Hybrid approach for optimizing on-the-fly web map generalization

Brahim Lejdel, Okba Kazar

University of el-Oued, Algeria, University of Biskra, Algeria.

lejdel82@yahoo.fr, *kazarokba@yahoo.fr.*

Abstract

The creation of the map on-the-fly becomes today an important domain in cartography. Thousands of the users need access to spatial data on the web specific to their needs. This requires generating a map in real time. Different approaches appeared for optimizing the on-the-fly generation maps, but those not suffice for guiding a powerful and efficient process. Thus, a new approach must be developed for optimizing the on-the-fly generalization process according to the user needs. This paper describe a new approach that combines the multi agent system and the techniques of genetic algorithm which improved by Tabu search method (GA-TS). We introduced the TS into the genetic algorithm to refine the solutions space found by GA toward the optimum solution. This approach uses the multiple representation and cartographic generalization.

Keywords- On-the-fly maps generalization, Agent, Genetic Algorithm, Tabu Search, cartographic constraints, multiple representations.

1 INTRODUCTION

The web mapping has known great growth in parallel of the rapid development of the internet. To provide on-the-fly web mapping to the user, the process of on-the-fly map generalization must rely on fast, effective, and powerful methods. A principal challenge of such on-the-fly maps generalization is to offer the user a spatial data in real-time and in height quality , it must allow also to solve spatial conflicts that may appear between objects especially due to lack of space on display screens [21]. To optimize the on-the- fly maps generalization; we have to formalize an efficient automatic generalization process. The automation of generalization process is an important research area in this last decade 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 vector geographic database very detailed [16]. Several methods and concepts proposed to model and implement the generalization process but a framework for their combination into a comprehensive generalization process is missing [2]. Several works model the spatial objects by agents such as the works of ([3], [14], [19], [21], [25], [26] and [28]). The strategy presented in [3] offers a good method 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 [21]. An important work that was suggested by [21], it present an approach based on the implementation of a multi-agent system for the generation of maps on-the-fly and the resolution of spatial conflicts. This approach is based on the use of multiple representation and cartographic generalization. In the same context and for reducing the spatial conflicts in the map, a good method was proposed in [19], this method is based on the genetic algorithm. Then, the technique presented in [25] is very important, it uses the least squares adjustment theory to solve the generalization problems, but it can't implement certain operations of generalization, such as elimination, aggregation or typification…etc. Also, to improve the process of on-the-fly map generalization, another approach was proposed in [28] which based on a new concept called SGO (Self-generalizing object). [6] propose an approach based on user profiles, which formally captures the user requirements (preferences) towards the base map and deploys those profiles in a web-based architecture to generate on-demand maps. The most recent approach is presented in [20] uses the agent approach based on the genetic algorithms. The advantage of genetic algorithms is their ability to find the solution space containing the optimum. However, it has difficulty when to find the exact value of the optimum in this space.

The work presented in this paper comes under these kinds of research; it uses the multi agent system equipped with genetic-tabu algorithm in order to generate data on arbitrary scales thanks to an on-the-fly map generalization process. This approach exclusively aims to solving the following problems related to on-the-fly web mapping applications:

- How the agent can find the optimal solution, which solves spatial conflicts in order to improve the quality of map?
- How can we adapt the contents of maps to users' needs and improve the time of generalization process of spatial data, which improve in result the transfer time of maps' data?

In artificial intelligent, choose an optimal action by agent is key mechanism for design an intelligent system [11]. thus, achieve optimal generalization process of spatial data implied that the agent determine at any

instant what the optimal action that do in the next [17], i.e , the optimal plan which satisfy the different constraints [1].
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) carry out in order to achieve its goals. We say in the above that, GA has difficulty when to find the exact value of the optimum in the solution space. In this paper, we propose an approach combine the agent with evolutionary methods such as GA which use a local search algorithm such us, tabu algorithm to find the exact value of the optimum. Thus, we propose to provide the agent a set of capacity; perception, communication with the other agents and optimizer that allow it to select the optimal plan. Each agent can be generalized itself by applying optimal plan which satisfy certain constraints [14]. In this context, optimal plan is a sequence of action. The action is an algorithm with good parameters which satisfy the most possible constraints [1]. These constraints can divide on two types; internal and relational. This paper is structured as follows. In the part 2, we present on-the-fly map generalization process and its problems. Part 3 presents the proposed approach for improving on-the-fly web mapping generalization. In part 4, we present the experimentation and some results. Finally, part 5 concludes and cites some perspectives of this work.

