ANATOMY OF A TOOLKIT: A COMPREHENSIVE COMPENDIUM OF VARIOUS AGENT-BASED MODELING TOOLKITS ON THE MARKET TODAY

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ABSTRACT

With so many toolkits available, the choice of which one is best suited for your project can be overwhelming. Moreover, different communities of users prefer different aspects of a toolkit. This paper is a survey of the toolkits that are available today and how they compare to each other from a multi-stakeholder perspective. Our goal is to provide users the ability to better choose a suitable toolkit based on the features abstracted from various documentation and the first hand experiences of a broad range of communities of users and compiled into an easy to use compendium. In addition, we expand the Agent Based Modeling body of knowledge to include information about a breadth of characteristically and historically diverse platforms.

Keywords: Agent Based Modeling and Simulation, Agent Based Modeling Toolkits, Multi-stakeholder Community

INTRODUCTION

Agent Based Modeling (ABM) toolkits are as diverse as the community of people who use them. With so many toolkits available, the choice of which one is best suited to a project can be overwhelming. Current toolkit surveys are helpful but are limited to four or five mainstay and characteristically or historically similar platforms (Railsback et al 2006; Tobias et al 2004; Castle et al 2006). Moreover, recent surveys are presented from the point of view and for the intended audience of one or two communities of interest (Railsback et al 2006; Tobias et al 2004). However, different groups of users prefer different and sometimes conflicting aspects of a toolkit. For example, social scientists, who may have little or no programming experience are concerned more with ease of use, the degree of programming skills required, and the inclusion of intuitive interfaces to manage simulations. Many, in general, are not concerned about whether the software is open source or restricted open source. To computer scientists, however, the type of license that comes with the toolkit is a big consideration; they want the ability to "get behind the scenes" of a toolkit and to have the programming flexibility to modify or extend the software with third party applications if necessary. They also generally prefer saving execution time by programming simulations themselves rather than using built-in interfaces. Teachers of ABM, on the other hand, want packages that are easy to learn, that offer pedagogical insights, and that provide the student with the ability to transition to more difficult and comprehensive toolkits in the future.

In this paper, we survey the current state of the art in ABM toolkits, and we compare them to each other from a multi-stakeholder perspective. Our goal is to provide users the ability

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to better choose a suitable toolkit based on the features abstracted from various documentation and the first hand experiences of a broad range of communities of users and compiled into an easy to use compendium. We use a combination of both scaled and quantifiable evaluations to create a taxonomy of toolkits for each characteristic of interest. This is followed by a text explanation of each feature, including how and why a feature is ordered in each paradigm. Some of the characteristics we evaluate include supported platforms, programming language and degree of programming skills required to create a model/simulation, major domains for which a toolkit may be used, type of license the toolkit includes, ease of use and completeness/robustness of a toolkit, the maximum number of agents supported, and the ability to extend a toolkit with third party software. We also capture a history of the toolkits, explaining the influences that united to produce them and how different parallel threads of the ABM community emerged over time.

This paper is structured as follows. In section I, we provide a short introduction to ABM. This is followed in section II by a description of our methodology; In section III, we include a preliminary compendium of taxonomies.

BACKGROUND

Agent based modeling is a framework for modeling a simulation based on creating a set of autonomous objects, called agents or entities. An agent is "an abstract or physical autonomous entity which performs a given task using information gleaned from its environment to act in a suitable manner so as to complete the task successfully. The agent should be able to adapt itself based on changes occurring in its environment, so that a change in circumstances will still yield the intended result."[1] The goal of agent based modeling is to have a many simple entities, by which we can discover the emergent behavior of a system. In this paper, we evaluate the toolkits on the market today which use this framework for modeling and simulating agents.

METHODOLOGY

Goals

We began this research by studying survey design techniques (Arsham 2002; Creative Research Systems 2006; US GAO 1993; US GAO 1992; Walonick, 1997). First we outlined the specific goals we hope to achieve through this survey so that we could identify our measurement variables, and structure our question designs appropriately. The specific goals of this research are:

1. to help multi-stakeholder users choose an ABM toolkit based on the characteristics available
2. to compile a broader list than is available of toolkit characteristics into one easy to use reference for users
3. to find out why type of classes of users are using each ABM toolkit
4. to ascertain what characteristics different communities of users when choosing an ABM toolkit

[1] there are many different and equally valid definitions of ABM, but for the purposes of this research, we will choose this one. This one is an informal definition by G.W. Lecky-Thompson quoted in (Hermans 97).

