new language support, and more than 20 new objects have been added, with new enhanced methods and properties for advanced solver handling and data management.

Premium Solver Platform, Risk Solver Platform, Solver Platform SDK—Frontline Systems Inc.

Features of this software include convex and non-convex smooth nonlinear optimization, non-smooth optimization, global optimization and IF/MIN/MAX linearization. Premium Solver Platform can be an add-in to Microsoft EXCEL. There are five built-in solvers, eight plug-in solvers including LP/QP, GUROBI, Xpress-MP, MOSEK, KNITRO, LSGRG, LSSQP, and OptQuest. Recent release of the software includes new modeless user interface, parameterized optimization, charts/graphs, multi-core nonlinear and global solvers, and video demos. Compatible upgrade is obtainable from developers of Excel Solver and Premium Solver. Premium Solver Platform is upgradable to Risk Solver Platform for simulation and stochastic optimization. This powerful Excel Solver upgrade integrates conventional optimization, simulation/risk analysis, stochastic and robust optimization, and decision analysis. On top of the functions in Premium Solver, the Risk Solver Platform performs Monte Carlo simulation optimization, stochastic programming and robust optimization. The newly released product includes parameterized simulations, multi-core simulation, and decision trees. Working outside Excel, Solver Platform SDK has these additional features: object-oriented and procedural APIs for C/C++, C#, VB.NET, VB6/COM, Java, and MATLAB. New features include Visual Studio 2008 support, and a large library of examples. It now reads/writes MPS, LP, OSIL files; IntelliSense and JavaDocs.

SAS—SAS Institute Inc.

The comprehensive software suite includes, among other items, quadratic optimization using an interior point solver, general nonlinear optimization that includes nonlinear objective and/or nonlinear constraints. There are several techniques for general nonlinear optimization with boundary, general linear, and nonlinear constraints. Two algorithms are designed for quadratic optimization problems and two other algorithms address nonlinear least-squares problems.

SAS integrates optimization with data access and handling. Recent upgrade includes irreducible infeasible set analysis, enhancements to the OPTMODEL modeling language, and interior-point nonlinear-programming solver. Given its statistical background, SAS integrates optimization with data access and handling, statistical analysis and data mining, forecasting, reporting and deployment.

Smart Optimizer (SOPT) 4.2—SAITECH, Inc.

Various heuristic search algorithms are implemented in SOPT to look for integer feasible solutions quickly. Quadratic or smooth nonlinear problems are solved fast by an interior-point algorithm. Solvers/modeling environments that link to the product include AMPL. Extended search capabilities are further developed to find feasible solutions to large-scale integer programs. Cuts are automatically generated by user parameters.

SYMPHONY—COIN-OR Foundation

SYMPHONY is an open-source solver for mixed-integer linear programs written in C. It can be used either (1) as a callable library through either a modeling shell, or (2) as a standalone program. Features include an open-source solver for bi-objective integer programs, warm starting for integer programs, basic sensitivity analysis for integer programs, and call backs for customization. These custom modules are included for specific combinatorial problems: vehicle routing, set partitioning, multicriteria knapsack, network routing, etc. Solvers/modeling environments that link to the product include GMPL, AMPL, GAMS. Here, GMPL stands for GNU Mathematical Programming Language. GMPL is also referred to as GNU MathProg—the two terms being interchangeable. Both represent a high-level language for creating mathematical programming models.

Vanguard System for Web-based Optimization—Vanguard Software

This is a new tool to build and deploy Web-based optimization applications. It supports access controls, version controls, and systems integration. The recent release is a development tool for Web-based optimization, stochastic optimization, grid computing, Web services, and collaborative modeling. Other features include forecasting, Monte Carlo simulation, decision tree analysis, statistical analysis, financial analysis, and sensitivity analysis.

What'sBest—LINDO Systems, Inc.

What'sBest is a large-scale optimization add-in for MS Excel. It allows the user to build linear, nonlinear and integer models in one's favorite spreadsheet. It is powerful enough for real world models and ideal for building models for clients. Other solvers/modeling environments that link to the product include LINDO API. Recent release includes stochastic programming capabilities, statistical sampling, K-best MIP solver, and expanded function support.

XA—Sunset Software Technology

XA has been around for decades. Recent development experienced a five-times speedup in solving mixed integer linear programming models. XA can serve as add-in to EXTEND, EXCEL, PYTHON, and Goldsim. Other solvers/modeling environments that link to the product include AIMMS, GAMS, MPL, and AMPL. New features include Conflict Analysis, piecewise linear, and concurrent primal and dual algorithm.