2 ON-THE-FLY WEB MAP GENERALIZATION

The on-the-fly web map generalization is defined as; the creation in real-time and according to the user's request, of a cartographic product appropriate to its scale and purpose, from a largest-scale database. The main characteristics of on-the-fly web mapping are:

- Required maps must be generated in real-time [21].
- Generation of a temporary and reduced scale dataset for visualization purposes from the database [13] in order to use the computer's memory efficiently [4].
- A real-time map generation process has to take into account users' preferences and contexts.
- A real-time map generation process must adapt maps' contents to display space and resolution of display media as well as to the contextual use of these maps [21].
- The scale and theme of the map are not predefined [4].
- There is no way to verify the quality of the final map that will be sent to the user [21].

The main problems linked to on-the-fly map generalization are the time of delivering the cartographic data and its quality. The generalization process time is a crucial factor to provide a user cartographic data. The waiting time must be compatible with Newell's cognitive band, which is less than 10 seconds [15]. Also, in order to produce maps suited to a user's requests, on-the-fly map generalization must be flexible enough to take into account the level of detail, the kind of the map [20]…etc.

3 PROPOSED APPROACH

System architecture

In our approach, we use an artificial agent which can find at any time, the optimal solution carries out, based on its perceptions, its memory, its goals and skills. The proposed approach based on the three flowing approaches:

A. 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" [18].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; the optimal generalisation process.

B. Genetic algorithms

Genetic algorithms (GA) are developed by Holland [9] to imitate the phenomena adaptation of living beings. They are optimisation techniques based on the concepts of natural selection and genetics [9]. 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. Genetic Algorithms are able to locate promising regions for global optima in a search space, but sometimes have difficulty to find the exact minimum of these optima [24]. They are used primarily to treat both problems [5].

- 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.

C. Tabu Search

The Tabu Search (TS) is a powerful optimization procedure [22]. It is an iterative procedure designed for the solution of optimization problems, which was been successfully applied to solve a wide number of hard optimization problems [23]. TS is a search strategy based on exploitation of memory, originally proposed in [8]. TS use basic, problem-specific operators to explore a search space and memory which is called the Tabu List (TL), 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 by employing a flexible memory system [27]. In this work, tabu list stores two kinds of information:

- The most recent operations, which avoids making the same crosses or mutations in the offspring.
- The best solutions found during the execution of GA. Each solution stored in the TL. We attach also the total cost of the solution.

In every generation, a solution is selected as the initial solution for TS. Once the TS are finished, the final solution is included in the next population. In this paper, a new algorithm, based on TS, is used to refine the result of GA. 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 which contain information about the internal state of the agent. Information on the environment is potentially collected from sensors. The gathered information used as input data to the Genetic-Tabu algorithm.
- Genetic-Tabu algorithms: the agent uses GA to find dynamically the optimal solution which will carry out by genetic agent.

The proposed approach is a hybrid multi-agent system, which benefits in high the advantages of generic algorithms and search Tabu to permit principally the agents to select the optimal plan, in reasonable time. The plan is a sequence of possible algorithms. The population of a genetic algorithm is a set of plans which resolve the most possible cartographic conflicts.

Genetic agent architecture

The main objective of using the GA-TS algorithm is to allow an agent to interact in order to find an optimal solution (the best compromise that satisfies competing constraints).

A. Genetic Agent

Figure 1 presents the architecture of a genetic agent:

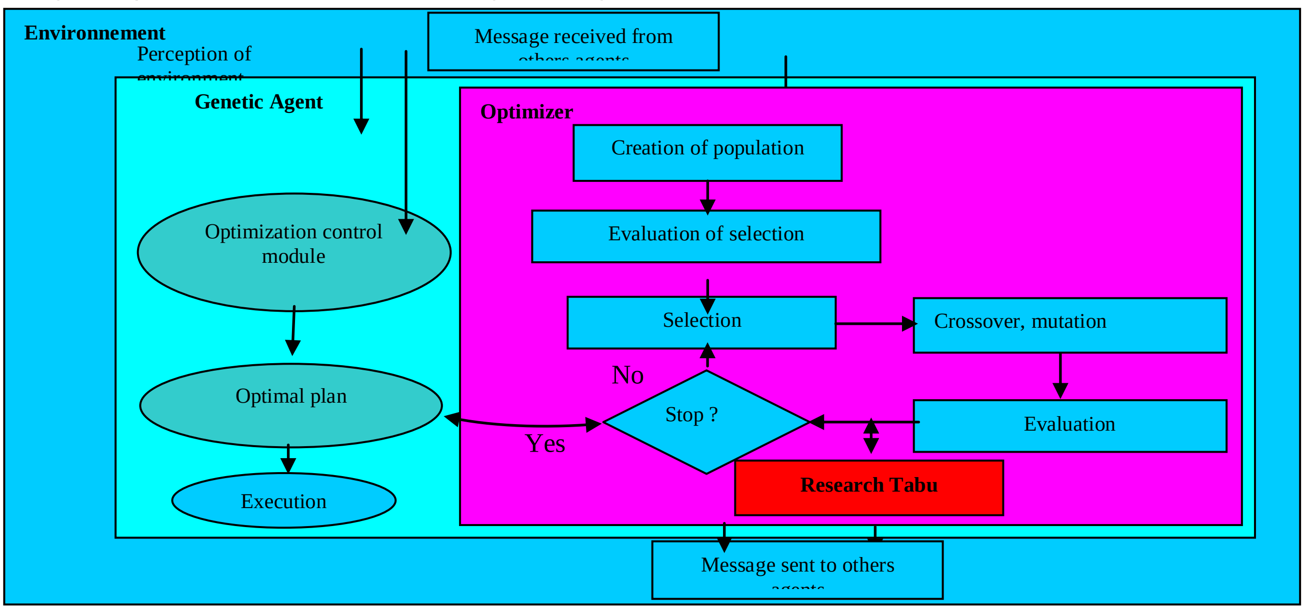


Figure 1 Architecture of Genetic agent.

B. 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 [1].

(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 process.

These algorithms can take parameters. The gene is coded by multiple forms; we use char form to code the identifiers, the binary to code 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 code the parameters of the algorithms. Thus, we can represent plan of road's agent in the figure 2:

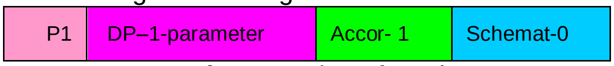


Figure 2 Plan of road.

(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. Thus, the following figure represents an example of plan of building's agent:

Figure 3 Plan of building.

C. Genetic agent Module

The main role of a genetic agent is to generalize its self, in order to adapt it to the level of detail requested by the user. Thus, the genetic agent is responsible for the satisfaction of its constraints. It must be collaborate with the other agent to avoid a constraints violation. It applies the optimal solution composed of a sequence of generalization's algorithms, which is generated by its optimizer. The architecture of genetic agent is composed of two main modules:

(1) Map Generalization module

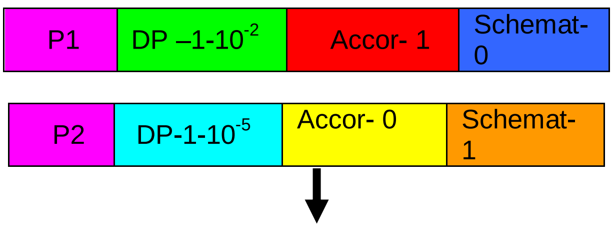
This module carries out the map's generalization process; it applies the solution found by the optimizer. The optimizer execute GA-TS algorithm to define the optimal chromosome. It follows the classical steps of a genetic algorithm are selection, crossover and mutation. The solution is represented by sequence of algorithms and their good parameters. GA used to find the optimal solutions space, and the TS used to refine it towards the optimal solution. If the optimal solution is found, the TS is stopped and the modified solution replaces the original solution in the next generation. The optimizer executes GA-TS algorithm which follow those steps:

(a) Selection

In this work, we used steady-state selection [19]. Main idea of this selection is that great part of chromosomes should survive to next generation. GA then works in a following way. In every generation, a few chromosomes (with best fitness) are selected for creating a new offspring. Then the other chromosomes (with bad fitness) are removed and the new offspring replace them. The rest of population survives to new generation.

(b) 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 offspring which partially inherit the characteristics of parents. Its main role is to allow the recombination of information contained in the genetic population. The figure 4 represents a solution generated by the optimizer, such as, each two chromosomes' parents together to make two offspring. The solution is refined gradually over the iterations until convergence to the optimal solution using TS. In the beginning, a certain degree of imperfection is acceptable.



