Optimizing the generalization process of spatial
data using Multi Agent System based on
improved Genetic Algorithm

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Abstract: The generalization process of spatial data is a very important process for delivering to the user a map according to its needs. Many approaches were proposed for modeling and implementing this process. The system multi-agent is the most used. But, the central problem of this approach is the selection of the optimal action performed by the agent in a given moment. Several mechanisms are used for this class of problem. In this paper, we proposed a hybrid approach that can optimize actions of SMA with using the improved genetic algorithm. This new hybrid optimization algorithm combines the techniques of genetic algorithm and tabu search method (GA-TS). We introduced the TS into the genetic algorithm to ensure an efficient of the best solution. The objective is to minimize the time of generalization process and resolving the most important conflicts constraints for improving the quality of generalized map.

Keywords: Generalization process, Agent, Genetic Algorithm, Tabu Search, spatial constraints.

1. INTRODUCTION

Automatic generalization process has been an important research area in the current GIS and continues in the future. It is a set of operations, inspired of traditional cartographic generalization. Its main role is to simplify geographic data when they are very detailed, in order to satisfy user needs in cartographic applications. The principal objective of this process is creating a clear map from a geographic database vector very detailed but this process is very complex and very long. Several methods and concepts proposed to automate the generalization process but a framework for their combination into a comprehensive automatic generalization process is missing [1]. Several works model the spatial objects by agents such as the works of ([1] and [2], [13]). The strategy presented in [2] is the recent proposition for automated the generalization process; nevertheless, it is not flexible enough since it does not enable the agent to choose the best action to perform according to a given situation [20].

According to our idea, achieve optimal generalization process of spatial data implied that the agent performs at any time, an optimal plan which satisfy the different constraints. Thus, in artificial intelligent, choose an optimal action by agent is key mechanism for design an intelligent system. Optimal Action Selection allows to an agent, to determine at any instant what the optimal action that do in the next [16]. More formally, given an agent some knowledge of its internal state, and some sensory information concerning environmental context, permits it to decide what action (or action sequence) to perform in order to achieve its goals. There are two key questions in optimal action selection [10]:

- What is being selected?
- How is it being selected?

In this paper, we propose to provide the agent a set of capacity; perception, communication and optimizer that allow it to select the optimal plan. In this context, optimal plan is a sequence of action. The action is an algorithm with good parameters which satisfy certain constraints. These agents carried a set of actions to reach a goal. To do this, they must have some capacity of environmental perception and communication with other agents. Each agent can be generalized itself by applying the suitable algorithms with good parameters which satisfy certain constraints [13]. These constraints can divide on two types; internal and relational. The proposed approach based on the genetic algorithm improved by tabu research which permits the agent to choose the best action at any time and in all situations.

The paper is structured as follows. Part 2 briefly reminds the generalization process of spatial data. Part 3 presents the proposed approach for optimising generalization process using multi-agent system, genetic algorithm and search tabu. In section 4 we present some results. Finally, part 5 concludes and cites some perspectives of this work.

2. GENERALIZATION PROCESS

The generalization process is defined as a set of algorithms used to generalize an object or a set of objects [1]. This process is guided by a set of constraints that must be satisfied. The main problems of this process are:

- Response time is very long.
- The quality of generalized data is too degraded.
To optimize this process, we must find a solution that puts all the constraints in a state of maximum satisfaction. Thus, we must find within a reasonable time, a compromise that satisfied these constraints in better for solving the most important spatial conflicts.

2.1 Generalization algorithms

To generalize a spatial object, there are several algorithms; these algorithms can be classified by the objects type:

- Buildings: simplification algorithm of contour, displacement [14]…etc.
- Roads: Douglas-Peucker algorithm [19], accordian algorithm [12], faille_max, faille_min [12] and schematization algorithm [4]…etc.

Each algorithm is parameterized by a set of values. The choice of these values is very intrinsic to guide a best generalization process.

2.2 Cartographic Constraints

The objects in the map database must respect a number of cartographic constraints. They are divided into two kinds [2]:

- Internal constraints: The constraints relate an isolated object. In this context, we take account for building agent; constraints of size, granularity, squareness, preservation of shape, etc.
- Relational constraints: They are the constraints which involve more than one spatial object, the constraint that prevents symbols from overlapping each others (e.g. the symbol of a road should not overlap with that of a house), or the constraint that requires aligned buildings to remain aligned.

