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USING GEOGRAPHIC INFORMATION SYSTEM IN A MULTI-AGENT SYSTEM FOR SITE SELECTION: AN APPLICATION TO UPCAT TEST CENTERS

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ABSTRACT:

This working proposal describes a research study that will use a combination of multi-agent system (MAS) and geographic information system (GIS) technologies for site selection. This combination shows potential in providing optimal solutions to distributed geospatial problems. A novelty presented in this study is its client-server architecture that enables online bidding of the site administrators. The proposed approach will be applied in the selection of sites for the University of the Philippines College Admission Test (UPCAT) test centres in Region IV-A (CALABARZON). Emphasis is placed on the use of open source and free software.

1. INTRODUCTION TO THE STUDY

This chapter of the proposal introduces the nature and objective of the study.

1.1 UPCAT

The University of the Philippines, by virtue of Senate Resolution 278, is the National University of the Philippines and a much coveted collegiate school in the country. It attracts over 62,000 examinees (2008) every year. As such, it is very selective in allocating slots for freshmen admission to each of its seven (7) campuses and its various degree programs in order to maintain its high standard of education and maximize its limited resources. This is done through the UPCAT, together with the assessment of high school grades, socio-economic status and geographic origins of the applicants. [1]

The UPCAT is a standardized exam open to Filipinos and foreigners who satisfy the stipulated qualifications (see [1] for the UPCAT requirements). It is being held in 75 test centres all over the country (41 in Luzon, 14 in Visayas and 20 in Mindanao) and in some test centres in the Middle East. [1]

At present, there is still no evaluation as to whether the location of UPCAT test centres are optimal in the sense of reaching out to the farthest corners of the country in upholding the University policy of democratization. That is, to make the student population more representative of the country’s cross-section. This study aims to evaluate if there are underserved areas in administering the UPCAT and to propose a set of criteria in the identification of UPCAT test centre sites. In this way, it is hoped that the process of identification and admission of freshmen is optimized.

1.2 MAS

“The term ‘multi-agent system’ (or MAS) is applied to a system comprising the following elements:
An environment, E, that is, a space which generally has a volume.

a) A set of objects, O. These objects are situated, that is to say, it is possible at a given moment to associate any object with a position in E. These objects are passive, that is, they can be perceived, created, destroyed and modified by the agents.
b) An assembly of agents, A, which are specific objects ($A \subseteq O$), representing the active entities of the system.
c) An assembly of relations, R, which link objects (and thus agents) to each other.
d) An assembly of operations, Op, making it possible for the agents of A to perceive, produce, consume, transform and manipulate objects from O.
e) Operators with the task of representing the application of these operations and reaction of the world to this attempt at modification, which we shall call the laws of the universe.” [2]

MAS has been applied to problem solving (distributed solving of problems, solving distributed problems and distributed techniques of problem solving), multi-agent simulation, building artificial worlds, robotics and program design [**2**].

Today, MASs are gaining popularity both in the industry and academia. It is seen as a new direction in software engineering since numerous domains actually consist of interacting, active and purposeful agents. Also, the distribution of data or control which is needed for the efficiency of software is inherent in MAS. [3]

However, [3] argued that MASs are just tools used to manage the complexity that is inherent in software systems. As such, its potential is enhanced if it is used in conjunction with another system.

1.3 GIS

Interest on GIS has grown over the years and its conception as a single monolithic software package running on a stand-alone workstation or a local-area-network has changed [4]. This change came about as a result of advances in technology and software engineering, not to mention the emergence of Internet and the World Wide Web. GIS has evolved into a one-size-fits-all system that incorporates different tools for input, storage, analysis and display of geographic information.

There are numerous GISs available nowadays. [5] identified five (5) categories of core geographic information tools: Desktop GIS, Mobile GIS, Remote Sensing Software, Software Libraries and GIS extensions. Moreover, [5] made a distinction of the advanced sets of geographic information tools suitable for large scale projects. These are Spatial Database Management System, Web-Map Servers, Server GIS, and Exploratory Data Analysis tools. Another distinction that can be made of GISs is to classify them either as proprietary or free and open-source (FOS). In this regard, FOS is gaining popularity both to end users and researchers because of the high costs incurred in using proprietary products. The expenditures and associated financial risk required to deploy proprietary products either delays the profitability gains of a new software initiative or simply prevents this initiative [6]. Also, proprietary enterprises lock their customers solely to their solutions [6], thereby, limiting the extensibility of the developed system.

Although a lot can be done with a GIS, its one-size-fits-all characteristic has a downside. GIS has not been designed as a simulation/modelling engine, hence, GIS will often fail to provide adequate performance with very large datasets and large number of iterations [7]; its data remain mere snapshots of a particular space at a particular time. The solution posted for this is to link (either through coupling or integration/embedding) GIS with simulation/modelling systems [7].

One such linkage of GIS with simulation/modeling which is relatively new [8] and has received special attention is that of GIS and MAS. This type of linkage will be used in this study; the specific objective of which is to optimize the selection of UPCAT test centre sites by integrating GRASS and Repast software. The design goal is to use FOS software whenever possible and to allow flexibility in each of the proposed system's modules.