F. Decision Analysis

Here are some decision analysis and multicriteria decision-making products to choose from. Most of them cover multi-objective decision analysis (MODA) and multi-attribute utility theory (MAUT). Again, we have done a judgmental screening, resulting in a selected list of more full-feature and popular packages. Once again, the reader is advised to consult additional references, particularly Buckshaw (2010) and Maxwell (2008). The Buckshaw and Maxwell surveys from the database from which we provide the following list. Whichever tool(s) are ultimately selected by our reader, they should be intuitive to the user, explainable to the client and support easy iterations among the various stages of the decision analytic process.

1000Minds—1000Minds Ltd.

The software includes MODA/MAUT. It also provides a procedure called PAPRIKA, which is based on the fundamental principle that any ranking of alternatives is uniquely defined by all possible pairwise comparisons of the alternatives—hence the acronym PAPRIKA, which stands for Potentially All Pairwise RanKings of all possible Alternatives. Another prominent building block is Conjoint Analysis, which involves surveying stakeholders about the relative importance of a product's (or service's) features. Recent release shows that the software now manages the entire process for developing a prioritization tool, including administrative functions for managing participants. The software features value for money analysis; selection of portfolio of alternatives with budget constraints; analysis of group elicitation, prioritization of patients for health care, selecting health technologies, project portfolio selection, and competition judging.

Crystal Ball Standard, Professional & Premium Editions—Oracle

The generalized software package includes, among other analytical features, MODA/MAUT. Other algorithms implemented package include Monte Carlo, linear and nonlinear programming. The 2008 release includes a new version of OptQuest. The new version features a new Wizard for setting up optimization procedures; full integration with Excel and Crystal Ball, including the ability to control optimization through Crystal Ball's control panel, and an updated version of OptQuest's global optimization engine. The new release supports both linear and nonlinear constraints. It includes a more aggressive algorithm. It caters for new variable types, including binary, category, and custom. It has the ability to create reports and extract data. And it includes a Developer's Kit of API for programming optimization functions.

DPL—Syncopation Software

Features in DPL include MODA/MAUT, decision tree roll back, and Monte Carlo. New features include Developer API, initial decision alternatives tornado, default states, arrays in the influence diagram, and database INIT links. Marketed under DPL Professional, DPL Enterprise, and DPL Portfolio, of particular interest is the capacity to control DPL from another application using OLE Automation,¹³ ability to build a custom front-end interface and invoke DPL in the background, and the aggregation of expert assessments. According to the vendor, DPL combines decision trees, influence diagrams and Excel spreadsheets to provide an intuitive and comprehensive modeling environment. Applications include portfolio prioritization, strategy, capital budgeting, and valuation.

ForeTellÆ—DecisionPath, Inc.

ForeTellÆ provides hybrid synthesis of Monte Carlo, system dynamics, agents/game theory, process and event models. There are automated RAD game tools¹⁴ to build models from enterprise database and loading simulation outputs back into repositories. ForeTell enables a user to “test drive” critical organizational decisions before committing to implement them. Recent features include bi-directional interfaces to BI Solutions on RDBMs and data warehouses, plus bar chart analytics.

Hiview3—Catalyze Ltd.

Hiview3 features include MODA/MAUT. Recent release provides model templates, the ability to deal with unknown data, improved reporting, and analytical and aesthetic improvement. A network version is also available. Extended features include model sharing. The user can fix the entire model and allow others to use Hiview3 to explore the model as a live document, or fix the structure and scores and invite others to update the weights to see how their judgements influence the results. Applications include evaluating capital projects, analyzing policy settings, strategy selection, relocation/site selection, and budget resourcing.

RPM-Decisions—Systems Analysis Laboratory, Helsinki University of Technology

RPM stands for Robust Portfolio Modeling. The software is built upon Multi-attribute Value Theory, considering incomplete information, non-dominated portfolios and core indexes. RPM defines a project’s core index as the share of non-dominated portfolios that include the project. Recent extensions include project interdependencies, incomplete cost information and variable budget levels. The problem is formulated as a multi-objective zero-one linear programming problem with interval-valued objective function coefficients.

SMILE (Structural Modeling, Inference, and Learning Engine)—University of Pittsburgh

SMILE is a fully portable library of C++ classes implementing decision-theoretic methods, such as Bayesian networks and influence diagrams. Its Windows user interface, GeNIe, is a versatile and user-friendly development environment for graphical implementation. Both modules—Bayesian networks and influence diagrams—have been made available to the community free-of-charge since 1998 and have now several thousand users worldwide. Contact Dr. Marek J. Druzdzel at the Decision Systems Laboratory, University of Pittsburgh, if interested.

II. SPATIAL ANALYTICS SOFTWARE

In Chapter 7, we discussed the salient features of spatial analytic software, including GIS, image processing, and vehicle routing. Here, we will provide a list of software that subscribe to these features.