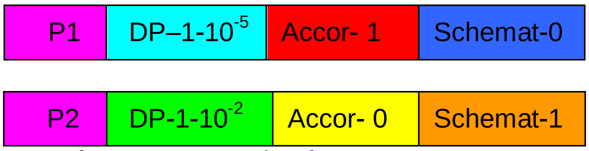


Figure 4 Example of Crossover operator.

(c) 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.

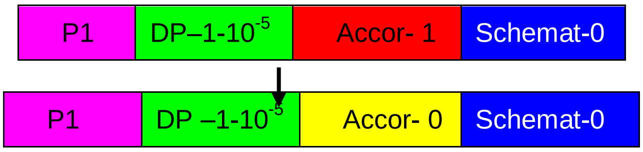


Figure 5 Point of mutation.

(d) Evaluation

The evaluation function of generalization process is based on certain measures that assess the quality of spatial data. In this work, we use the following 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 [12]:

$$OS = \sum \Delta S + \Delta\,(\text{McMaster}) \qquad (1)$$

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.

$$DP = \sum_{1}^{n} \sqrt{\left(dx_i^2 + \mathrm{dy}_i^2\right)} \qquad (2)$$

Also, a minimum number is a good solution.

So, the general function is:

$$f = NC + DP + OS \qquad (3)$$

(e) Tabu Search

A genetic algorithm is a strong approach used for solving the optimization problems, because it has the abilities to find the solutions space containing the optimum. However, it has difficult to find the exact value of the optimum in this space, which, guide us to use a local optimization algorithms such us, tabu search algorithm to refine the result of GA.

The proposed approach is highly efficace because it benefits the advantages of an efficient local search for exploiting the neighbourhood of solutions. We proposed an algorithm wherein GA used to generate the possible solutions (the population of solution) and TS used to guide the search towards the optimal solution.

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

1. Initialisation: A chromosome is randomly selected from the current population of GA.
2. Few neighbour solutions of chromosome selected in step 1, 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 proposed algorithm stopped 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.

(2) Optimization Control module

The control optimization module could achieve a satisfactory balance between discovery time of optimal solution and quality of the results (that have the best fitness). Thus, this module controls generalization's time for not exceeds the maximum limits and receive the message from neighboring agents which contain relevant information, such as the number of conflict agents, the distance between the neighboring objects …etc. It stops executing the genetic-tabu algorithm for the three reasons, presented above.

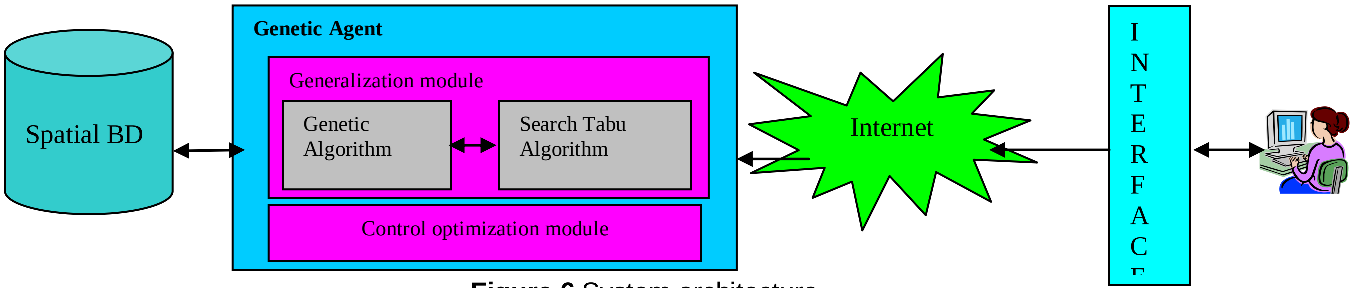


Figure 6 System architecture.

4 THE INITIALS RESULT

In this experimentation, all spatial objects are represented by genetic agents. We use in this work the Jade platform [10], 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 [7].

We have implemented in Java; two principals' agent (building agent and route agent) and the different algorithms of generalization such as simplification, displacement, aggregation and smoothing algorithms. We implement also the various steps of the GA; selection, crossover, mutation, and the fitness function to evaluate the solution which composed of a sequence of generalization algorithms with good parametric values. Also, the search tabu (TS) algorithm was implemented in Java and incorporated on the GA.