If a cartographic constraint is not respected, this creates a cartographic conflict [2]. This conflict can be addressed by a combination of possible actions (algorithms), such as elimination, displacement, amalgamation and simplification, combined with appropriate techniques for evaluating the quality of the result. However, the application of an individual operator may have an effect on map objects that was not previously in conflict, resulting in propagation of conflict within the map space [1]. So, to avoid these problems, we propose in this paper to model spatial objects by agents with capabilities of perceptions, communication and also have an optimizer which running a hybrid Genetic-Tabu algorithm.

3. Proposed approach

3.1 System architecture

The Architecture of action selection is a set of mechanisms that allows an artificial agent to choose at any time, the action to perform based on its perceptions, its memory, its goals and skills. The proposed approach based on the three flowing approaches:

3.1.1 Multi-agent system

An agent is a computer system that is situated in some environment, and that is capable of autonomous action in order to meet its design objectives” [17]. That is, on the one hand this autonomous agent perceives its environment and on the other hand an agent modifies its environment by its actions. Hence, an agent can dynamically adapt to a changing environment. This set of agent, called multi-agent system. In this context, Multi agents are groups of collaborative agents, which cooperate to achieve a common goal.

3.1.2 Genetic algorithms

Genetic algorithms (GA) are developed by Holland [8] to imitate the phenomena adaptation of living beings. They are optimisation techniques based on the concepts of natural selection and genetics [8]. It searches an optimal solution among a large number of candidate solutions within a reasonable time (the process of evolution takes place in parallel). Each of these solutions contains a set of parameters that completely describe the solution. This set of parameters can then be considered the “genome” of the individual, with each parameter comprising of one or more “chromosomes”. They allow a population of solutions converging step by step toward optimal solutions. To do this, they will use a selection mechanism of the population of individuals (potential solutions). The selected individuals will be crossed with each other (crossover), and some will be mutating by avoiding, whenever possible, local optima. They are used primarily to treat both problems [4].

- The search space is large or the problem has a lot of parameters to be optimized simultaneously.
- The problem can not be easily described by a precise mathematical model.

Generalization process of spatial data is a problem characterized by different and most likely even contradicting constraints, which must be satisfied at the same time, and also there is no mathematical model that perfectly describes this process.

3.1.3 Tabu Search

Genetic Algorithms are able to locate promising regions for global optima in a search space, but sometimes have difficulty finding the exact minimum of these optima [7]. In this paper, a new procedure, based on TS, is used to refine the GA. TS is a search strategy based on exploitation of memory, originally proposed in [7] to guide the local search methods to overcome local optima. TS uses basic, problem specific operators to explore a search space and memory (which is called the tabu list) to keep track of parts already visited. By guiding the optimisation to new areas, TS is able to overcome local minima and hopefully reach the global optimum. Tabu list stores two kinds of information:

- The most recent operations, which avoids making the same crosses or mutations in the offspring.
- The solutions found during the search for optimal
routes by GA. Each solution stored in the TL (Tabu List). We attach also the total cost of the solution. In every generation, a solution is selected as the initial solution for tabu. Once the tabu search is finished, the final solution is included in the population. We are combining multi-agent systems with Genetic Algorithms and Tabu algorithm, for permitting the agent to choose the optimal action. Therefore, our proposal is based on the following three points:

- Genetic agents: managing the local optimization process and exchange relevant data with neighbouring agents.
- Data flows: the neighbouring agents exchange messages that contain data about the internal state of the agent. Information on the environment is potentially collected from sensors. The gathered data used as input to the genetic algorithm.
- Genetic algorithms: the agent uses GA to find dynamically the optimal solution which performed by genetic agent.

The proposed approach is a hybrid multi-agent system, which benefits in high the advantages of genetic algorithms and search Tabu to permit principally the agents to select optimal plan which optimize selection action in multi agent system. The plan is a sequence of possible action. The population of a genetic algorithm is a set of plans which resolve all the spatial constraints.

3.2 Genetic agent architecture

The agent equipped with an optimizer. It is used to help the agent to choose the optimal action, depending on the environment condition. Using a hybrid genetic-tabu algorithm for optimization has a major advantage compared to systems that are based on genetic algorithm alone.