A. GIS

There are many GIS software packages offered, but only a handful is true benchmarks (Galati 2006). Notable ones on the commercial market include ESRI's ArcGIS, Intergraph Corporation's G/Technology, General Electric's Smallworld, Clark Labs' IDRISI Kilimanjaro, Autodesk's GIS Design Server, Delorme's Xmap, and Pitney Bowes' MapInfo. Most are developed with full GIS functionality, concomitant with a corresponding price tag. Perhaps worth mentioning is Delorme's Xmap and IDRISI Kilimanjaro, which are lower cost options among this peer group, with the latter characterized by user-friendliness and built around raster-based instead of vector-based files.

Unlike the generalized analytics software listed above, GISs are fewer in number, as they are specialized packages for spatial application only. There are currently only a handful of GIS packages, but many more are expected to be published in the next decades (Prastacos 1992). For the packages listed below, they are constantly being improved.

ARC/GIS—ESRI

This is the most widely-used GIS system available for a variety of computers, including desktop, laptop, tablets, servers and mobile devices. It is a powerful, command-driven GIS with extensive capabilities for data storage, editing, display, and geographic analysis. Users can install plug-in's, called extensions, to add functionality. ArcExplorer is a free GIS data viewer that allows basic mapping and spatial querying. ARC/GIS has been a leader in the GIS software market.

GIS Design Server—Autodesk

This package is from a company that developed AutoCAD, a computer-aided-design tool familiar to the engineering community. Through AutoCAD, Autodesk has earned user trust in the community. For GIS, what the developer offers is Autodesk Map, which designs, maintains and produces maps and geographic data. The program suite supports desktop, laptop, tablet, and mobile platforms. On top of this, the GIS Design Server provides an environment that allows flexible data integration, although the integration is most seamless with AutoCAD files. With the familiar program exchange through AutoCAD, Autodesk's GIS product commands a huge following.

G/Technology and GeoMedia Software Suite—Intergraph Corporation

The G/Technology suite of programs offers industry-specific data models for utility, pipeline, water and communications companies. Its open GIS architecture allows it to work with many GIS formats. The companion GeoMedia Software Suite facilitates map design, presentation and sharing. The software allows desktop, laptop and enterprise wide compatibility. GeoMedia viewer is a free GIS viewer, facilitating desktop geospatial viewing and the sharing of data among users. The combination of G/Technology and GeoMedia offers a formidable GIS environment.

IDRISI Kilimanjaro—Clark Labs

With an academic genesis, IDRISI Kilimanjaro is a widely used raster based GIS and image processing software. It is user friendly and highly accessible. Over the years, it has become a benchmark in geospatial standard. Its functionality includes modeling, database querying, spatial data development and geostatistics. Its low cost and research functionality explain why its object-oriented development tools

are popular for focused research. IDRISI Kilimanjaro has been particularly popular for environmental analysis and modeling.

MapInfo—Pitney Bowes Business Insight

MapInfo is a menu-based, user-friendly desktop mapping and GIS systems that can store and display street networks and zone boundaries. It has sophisticated routines for geocoding. The proprietary data structure is not topological, hence paths and routes, for example, cannot be defined. MapInfo is noted for its capacity to allow further development. For example, MapX is an Active X component that enables active software embedding, allowing embedding mapping applications within other applications, such as MS Word, Excel, and Lotus 123.

Smallworld Suite—General Electric

A unique feature of the Smallworld Suite is its advanced spatial technology and seamless existing system integration. Key components include the Core Spatial Technology, Spatial Intelligence, Enterprise Integration Tools, and Design Manager. The software offers desktop, laptop and Internet interoperability. Its architecture is different from ESRI's all purpose design, and Intergraph's specialized and all-purpose programs. Unlike these broadly focused programs, the Smallworld Suite centers upon engineering, scientific and business-oriented applications.

TransCAD—Caliper Corporation

TransCAD is a powerful and easy-to-use GIS-based transportation package. The system consists of two parts: a GIS engine and a tool box of transportation models and procedures. The GIS engine is menu driven and, in addition to the standard GIS functions, can directly support transportation data structures such as nodes, links, networks, paths, and tours. TransCAD has a set of dynamic segmentation and linear referencing tools for managing highway, rail, pipeline, and other networks. TransCAD also provides a platform for users to develop their own transportation-related models. The software is developed for the desktop PC MS operating systems, including Windows 2000, Windows XP, Windows Vista, and Windows 7.

Xmap—Delorme

Through Xmap, the mapping giant Delorme offers a low-cost GIS and GPS mapping capability, complete with robust functionality. Xmap's modular design allows for expandability and interoperability. XMap is a three-tiered GIS software suite designed for transfer of information between GIS administrators and field personnel. XMap Enterprise provides database management tools and is intended for corporate GIS administration and data deployment. XMap Editor, a full featured GIS, offers an extensive set of GIS layer importing, creating and editing tools, ideally suited for small scale GIS operations. XMap Professional is primarily a GIS data viewing application. However, when used in conjunction with XMap Enterprise, it becomes a proficient field data collection and updating tool, ideally suited for field personnel. Xmap supports open GIS and most GIS data formats.