Population Sample

Next we selected a sample population to achieve each of the goals. In order to achieve goals 1 and 2, we have decided to contract a developer from each toolkit under consideration. We have developed a specific survey for this group and this set of goals. (See appendix A for a list of toolkits under consideration) In order to achieve goals 3 and 4, we have decided to sample the users of each toolkit. We will sample about 5-10 users from each toolkit. We will achieve this by contacting the user's groups and/or the mailing list of the toolkits. We have developed a specific survey for this group and this set of goals.

Data Analysis

In order to analyze the data, we will use three main analysis techniques: measures of central tendency; measures of distribution, measures of association, and measures of causation. In order to facilitate this, we have designed the survey questions to facilitate these types of data analysis. For example, we have structured the survey with as few open ended questions as possible. For most values, we have a list of qualified answers. We also have incorporated many questions from an open ended format to a qualified, anchored scale.

Sources of Error and Countermeasures

The major sources of error in this research are various forms of biases that may be inadvertently or intentionally introduced. In order to reduce inadvertent biases introduced in the structure of the questions themselves or from the respondents, we researched and applied proven survey design techniques that address exactly these issues (Arsham 2002; Creative Research Systems 2006; US GAO 1993; US GAO 1992; Walonick, 1997). For example, we familiarized ourselves with the population by reviewing the literature on the subject and talking with subject matter experts. We specifically selected the sample populations and determined sample sizes to eliminate biases and errors and be able to generalize to the population at large. We developed the goals and identified corresponding measurement variables and then designed our questions to evaluate the measurement variables and achieve our goals. We determined appropriate sample populations and sample sizes. We also structured the questions such that we addressed the limitations of each type of question to reduced its inherent biases. Some of the techniques we used include writing clear questions, using syntax and linguistics to facilitate question understanding and respondent recall, developing unscaled response lists, developing questions to minimize question bias and memory error, tailoring questions to minimize respondent bias, tailoring questions to minimizing measurement error, using odd numbered Likert scales to allow for neutrality in decisions by the respondent, quantifying all scaled values, anchoring our scaled lists, allowing escape choices for the respondent, including room for additional comments, incorporating a pledge of anonymity, avoiding inappropriate questions and questions that do not contribute to the goals, including an incentive, organizing the line of inquiry to maintain user interest and avoid bias, categorizing topics by heading, using lists to avoid biases in memory recall, qualifying the alternatives equally to avoid question biases, avoiding "yes" biases, asking more specify questions at beginning and more broad question at the end of the survey, initiated plans for follow-up for respondents and non-respondents, designing the questionnaire layout and graphics to facilitate user satisfaction and interest in the survey, defining words that could be

construed in a non-standardized way or in a different context to facilitate standardization interpretation of the questions, and finally pretesting the questionnaire to help validate our survey.

In order to eliminate potential intentional bias, we only ask the developers to evaluation their own toolkit; we let the user's evaluate comparable toolkits on the market. However, because the developers can be biased toward their own software, in order to validate answers to these questions, we ask the users directly to evaluate important characteristics of the toolkit and comparable toolkits on the market. In order to eliminate skewed sample data toward one or two major platforms, we have chosen samples from each toolkit user's group.

Data Validation

We will use current literature and expert opinion to validate developer and user responses; we also will use information collected through open source channels and expert opinion to validate the responses.

Potential problems noted

The major potential problems we may encounter are low response rate. In order to reduce non-responses, we plan to implement proven techniques to make the surveys easy, simple, understandable, standardized, and pleasurable to the user. We also have included an incentive: at the end of the collection period, we will have a drawing to give away three $20 gift certificates to developers who respond to the survey. In addition, we will have a drawing for three $20 gift certificates for users who complete the survey. We will attempt follow-up contacts with the non-respondents per the survey design guidance. If we still do not have a response, we will try to fill in the missing data as best as we can. A similar problem we may encounter is if people do not answer questions or if answers to questions are unclear to the authors. In order to account for missing data and information for which we need respondent clarification, we will attempt to contact the individual, if follow-up contact has been authorized by the respondent.