The main objective of using the GT algorithm is to allow an agent to achieve a satisfactory balance between the research’s time and optimal quality of results. The choice of optimal solution by the agent is based on a list of constraints that must be satisfied and the current state of the environment. So, the optimizer runs the GT algorithm to identify the optimal solution from the population. The solution is the sequence of actions. The best sequence of actions that are achieved by the agent improves overall system performance. The lists of actions have been selected by straightforward evolution of candidate solutions.

3.2.1 Genetic Agent

Each agent has three main components:

- Patrimony genetic.
- An optimizer: execute the GT algorithm to find the optimal solution according to the interne and relationships constraints.
- Ability to communicate with neighboring agents.

Figure 1 presents the architecture of a genetic agent:

(a) Structure of genetic agent plan’s

The genetic agent is an agent which has a patrimony genetic. In this context, we consider two main kinds of genetic agent: road’s genetic agent and building’s genetic agent. The optimizer of the genetic agent executes a plan. In the following, we represent the plan of these two kinds:

(1) Plan of Road

An agent road can be characterized by its identified, and a set of algorithms that can be applied on it, to perform its generalization. These algorithms can take parameters. The coding of gene is made by multiple forms; we use character code for coding the identifiers, the binary form to encode the application or not of such algorithms (0 to say that the algorithm is not applied, 1 for say that the algorithm is applied) and the real forms to encode the parameters of the algorithms. Thus, we can represent plan of agent roads by the figure 2

(2) Plan of Building

An agent Building can be characterized by its identifier and by their generalization algorithms: simplification algorithm and algorithms of displacement, etc. The same type of coding is used to encode this type of gene. So, the following figure represents an example of building gene plan:
(b) Optimizer

The optimizer executes GT algorithm which follow those steps:

(1) Selection

In this work, we used steady-state selection [18]. The main idea is that much of the population can survive the next generation. Thus, the genetic algorithm works as follows: in every generation a few chromosomes are selected (among those with the best cost) to create chromosomes child. Then, the worst chromosomes are removed and replaced with new ones. The rest of the population survives to the next generation.

(2) Crossover

It is an operator that is used by genetic algorithms. It is the transposition of the computer mechanism which permits, in nature, producing chromosomes which partially inherit the characteristics of parents. Its fundamental role is to allow the recombination of information contained in the genetic population.

(3) Mutation

A change that occurs randomly on the chromosome, it aims to maintain some diversity in the population. This mutation occurs only on some small enough not to destroy the features that were selected but large enough to bring new elements to a genetic agent. The percentage of the mutation must be very low. It is applied to all parameters that represent a chromosome, if the mutation point has a Boolean values “Yes”; it is replaced by “No” and vice versa. If it has a real value, the new value is randomly generated from a given interval.

The evaluation system receive the message from neighbouring agents which contain relevant data, such as the number of conflict agents, the distance between the neighbouring objects …etc, which permit it to calculate the total fitness.

(4) Evaluation

The evaluation function of generalization process is based on certain measures that assess the quality of spatial data, is restricted to a set of measures:

- **OS** (object shape): calculates the loss of the characteristic’s shape of the object during processing. For buildings, we compute the differentiation in the surface S and for roads, using measures of McMaster (1983):
  \[ OS = \sum \Delta S + \Delta (McMaster) \]  

A minimum number is a good solution.
- **NC**: number of objects in conflict, a minimum number is a good solution.
- **DP**: sums the normalised, absolute, distance of each object has been displaced from its starting position.
  \[ DB = \sum \sqrt{dx_i^2 + dy_i^2} \]

Also, a minimum number is a good solution. So, the general function is:

\[ f = NC + DP + OS \]

### 3.2.2 Genetic algorithm improved with Tabu Search

In this paper, we propose a hybrid GT algorithm for providing an acceptable solution within a relatively short time. The genetic algorithm samples a large search space, climbs many peaks in parallel, and is likely to lead the search towards the most promising solution area, and the local searches [21]. Then, Tabu search is used to narrow down the global optimal solution area [21].

After the execution of genetic algorithm, the tabu search will perform. We propose the following algorithm for improving the result of genetic algorithm:

1. Initialisation : A chromosome is randomly selected from the current population
2. For the selected chromosome in step 1, a few neighbour solutions are generated and their fitness function values are calculated.
3. The neighbours are sorted in an ascending order according to their fitness value.
4. The following test is performed on the set of neighbours one by one until one of them is accepted.
a. The selected neighbour is checked. If it is a TABU, update list tabu.
b. If stop condition (SC) is satisfied, the solution is accepted.
c. If SC is not satisfied, the process returns to the step 1.