2. REVIEW OF RELATED LITERATURE

The rapid development of accurate spatial databases has opened opportunities for resource scientists to extend the use of these data by integrating GIS with emerging technologies [9] such as agent-based models (ABMs). The integration of GIS and ABM is a recent development in the area of complex dynamic systems and is used to simulate dynamic spatial processes [10]. Three approaches to integrating GIS and ABM have been identified in [11]: models that use separate GIS and ABM programs/libraries and communicate via files written to disk; models that use separate programs but communicate via a shared database or virtual memory; and stand-alone models that implement GIS-functionality within the ABM model. The last configuration will be used in this study.

3. METHODOLOGY

Optimized selection of UPCAT test centre sites in Region IV-A will be done through the integration of GIS and MAS. Particularly, the third type of integration identified in [11] will be implemented, that is, GRASS GIS will be embedded in Repast.

There will be three main modules in the proposed system (Data Management module, User Interface module and Model Management module) as depicted in Figure 1.

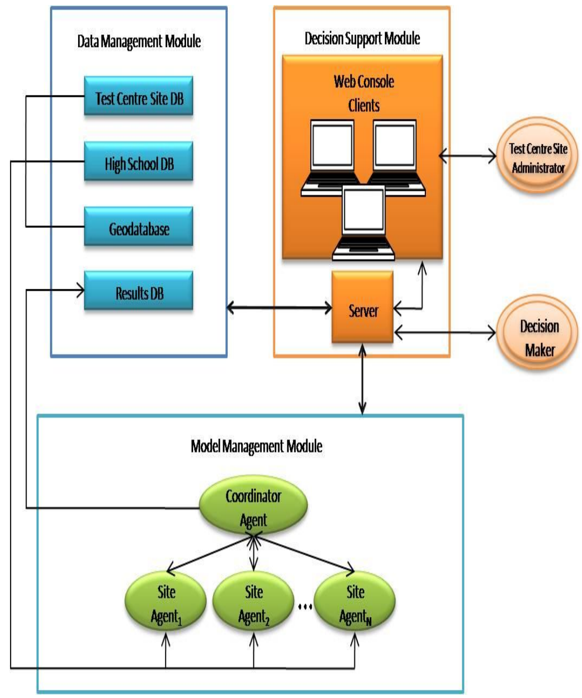

Figure 1: System Architecture

3.1 Data Management Module

The Data management module will serve as repository of all the data that will be used in the selection of test centre sites, as well as of the results of the optimization process. This module is comprised of the following databases:

3.1.1 Test Centre Site DB: The Test Centre Site DB will contain all the attributes of a test centre site that will be needed in the optimization process such as site address, number of buildings that can be used as test centre, building capacity, cost, quality of facilities, and security. Aside from security, the value of which will be assessed by the UP Office of Admissions, all the data will come from the test centre site administrator. A novelty presented of this study is that test centre site administrators may participate in an online bidding process wherein they can change the attributes of their site in order for it to be chosen as the optimal test centre site in the optimization process. The online bidding is a sealed-bid auction, wherein the administrators are not able to determine the bids made by other administrators. [12]

3.1.2 High School DB: The High School database will contain data pertaining to the UPCAT applicants such as name of the High School, address of the High School, number of fourth year high school enrolees, and number of UPCAT applicants. This is done since a test centre site's accessibility for an UPCAT applicant will be determined by the proximity of a test centre site to the applicant's High School following a road network. The initial data for this database will be obtained by asking fourth year high school students through survey forms in random schools in Region IV-A. Yearly updates for this database will then be made through survey forms attached to the UPCAT application forms.

3.1.3 Geodatabase: The Geodatabase will contain spatial data such as boundaries of a province, cities in the province, number of High Schools in the province, number of possible test centre sites in the province and road network.

3.1.4 Results DB: The Results Database will contain the history of the results of the optimization processes done such as date and time when the optimization process was executed, parameters used, weights assigned to the different parameters, top ranking test centre sites, and the bids of these selected sites.

3.2 Model Management Module

The Model Management Module will carry out the optimization process through the use of agents engaged in an auction. An auction takes place between an agent known as the *auctioneer* and a collection of agents known as the *bidders*. [12] The goal of the auction is for the auctioneer to allocate the good, task or resource to one of the bidders. [12] In this study, First-price sealed-bid auction will be used. That is, for each time the optimization process is executed there will only be one (1) round of bidding, in which bidders submit to the auctioneer a bid for the resource. [12] There will be no subsequent rounds and the resource is awarded to the agent that made the highest bid. [12]

In this study, the auctioneer is referred to as the *Coordinator Agent* while the bidders are the *Site Agents*.
One auction per province will be done in each time the optimization process is executed by the Decision Maker, in this case the UP Office of Admissions. Once the optimization process is executed, the *Coordinator Agent* starts the bidding process by giving signal to Site Agents in the province in consideration informing them that they can now place their bids. However, not all Site Agents in the province are allowed to bid. Only those Site Agents whose capacity can accommodate the total number of applicants for the province in consideration will be qualified to bid. It is the Coordinator Agent's task to decide if a Site Agent is qualified for a particular round of bidding.