Limitations

Some of the limitations of this research are that we have a relatively small sample size, so the extrapolation may be less accurate for the entire population. There are general limitations of survey data and of this form of questionnaire, which include missing data, non-responses, question biases, memory biases, respondent biases, unstandardized interpretation of the questions. Another limitation is that we assume that all toolkits written in different languages by the same developers or development groups have congruent capabilities. For example, we assume that anything one can do with the objective C swarm toolkit can also be implemented with similar results in Java based swarm. In reality, there are subtle differences and nuances between the two that may be important to users of the toolkits. Fourth, this survey is more of a broad study of the ABM field rather than an in-depth study of one or two platforms. As such, we do not go in depth for any one toolkit. Finally, the current list of important characteristics that are being evaluated for each toolkit are based on current literature, which is has been geared mostly toward the social science community.

Preliminary Results

Then we gathered and assembling as much information as possible on various toolkits from open sources and documentation. Taking some the questions that are important based on current literature (Railsback et al 2006; Tobias et al 2004; Castle et al 2006), we use the following list of characteristics that commonly are traded off in choosing a toolkit. Some of these characteristics include platforms supported, programming language required, degree of programming skills required, ease of use, maximum number of agents supported, license employed, ABM history/roots. Note that this list is not complete and may change as the responses from our questionnaires direct. They simply are a starting point and a preliminary point of validation for this research. (See appendices B-E for beginning taxonomies for several characteristics)

Completion of the taxonomies and more in-depth explanations will follow when as we obtain and validate results from our surveys. Note, in the final results, we also will include a full representation of features for each toolkit in an easy to use matrix format that allows for quick and comprehensive comparison of particular characteristics across different toolkits, or an examination at all characteristics across one specific toolkit.

FUTURE WORK

Currently, we are in the pretest phase of the survey design. In the next step, we will deploy our surveys, collect the responses, and start analyzing and interpreting the results.

CONCLUSION

Different communities choose a toolkit based on various sometimes conflicting and contradictory aspects as other communities. In this work, we explore what aspects different communities value in choosing a toolkit. We also survey the current capabilities of the toolkits that are available today to help users choose an appropriate toolkit for their purposes. We explore a breadth of the current state of the art, and we organize the information into a compendium of taxonomies for easy access and comparison of features. When we complete the work, we will include a tabular formulation of the results as well.

ACKNOWLEDGEMENTS

We are very grateful to Dr. Greg Madey, Tim Wright, Scott Christley, Ryan Kennedy, Alec Pawling, Matt Van Antwerp, and Ying Zhoufor their contributions to this paper.

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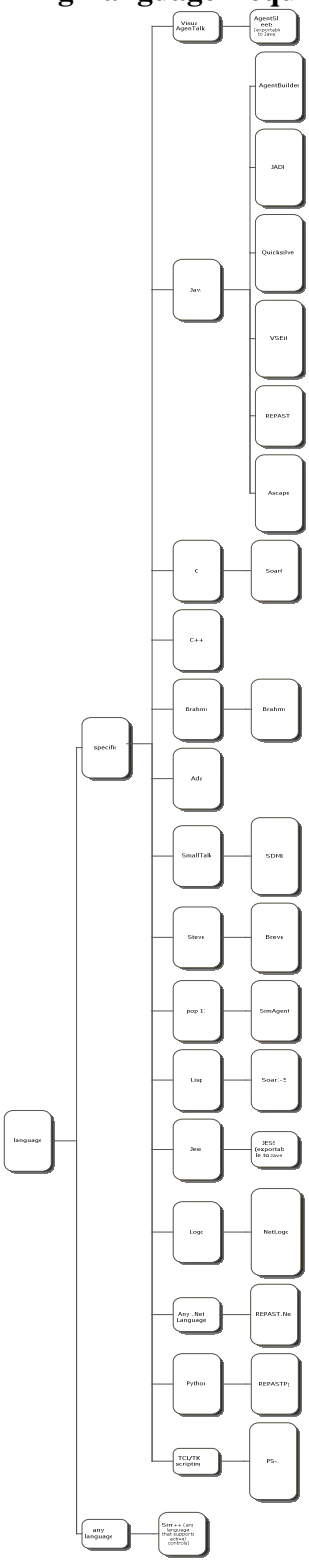
Appendix A