Prominent among the public domain software is Geographic Resources Analysis Support System (GRASS), a fully functional GIS environment. Originally developed by the U.S. Army Construction Engineering Research Laboratories, it has

been maintained by Baylor University in Waco, Texas since 1995. Other free GIS software has been developed by university researchers, programmers, philanthropists, geospatial organizations, governmental agencies, and private developers since the 1980's. Listings of these freeware can be found on the Web through FreeGIS.org, GIS Lounge and the Open Geospatial Consortium. A parallel organization, OpenGIS, is dedicated to developing and standardizing geospatial and geo-processing specifications. Open Source programs are applications of which one can access the source code. Listed here are available open-source GIS-based applications one can download, written for a variety of platforms and in various languages.

GRASS—Baylor University

GRASS is a public-domain raster GIS, a vector GIS, an image-processing system, and a graphics-production system. It is extensively used at government offices, universities, and commercial organizations. It is written mostly in C for Unix. GRASS is a powerful but often difficult to use GIS program, being a command-line software. Quantum GIS is currently implementing an easier interface for GRASS's capabilities. Meanwhile, a Java version of GRASS (JGRASS) is being built on top of uDig, where uDig was built and maintained by HydroloGIS—concentrating on hydrogeological and geomorphological capabilities. Rather than duplicating the effort of uDig and GeoTools, the JGrass team chose to focus on the unique parts of their project, which are tools and algorithms. At the same time, the team gets the basic infrastructure—consisting of vectors, formats, re-projection, and workbench—from the uDig framework.

Quantum GIS—QGIS Development Team

Quantum GIS (often abbreviated to QGIS) is a free desktop GIS application that provides data viewing, editing, and analysis capabilities. QGIS runs on Linux, Unix, Mac OSX, and Windows. Quantum GIS is written in C++, and its GUI uses the Qt library. Quantum GIS allows integration of plug-in's developed using either C++ or Python. Qt library provides the cross-platform application development framework. Supported by other software, QGIS provides integration with other open-source GIS packages, including PostGIS, GRASS, and MapServer to give users extensive functionality. QGIS is continually maintained by an active group of volunteer developers who regularly release updates and bug fixes.

A GIS-component software is a building block that, when added to GIS software, forms an enhanced, personalized environment for the user. A specific-function component performs a dedicated task that adds to the GIS-environment tools. Such components include data format converters, flow-data analyzers, and image-processing software. User-development software, on the other hand, is a development toolkit that enables the user to program components to perform specific functions. For example, one may need to embed maps into a non-GIS program, and there is no pre-developed component for a raster-only GIS. User-development software is the only answer in this case.

A very popular component software is Geotools, an open-source GIS development toolkit that is freely distributed. The software is Java based and offers users the ability to develop Open-GIS-compliant products. What makes Geotools attractive to users is its modular design, which allows easy installation and removal of components. The software works well with Java fee-based and free GIS environments (Bruce 2007).

GeoTools—Open Source Geospatial Foundation (OSGeo)

GeoTools is an open-source Java-code library which provides standards compliant methods for the manipulation of geospatial data, for example, to implement GIS. Specifically, it is distributed under the GNU Lesser General Public License (LGPL). The GeoTools library implements Open Geospatial Consortium (OGC) specifications as they are developed. Geotools is used by a number of projects including Web Feature Servers, Web Map Servers, and desktop applications. GeoTools' modular architecture allows extra functionality to be easily incorporated. GeoTools aims to support existing-or-evolving OpenGIS and other relevant standards.

MapServer—OSGeo

MapServer is an open-source development environment for building spatially-enabled Internet applications. It can run as a **Common Gateway Interface (CGI)** program or via Mapscript which supports several programming languages. Here, CGI is a standard that defines how Webserver software can delegate the generation of Webpages to a console application. MapServer renders data for spatially-enabled Internet applications. It has excellent cartographic output. It can be used both as a WMS and WFS server and client. Here, WMS stands for Web Map Service—a standard protocol for serving georeferenced map images over the Internet that are generated by a map server using data from a GIS database. And WFS stands for Web Feature Service interface standard. WFS provides an interface allowing requests for geographical features across the Web using platform-independent calls. It can deal with a large amount of vector and raster data formats. It supports many scripting languages for developing Internet applications, e.g., PHP, Python, C, C++, C#, Perl, Ruby, and Java. Other functionalities include on-the-fly map projection.