The test centre sites are modelled as Site Agents. These agents engage in a sealed-bid auction for them to be allocated as the test centre site of the province in consideration. Once signalled by the Coordinator Agent to place a bid, the Site Agent gathers all the data it needs and makes the necessary computations according to the parameters set by the Decision Maker. It is the Site Agent's goal to make its bid as high as possible in order to win the auction. The winner of the auction will be the optimal site for test centre. Figure 2 shows the algorithm that will be used in selecting the optimal test centre site in one province:

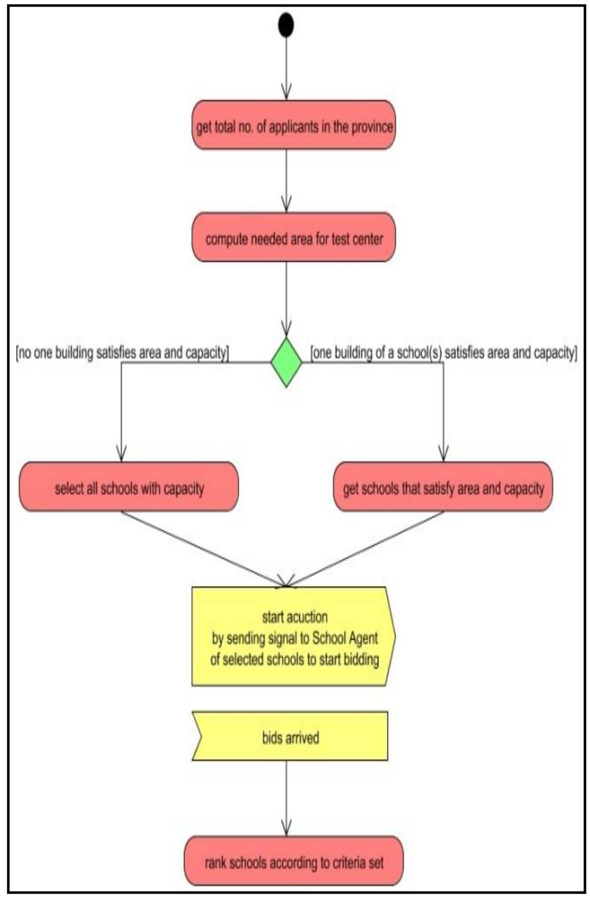

Figure 2: Selection Process

3.3 User Interface Module

The User Interface Module will serve as the front-end of the proposed system. It will carry out all the interactions of the system with the Decision Maker and the test centre site administrators. The interface available to the Decision Maker, which will reside in the server, is different from the interface that will be made available to the test centre site administrators in the Web Console client via the Internet.

It is only through the interface of the server that the optimization process may be executed so that this function is only made available to the Decision Maker. Also, through this interface the Decision Maker may choose the parameters that will be used in the optimization process and assign different weights to them at each execution. All the data in the system will be made available in the server. These data will be organized in different layers wherein different queries can be done. Adding, editing and deleting of the data in the Data Management Module will be done through this interface. The optimization results will be also presented in this interface through a map and a text format. Figure 3 shows the algorithm for adding and removing parameters as well as changing the weights assigned to the parameters.

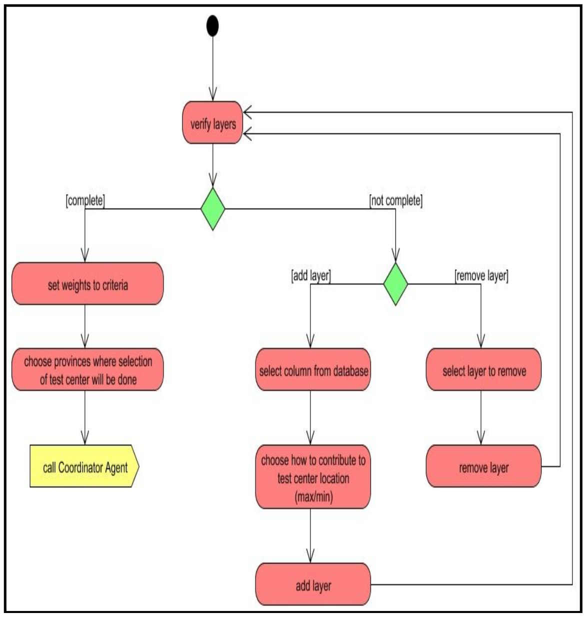

Figure 3: Pre-selection Process

The interface available in the clients via the Internet is only for the purpose of bidding. Through this interface, the test centre site administrator may change the different attributes of his/her site in order for the Site Agent associated to his/her site to increase its bid and increase the probability of being chosen as the optimal site for test centre. The test centre site administrator, however, only sees the attributes of its site and the current optimal site selected by the system for the province where its site is located. Only the summary of the optimization process will be shown here and not the actual bids of the Site Agents. The attributes given by the other administrators are hidden and are shown only to the Decision Maker. The administrator may change its bid anytime during the allowed dates set by the Decision Maker.

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