Stopping Condition (SC)
The optimization control module could achieve a satisfactory balance between discovery time of optimal solution and quality of the results (that have the best fitness). In our hybrid algorithm, it stops the process if one of the following three conditions is satisfied: when it achieves certain fitness, when it achieves a set number of iterations or when it has passed a certain running time. In the two latter cases, we choose the solution that has the best fitness.

3.3 Cycle life of Genetic Agent
In the beginning of map generalization process, the geographic agent has evaluated its internal and relational constraints, in its agents group. In our Multi-agent system, the agents aim to satisfy the offensive constraints without violating one of defensive constraints [1]. Fitness is utilized for measuring the satisfaction of the constraints (calculate the degree of constraints satisfaction). A list of possible plans is attached which represent the populations of the genetic-tabu algorithm. A plan proposes a sequence of generalization’s algorithms and its required parameters which improves the agent’s state. The agents active and run theirs genetic algorithms in parallel for reducing the time of map generalization process.
The process of improving an agent’s state represented in the following sequence: constraints evaluation, proposing a plans which represent the populations of the genetic-tabu algorithm, the execution of the GT algorithm by the optimizer, the generalization process is controlled by the optimization control module, the previously steps are the same generic behavior of all genetic agents, the figure 5 represent the life cycle of agent.

4. THE INITIALS RESULT
This experimentation is intended to both clarify and illustrate the ideas (concepts of our approach) in automatic generalization process of spatial data. So, all spatial objects are represented by genetic agents. We use in this work the Jade platform [9], JADE is a software framework, fully implemented in Java that simplifies the implementation of multi-agent systems through a middleware. JADE implements FIPA’s (Foundation of Intelligent Physical Agents) specifications [6].
We have implemented in Java; the different algorithms of generalization such as the algorithms of reducing the size, displacement and the aggregation algorithm. We implement also the various steps of the genetic algorithm; selection, crossover, mutation, and the fitness function for evaluate the solution which composed of a sequence of generalization algorithms with good parametric values to guide an optimal generalization process. Also, the search tabu algorithm was implemented in Java. The optimizer of each genetic agent executes a genetic algorithm which follows the classical steps: selection, crossover and mutation. We use in this experimentation sets of data (buildings and roads) extracted from cadastral data. An example of initial results is illustrated in Figure 7.

When we compare the results of our approach with others result, such as presented in [2] which offered a solution but it does not guarantee that this solution is optimal. Our approach is very flexible; it uses a hybrid approach GA-TS which allow agent to choose the optimal action to perform according to a given situation and it permit to deliver demanded map in short time. Thus, the results are very encouraging, which show the pertinence of the proposed approach and encourage us to pursue this way.

5. CONCLUSION
Action selection is a fundamental part of agent; the proposed approach will allow agents to cooperate so as to find the best plan possible between proposed scenarios. We applied this approach in the automatic generalization process of spatial data. So, each geographic agent has equipped with optimizer which execute a hybrid GT algorithm to determine the optimal plan executed according to its current state, in condition to satisfy the
most possible of internal and relational constraints. This approach gets a best results and permits to agent to select the optimal plan in all time.

The genetic agents exchanged the messages. Hence, these messages are received by agent that helps it to discovering the optimal plan. The initial experiments have shown us the potential advantages of using collaborative agent communities that each agent has an optimizer which execute a GT algorithm. The proposed hybrid GT algorithm differs from other evolutionary computing techniques in providing an acceptable solution within a relatively short time and resolves the most important spatial constraints. Thus, Each genetic agent:

- Can define the optimal actions of generalization and it can generate its self.
- Can adapt its generalization with the other geographic agent.
- Collaborate with the others agent for accelerating the time of map generalization process and resolve the most important spatial conflicts for delivering a map in good quality.

Our work opens many direction of research:

- In generally, the generalization process not concerned only the graphic part but the semantic part is very necessary to be analyzed. Thus, we must add other methods which can perform this hand.
- Improving the performance of our approach with the utilization of the others methods of optimization that allow the agent to define the optimal solution, such as the hybrid genetic and simulated annealing algorithm.

References