Finally, previously created databases and bi-product datasets are distributed primarily through geospatial data clearinghouses, data warehouses, and data depots. The reader is referred to Data Depot, which is dedicated to free data and metadata. For a listing of data sites, refer to the University of Edinburgh - Association of Geographic information's GIS Resource list for links to several hundred U.S. and international GIS data sites.

B. Image Processing

In a survey, Vanderzee and Singh (1995) found out that there was not a direct relationship between functional capability and price for commercial image-processing software, where the products ranged in price from a few hundred to several tens of thousands of dollars. In the area of full-featured image processing (IP) systems, ERDAS Inc. was the leader. And for both basic GIS and IP capability at a low price, IDRIST's product for PC's has been the leader. For AM/FM, Accugraph has been the leader.

There were also some capable systems in the public domain, to which we will devote the bulk of the discussions here. While a few of these programs are general image analysis/manipulation programs, most are specifically designed to display and analyze satellite or aerial imagery (Pawlowicz 2009). In the following, we will group applications alphabetically rather than by function. Notice there are a number of general purpose GIS programs that also include significant satellite/aerial imagery functionality. They have been covered above under the GIS review section, and will not be repeated here.

FWTools—Frank Warmerdam

FWTools is a set of open-source GIS binaries for Windows (win32) and Linux (x86 32bit) systems produced by Frank Warmerdam (i.e., FW). The kits are intended to be easy for end users to install and deploy. There is no need to build from source, or having to collect lots of interrelated packages. FWTools includes OpenEV, GDAL, MapServer, PROJ.4 and OGDl as well as some supporting components. OpenEV is an open source library and reference application for viewing and analyzing raster and vector geospatial data. GDAL stands for Geospatial Data Abstraction Library, and is a veritable tool set of GIS data functionality. As reviewed in the GIS section, MapServer is an Open Source platform for publishing spatial data and interactive mapping applications to the Web. PROJ.4-Cartographic Projections Library is a GIS package that offers command-line tools and a library for performing respective forward and inverse transformation of cartographic data to or from Cartesian data with a wide range of selectable projection functions. Overall, the FWTools kit aims to include the latest development versions of the packages as opposed to official releases.

GVAR—Dartcom

GVAR stands for GOES VARIABLE format image acquisition, display and processing system. Dartcom supports GVAR data from GOES 8, 9, 10, 11, 12 and 13 with automatic detection during ingest. The system acquires high-resolution digital data (0.8 km visible, 4 km infrared) with calibrated temperature read-outs from infrared images. The system comes with fully automatic Windows-based GVAR Ingester, a data-ingest software. A companion software MacroPro automatically processes the acquired data to enhance, mask, print, animate, re-project and create products. A third software iDAP further displays and processes the data for image enhancement, product creation, projection transformation, land and sea masking, printing and exporting. As such, GVAR is among a handful of tools for aviation weather information, storm warning systems, forecasting, agriculture, oceanographic studies, and environmental and meteorological programs.

HEG—NASA

Hierarchical Data Format (HDF) is the prescribed format for standard data products that are derived from Earth Observing System (EOS) missions. HDF-EOS is a self-describing file format for transfer of various types of data between different machines based upon HDF. HDF-EOS is a standard format to store data collected from EOS satellites such as TERRA, AQUA and AURA. GeoTIFF is a GIS compatible format under a public-domain metadata standard which allows geo-referencing information to be embedded within a TIFF file. HEG stands for HDF-EOS to GIS, and is the acronym of a data converter. The HDF-EOS to GeoTIFF conversion tool (HEG) is developed to allow a user to reformat, re-project and perform stitching/mosaicing and subsetting operations on HDF-EOS objects. The output GeoTIFF file is ingestible into commonly used GIS applications. HEG will also write to HDF-EOS Grid and SWATH formats (i.e., for subsetting purposes) and native (or raw) binary. HEG presently works with MODIS (AQUA and TERRA), ASTER, MISR, AIRS, and AMSR-E HDF-EOS datasets.

HighView—various sources

The free trial version of GUI-based HighView is fully functional for band combination of 8- or 16-bit satellite imagery. These images include the global orthorectified

Landsat 7 ETM+ imagery available at USGS GloVis and the Global Land Cover Facility. Also included is the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), which is a high resolution imaging instrument that is flying on the TERRA satellite. Other satellites include SPOT, QuickBird and IKONOS. There is no limitation on image size and output format. Stretched output in 24-bit BMP format and/or un-stretched output in native GeoTIFF format can be readily used as base maps or backdrops in major GIS software, such as MapInfo and ArcGIS. Various options of linear and nonlinear stretches are allowed during the band combination.