During the map generation process, the optimizer of each agent executes its genetic algorithm for solving its possible spatial conflicts, maintain the spatial relationships between the objects they handle and preserve their legibility. At every spatial processing cycle, each agent supervises the changes in its immediate environment and evaluates its current state. According to the environment changes, it plans and performs the relevant actions found by its optimizer. The agents exchange information with its neighbour agents for calculating the general fitness. Therefore, in order to shorten the processing time, the optimizer of different agents executes its genetic algorithm, in parallel. In this work, we restricted the agents' interactions to only cooperation for calculating general fitness. Also, our approach reduces users' waiting delays since it generates and transfers the requested maps at the same time. An example of initial results is illustrated in Figure 8.

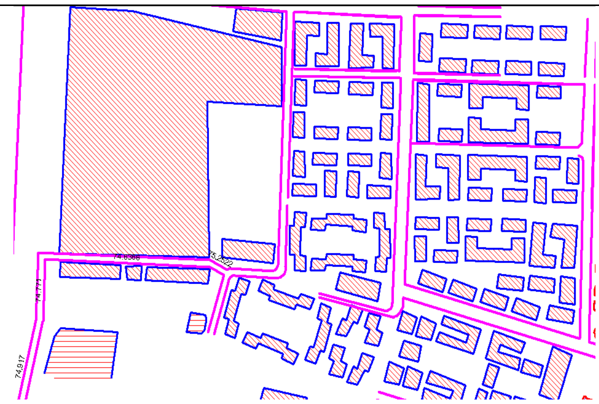
	
INITIAL MAP (1:1000)	1: 1500

Figure 7 Generalization results (simplification, displacement, aggregation, smoothing).

All the other methods used to optimize the generalization process provide near optimal solutions and the quality of solution is affected by either the solution time limitation, or the feasibility of the final solution. Nevertheless, our approach permits to find the exact solution in short time compared with the results of others approach, such as presented in **[3]**. This latter offered a solution but it does not guarantee that this solution is optimal. Also, the technique presented in [19] does not allow to apply discontinues operations such as remove an object or aggregate a group of objects.

For all these reasons, we combine the agent approach and the technique GA-TS for solving the problem of generalization process. It is very flexible; since allow agent to find the optimal action carried out according to a given situation. The optimal solution is obtained within a time that makes the proposed approach useful for generate map at short time because the optimizers of the agents execute theirs GA in parallel. Thus, the results are very encouraging, which show the pertinence of the proposed approach and encourage us to pursue this way.

5 CONCLUSION

The proposed approach is a very important because it allows agent to define the optimal solution possible between the proposed scenarios found by the GA. the result of GA will be refined by using the Tabu Search. Thus, each geographic agent was modelled by agent equipped with optimizer. The optimizer executes a hybrid GA-TS algorithm to determine the optimal plan carried out, according to current state of agent, in condition to satisfy the internal and relational constraints. The genetic agents exchanged the messages. Hence, these messages are received by agent, can help it to find the optimal plan with short computation time.

The initial experiments have shown us the potential advantages of using collaborative agent communities that each agent has an optimizer which execute a GA-TS algorithm. The optimizer gets a best result, in reasonable time. Thus, the proposed algorithms enable the agent to generate itself in real-time and with height quality. The proposed hybrid GA-TS algorithm differs from other evolutionary computing techniques because it provides an optimal solution which resolves the most possible number of spatial conflicts, in short time. Thus, each agent can:

- Define the optimal actions of generalization and it can generate its self.
- Adapt its generalization with the other geographic agent.
- Collaborate with the others agent to improve the result of map generalization process and resolve the spatial conflicts, in reasonable time.

Our work opens many directions of research:

- The prototype developed in this work permit to apply the simplification, displacement, aggregation and smoothing. In the future, we will try to integrate the other algorithms of generalisation.
- Improving the performance of our approach with the utilization of the others methods of optimization that allow the agent to define the optimal solution within a reasonable time, such as the hybrid genetic and least squares methods.

6 REFERENCES

[1] B. Lejdel & O., kazar 2012, “genetic agent for optimizing generalization process of spatial data”, International Journal of Digital Information and Wireless Communications (IJDIWC), Vol. 1, No. 3, pp-729-737.

[2] M. Bader,2001, “Energy Minimizing Methods for Feature Displacement in Map Generalization”, Thesis (PhD), Department of Geography, University of Zurich.