Toolkits Under Consideration

ABLE
Act-R
Ada
Agent Development Kit
AgentBuilder
AgentKit
AgentSheets
AnyLogic
Ascape
Brahms
Breve
Cormas
Cougaar
DeX
DOMAR
ECHO
ECJ
iGen
ISAAC
JADE
JAS
JASA
JCA-Sim
jES
JESS
LSD
Madkit
MAGSY
MAML
Mason
MAS-SOC
Matlab
MIMOSE
Moduleco
NetLogo
OBEUS
openStarLogo
oRIS
Ps-I
Quicksilver
Repast
SDML
Sim++
SimAgent
SimBioSys
SimPack
SME
SOAR
StarLogo
StarLogoT
Sugarscape
Swarm
TeamBots
Vensim
VSEit
ZEUS

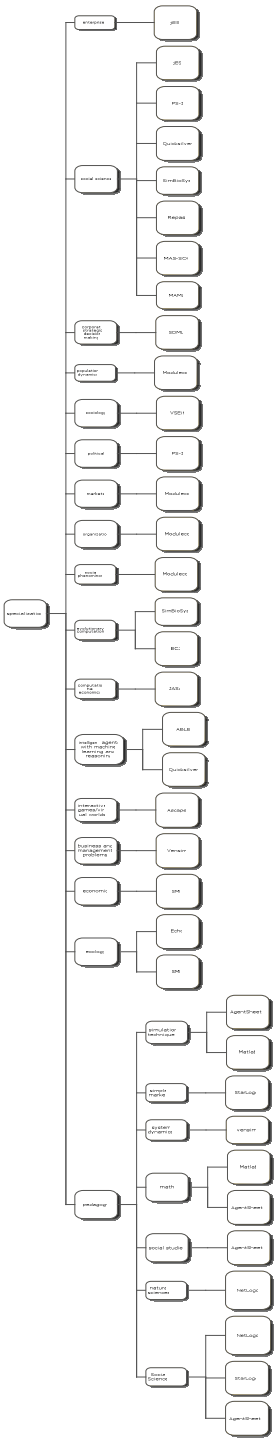
Appendix B

Programming Language Required



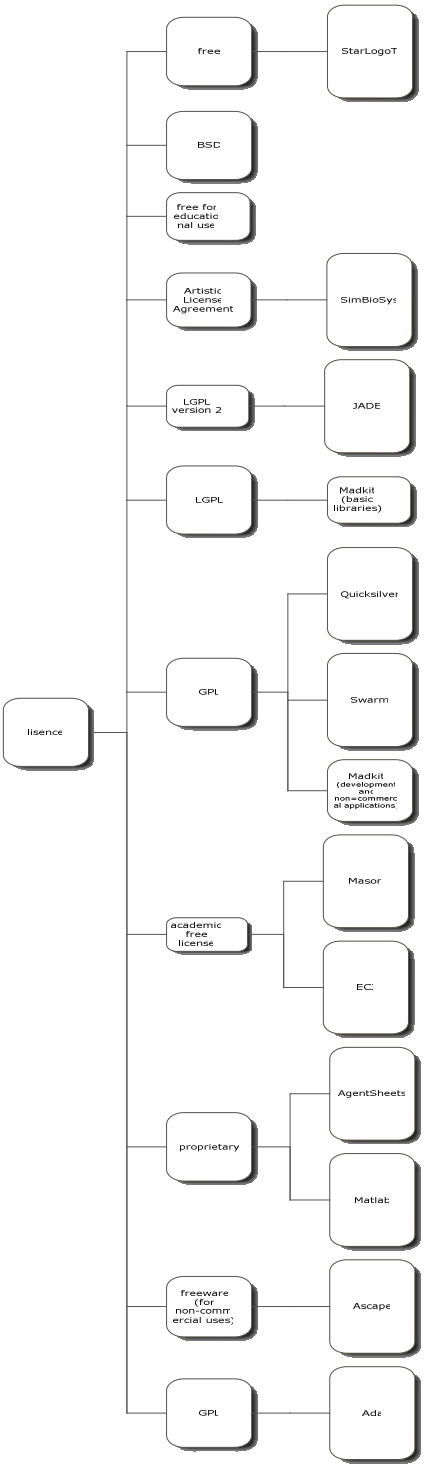
Appendix C

Domain Designed For



Appendix D

License Employed



Appendix E

History/Roots of ABM Toolkits