NASA HDF-EOS Web GIS Software Suite (NWGISS)—NASA

NWGISS is a suite of web GIS software that makes HDF-EOS data available to GIS users based on Open GIS Consortium's (OGC) interoperability protocols. It consists of the following components: a map server (WMS), a coverage server (WCS), a catalog server, a Multi-Protocol Geoinformation Client (MPGC), and a toolbox. Those components can work both independently or collaboratively. The toolbox consists of two-way translators between HDF-EOS and major GIS formats, as well as the CreateCapabilities tool that automatically creates the XML capabilities descriptions from the metadata in HDF-EOS files. Both tools are available now. NWGISS map and coverage servers have been used by NASA and other space agencies. NWGISS is free to data providers who want to serve HDF-EOS data to GIS clients.

SamplePoint—NASA Goddard Space Flight Center

SamplePoint is a manual image-analysis program designed to facilitate vegetation cover measurements from nadir digital images of any scale. Here nadir is a point on the celestial sphere directly below the observer, referring to the downward-facing viewing geometry of an orbiting satellite. Operating essentially as a digital point frame, the software loads images, places classification points on the image, and stores classification data to a database as the user classifies each point. Up to three simultaneous views of each classification point, at varying zoom levels, are possible. The software appears to be primarily for close-up vegetation-cover analysis, but may be useful for other applications as well. Installation file contains SamplePoint, SPTracker, a Help Manual, a PowerPoint Tutorial and two sample images. The software is recommended for calibrating the threshold-detection level of image-analysis software or for making direct measurements of percent occurrence from digital images.

StarSpan—University of California at Davis

StarSpan is designed to bridge the raster and vector worlds of spatial analysis using fast algorithms for pixel-level extraction from geometry features such as points, lines, polygons. StarSpan generates databases of extracted pixel values from one or a set of raster images, and fuse them with the ancillary database attributes from the vector files. This allows a user to do statistical analysis of the pixel and attribute data in many existing packages and can greatly speed up classification training and testing. This feature is also found in other "mainstream" GIS software, such as ArcGIS and GRASS. However Booth et al. (2006) found that these two "mainstream" software have their limitations and neither really handles categorical raster summaries by polygon. They found that StarSpan appeared to be a more efficient option in terms of speed, scriptability and capabilities.

TerraLook—U.S. Geological Survey

TerraLook is a collaborative project that provides access to satellite images for users that lack prior experience with remote-sensing or GIS technology. The TerraLook Archive contains thousands of satellite images from the TERRA and LANDSAT satellites. Formerly known as the Protected Area Archive, TerraLook combines collections of geo-referenced JPEG images with a set of simple visualization and analysis tools. This allows users to explore the data and employ it for useful purposes in a variety of disciplines including conservation, development planning, education, urban studies, disaster planning and response, and others. It may be of particular use in developing countries that may have less capacity to purchase or work with remote sensing data. TerraLook is built on top of OpenEV, where OpenEV is an open-source software library and application for viewing and analyzing raster and vector geospatial data.

C. Routing

Routing software has come a long way since providing simply a route and schedule (Partyka and Hall 2010). Many of the following reviewed packages have more comprehensive functions for data keeping, analysis and planning. There is a clear trend to link routing software with tracking functions through GPS devices. The ability to communicate with mobile computing platforms is gaining prominence as computers are getting more portable, and as the tracking function becomes more prominent. Again, the list below represents a selected number of software that has been screened by the author. The screened packages tend to be software with broader functionality, and they have been on the market long enough to attract a clientele. Readers are encouraged to go to the references for more details when they wish to consider acquiring a particular software.

Accellos One Optimize—Prophesy Transportation Solutions, an Accellos Company

Integrated with Maptuit, Accellos One Optimize is a two-way-connected routing technology. Drivers receive real-time, turn-by-turn driving directions. Prophesy has implemented a new proprietary integration module for quick and common integration with other related software. Accellos One Optimize can communicate with cell phones, black boxes, and various Mobile Data Terminals. Currently, Accellos One Optimize is shaping up to be a full suite of supply-chain execution software and solutions for the industry. Clients include Boston Beer, Gold Medal Bakery, and Piggly Wiggly.

Paragon Routing and Scheduling Optimizer—Paragon Software Systems, Inc.

The software provides single/multi-site/integrated fleets planning. It is linked with truck tracking, resulting in actual movements tracked against the schedule. Paragon can be fully linked with satellite navigation and proof-of-delivery technology. Paragon's multi-tripping function optimizes resource in double dispatch operations.¹⁵ Clients of Paragon include Airgas, McLane Company, CEVA, Exel Logistics, Toyota Material Handling, National Food Corporation, Red Ball Oxygen, and Ryder.