[3] Duchêne, 2004, “The CartACom model: a generalisation model for taking relational constraints into account”, 7th ICA Workshop on Generalisation and Multiple representations, Leicester, UK.

[4] Cecconi, ,2003, “Integration of cartographic generalization and multi-scale databases for enhanced web mapping”, PhD. Thesis, University of Zurich.

[5] K. DeJong & J., Sarma, 1993 “Generation Gaps Revisited, Foundations of Genetic Algorithms 2”, D. Whitley, Morgan-Kaufmann Publishers, San Mateo.

[6] T. Foerster et al., 2011 "On-demand Base Maps on the Web generalized according to User Profiles", International Journal of Geographical Information Science, Taylor & Francis, pp.1-26.

[7] GeoTools,2006" the open source java GIS toolkit", Available from: http://docs.geotools.org/, [Accessed 10 may 2011].

[8] F. Glover, and M.,Laguna, 1997, "Tabu Search", Kluwer Academic Publishers.

[9] Holland,1975 "Adaptation in Natural and Artificial Systems", University of Michigan Press, Ann Harbor.

[10] JADE,2006 "Java Agent Development Framework", Available from: http://jade.tilab.com/ [Accessed 10 may 2011].

[11] B.Joanna, 2004 "Action Selection and Individuation in Agent Based Modelling", University of Bath, UK.

[12] R.B. McMaster,1983, "Mathematical measures for the evaluation of simplified lines on maps", PhD thesis, University of Kansas., USA.

[13] V. Oosterom, & V. Schenkelaars., 1995, "The development of an interactive multi-scale GIS", International Journal of Geographical Information Systems, Vol. 9(5):489-507.

[14] Regnauld,2001 "Constraints based Mechanism to achieve automatic generalization using agent modelling", Proceedings of GIS Research UK 9th Annual Conference, 329–332, university of Glamorgan, UK.

[15] A. Newell., 1990, "Unified Theories of Cognition, Harvard University Press, Cambridge MA", p.p 549.

[16] A. Ruas, 1999 "Modèle de généralisation de données géographiques à base de contraintes et d'autonomie", Thesis (PhD), université of "Marne-la-Vallée, France.

[17] J. Prescott Tony, 2008, "Action selection", Dept Psychology, University of Sheffield, UK.

[18] G. Weiss, 1999, "Multi-agent Systems, A modern Approach to Distributed Artificial intelligence", The Mit Press, Cambridge, MA.

[19] I.D. Wilson et al, 2003"Reducing Graphic Conflict in Scale Reduced Maps Using a Genetic Algorithm", 5th ICA Workshop on Progress in Automated Map Generalisation, Paris, France.

[20] B.Lejdel, & O. kazar ,2012 "genetic agent approach for improving on-the-fly web map generalization", International Journal of Information Technology Convergence and Services (IJITCS) Vol.2, No.3.

[21] N. Jabeur, 2006, "a multi-agent system for on-the-fly web map generation and spatial conflict resolution", University of Laval, Quebec.

[22] M. Sudhakaran ,P. , & Ajay-D-Vimal Raj, 2010, "Integrating genetic algorithms and tabu search for unit commitment Problem", International Journal of Engineering, Science and Technology, Vol. 2, No. 1, pp. 57-69.

[23] A.H Mantawy, et al., 1999 "Integrating GA, TS and SA for the unit commitment problem", IEEE Transactions on Power systems, Vol.14, No.3, pp. 829-836.

[24] D. Goldberg, "Genetic Algorithms in Search, 1989," Optimisation and Machine Learning", Addison Wesley,Reading,MA.

[25] M. Sester, 2000 "Generalization Based on Least Squares Adjustment. International Archives of Photogrammetry and Remote Sensing, vol.33, ISPRS, Amsterdam.

[26] M. Galanda, 2003 "Automated Polygon Generalization in a Multi Agent System. Dissertation zur Erlangung der Doktorwürde, Mathematisch-naturwissenschaftliche Fakultat, Universitat Zürich.

[27] J.A. Hageman , et al., 2003 "Hybrid genetic algorithm–tabu search approach for optimising multilayer optical coatings", Analytica Chimic aActa , pp.211–222.

[28] M. N. Sabo, 2007"généralisation et des patrons géométriques pour la création des objets auto-generalisants (SGO) afin d'améliorer la généralisation cartographique à la volée ", Université de laval , Quebec.