Roadnet Anywhere, Roadnet Transportation Suite—UPS Logistics Technologies

Roadnet Anywhere is a Web-based, easy-to-use daily routing and GPS tracking application. Through a Web-enabled application, Roadnet Anywhere captures

vital historical data that the user can review at any point, including historical traffic of “breadcrumb trails” on completed routes. The software also communicates with mobile devices. Altogether, the technologies enable a paperless office, GPS tracking, and pro-active service failure detection. Roadnet Transportation Suite performs strategic planning and analysis of daily route operations. The software records historical traffic, commercial road restrictions, and can perform CO₂-emission calculation. It includes multiple Web-based reporting tools for daily and historical analysis. Roadnet clients include Otis Spunkmeyer, Goodness Greeness, Lion Plumbing, and Oxygen One. Clients of Roadnet Transportation Suite include Anheuser-Busch, Office Depot, Sysco, Mohawk Industries, and Apria Healthcare.

StreetSync Basic, StreetSync Desktop—RouteSolutions

StreetSync Basic is a Web-based subscription routing-system. It allows integration with commercial Garmin and TomTom GPS devices. The one-click import and export function allows import from Excel or Access, and export to Garmin and TomTom units. Advanced integration with TomTom WORK is also possible, providing fleet-management and fleet-tracking solution combined with GPS navigation. Meanwhile, a distinguishing feature of StreetSync Desktop is an integrated customer database for analysis and planning. Clients of StreetSync Basic include Walco International Incorporated. Clients of StreetSync Desktop include Navteq, Coca-Cola Enterprises, Cintas, and Duncan Telecom.

III. CONCLUDING COMMENTS

The IT community is moving to tools like extensible markup language (XML), service oriented architectures (SOA), and Web services that facilitate distributed computing. XML’s design goals emphasize simplicity, generality, and usability over the Internet. It is a textual data format with strong support via Unicode for the languages of the world. XML, SOA, and Web services have facilitated the growing prevalence of software as a service; that is, software residing on a server that is accessed by numerous client machines over a network, as opposed to software residing in multiple copies on its users’ machines.

Sometimes referred to as “cloud computing,” this new movement requires a set of standards (or protocols) when adopted for a particular application. Let us use a classic analytic tool such as optimization as an example. Fourer et al. (2010) are designing a platform called Optimization Service (OS) to implement cloud computing for optimization. The OS standards or protocols in this case include

- registration and discovery of optimization-related services in a distributed environment;
- representation of optimization instances, results, and solver options; and
- communication between a client on the user’s end and solvers.

LogicBlox (<http://www.logicblox.com>), developer of online predictive and optimization software, is currently developing a product based on OS. This product allows users to develop optimization models through a Web-based graphical user interface. A model instance is sent to a solver on a local or remote

machine; the underlying result is returned, where it is then converted into a more user-friendly solution report. A browser is the only required software on the client.

Following the analytics schema laid out in Chapter 7, the current chapter specifically reviews solution methodologies and software configurations. Once again, we like to conclude by suggesting that the software listed here are screened subject to our best judgment. We tend to favor more “popular” packages over the more obscure ones. For this reason, its inclusion does not imply our endorsement of the product. What shows up in this exercise is that there appears to be a trend to consolidate commercial software into comprehensive packages that perform multiple functions. These packages tend to be more popular and hence command a larger market share. Examples of these consolidated packages include Crystal Ball, Vanguard System and more.

In Chapter 7 and here, we make a distinction between general vs. spatial analytic software. As alluded to earlier, the fine line between general and spatial-analytic software is not as distinct as it used to be. AIMMS, the modeling system, is listed under optimization, but it has the following spatial-analytic functions: GIS, MS Virtual Earth link, Yahoo Maps, ESRI Shape files, and geocoding functionality. Thus the review here highlights a point that we made in Chapter 7: There is an emerging market for spatial information technology (IT), as evidenced by the increasing number of commercial routing, GIS and image-processing software. At the same time, we stipulate that while the demand is growing, the market is not strong enough to support some rather specialized applications, such as facility-location models, spatial statistics software and to a lesser degree image processing. This explains why we reported no commercial facility-location software here in this chapter. Instead, there are quite a few open-source or free spatial-IT products. These products may find their niche in the commercial marketplace in the future as demand grows over time.

ENDNOTES

¹ Most optimization software employs the generalized reduced gradient (GRG) methods for global optimization. However, multistart methods can overcome some of the limitations of the GRG Solving method alone. The multistart methods will automatically run the GRG method from a number of starting points and will display the best of several locally optimal solutions found. Because the starting points are selected at random and then “clustered” together, they will provide a reasonable degree of “coverage” of the space enclosed by the bounds on the variables. As a result, it is highly probable that the best local optimum is the global optimum.

² Inheritance is the process by which new classes called derived classes are created from existing classes called base classes. The derived classes have all the features of the base class and the programmer can choose to add new features specific to the newly created derived class. According to Wikipedia, inheritance is what separates abstract-data-type (ADT) programming from object-oriented programming. ADTs are often implemented as modules: the module’s interface declares procedures that correspond to the ADT operations, sometimes with comments that describe the constraints. This information-hiding strategy allows the implementation of the module to be changed without disturbing the client programs. The notion of ADTs is related to the concept of data abstraction, which is important in object-oriented programming.

³ Optimization procedures in a traditional compiler are applied sequentially, with each optimization operation destructively modifying the program to produce a transformed program. The transformed program is then passed to the next optimization. Incremental computation of this kind takes advantage of repeated computations on inputs that differ slightly from one another, computing each output efficiently by exploiting the previous output. Since every non-trivial computation proceeds by

recursion, the approach can be used for achieving efficient computation in general. The key is to compute each iteration incrementally using an appropriate program. Tate et al. (2009) presented such an approach for structuring the optimization phase of a compiler. In their approach, optimizations take the form of *equality analyses* that add equality information to a common intermediate representation. Iterative program transformation is accomplished by direct tree manipulation. The Tate et al. optimizer works by repeatedly applying these analyses to infer equivalences between program fragments, thus saturating the intermediate representation with equalities. Once saturated, the intermediate representation encodes multiple optimized versions of the input program. At this point, a profitability heuristic describes which of the legal transformations to actually perform. It picks the final optimized program from the various programs represented in the saturated representation. Here, program expression graphs (PEGs) are employed, which is an intermediate representation designed specifically for equality reasoning. As far as compiler optimization is concerned, several operations are performed at this juncture. Common sub-expression elimination (CSE) reduces the number of duplicated computations by reusing previously defined and still available non-trivial expressions. If the same expression is computed in two different program points, CSE eliminates one of the computations, by replacing the second operation by an access to the register containing the result of the first evaluation. CSE is similar to constant propagation, in that the transformation is triggered by conditions represented by an equality between a register and an expression. In constant propagation this expression corresponds to a constant value, whereas in CSE it may be a more complex expression (involving arithmetic operators). The process of converting to and from PEGs produces optimizations well beyond constant propagation and CSE. It includes loop *invariant branch* hoisting and sinking, and several other operations.

⁴ Lazy constraints are constraints not specified in the constraint matrix of the MIP problem, but must not be violated in a solution. It is used to speed up the solution algorithm.

⁵ GUROBI is a set of high-end libraries for math programming, particularly for MIP and LP.

⁶ MOSEK is a large-scale optimization software that solves linear, quadratic, general convex and mixed integer optimization problems.

⁷ The NEOS server is the first network-enabled problem-solving environment for a wide class of applications in business, science, and engineering. The server is designed as a generic application service provider. Users submit a problem and their choice of an optimization solver over the Internet. The NEOS server computes all information (for example, derivatives and sparsity patterns) required by the solver, links the optimization problem with the solver, and returns a solution.

⁸ For stochastic programming, a two-stage planning horizon is one where immediate (Here and Now) decisions (\mathbf{x}_1) have to be taken before all the problem elements have become known. Once this happens there are further, second-stage decisions (\mathbf{x}_2) to be taken according to the newly discovered events. So for the expectation we combine the probability-weighted minima of all the second-stage models, the resulting formulation of the problem is known as the Deterministic Equivalent (DEQ). It was observed in the resulting model form is precisely the form solvable by Benders' decomposition, the dual of Dantzig-Wolfe decomposition. In this method a solution \mathbf{x}_1 allows a subsequent dual-solutions to be calculated and applied to form an aggregated 'cut', which is a constraint added - thus giving a new solution \mathbf{x}_1 , and so an iterative process is developed. Theory shows that the iterations converge to precisely the solution of the deterministic equivalent (DEQ) model.

⁹ SMPS is a standard input format for multi-period stochastic programs based on MPS.

¹⁰ Automake scans the package's "configure.in" to determine certain information about the package. Some autoconf macros are required and some variables must be defined in "configure.in." Automake will also use information from "configure.in" to further tailor its output.

¹¹ POPT stands for Interior Point OPTimizer. Pronounced I-P-Opt, it is a software package for large-scale nonlinear optimization.

¹² Microsoft Solver Foundation is a new .NET-based optimization platform that includes a variety of solvers.

¹³ In MS Windows applications programming, OLE Automation is an inter-process communication mechanism based on Component Object Model (COM) that was intended for use by scripting languages. It provides an infrastructure whereby applications called automation controllers can access and manipulate shared automation objects that are exported by other applications. In OLE Automation the automation controller is the "client" and the application exporting the automation objects is the "server."

¹⁴ RAD Game Tools is a privately-held company that develops video and computer game software technologies which are licensed primarily by video game companies.

¹⁵ In object-oriented programming and software engineering, double dispatch is a mechanism that dispatches a function call to different concrete functions depending on the runtime types of the two objects involved in the call.

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