An Architecture based on Ontologies, Agents and Metaheuristics Applied to the Multimedia Service of the Brazilian Digital Television System

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Abstract: With the advent of the Brazilian Digital Television System, that arrives on approximately 95% of Brazilian homes, the users will be able to have an interactive channel by the utilization of the digital television. Thus, will be possible to access the multimedia application server, i.e., to send or to receive emails, to access interactive applications, to watch movies or specific news. This paper proposes the development and the implementation of an architecture that includes a module that suggests the content to the user according to his profile and another module to optimize the content that will be transmitted. The implementation was developed using ontologies, software agents, Tabu Search and Genetic Algorithm. The validations of the results are done using a metric.

1 INTRODUCTION

In Brazil is occurring a technological evolution with the advent of digital television, for example, the signal that was received by viewers in analog way before, now is received in digital way, which improves the image quality avoiding the appearance of the flickering screen and of the images ghosting, commonly found in analog transmissions (Carvalho, 2006).

Nowadays, in Brazil, the broadcast television is the most important access to information. Considering the 58.4 million Brazilian households, 55.4 million have at least one receiver. In other words, the public television reaches 95% of Brazilian Households (Bip, 2001).

Beyond the quality improvements and the image transmission, the Brazilian Digital Television System includes the interactive channel that allows the interactive applications access by users. The station may have a server with multimedia applications and the user can access them through the interactive channel. In this context, the return channel can be used for data transmission such as emails, interactive questionnaires and multimedia content like interactive distance courses, presentations with interact content, among others (Manhães, 2005).

The purpose of this work is the implementation of a system divided into two modules: content suggestion module and content transmission module. In the content suggestion module will be used software agents and ontologies in order to classify content crossing it with the user profile suggesting the appropriate content. In the content transmission module will be used software agents that with the Tabu Search (TS) and the Genetic Algorithm (GA) will define the better transmission policy, through the optimizing of the transmission parameters, such as transmission rates of audio and video, among others.

This paper is organized as follows. Section 2 presents the related work. Section 3 presents the proposed architecture. Section 4 shows the results obtained. And Section 5 presents the conclusions.

2 SIMILAR WORKS

In this section will be presented similar studies that used each of the technologies that are involved in this work. Will be presented related works that use ontologies to suggest content for Digital TV with software agents and other works that use metaheuristics to the transmission parameter optimization. In Literature aren't found papers that

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addressing in a unique work all the technologies applied in this work. Also, were not found works in the literature that optimize the same types of parameters considered in this work and therefore it is hard to compare it to existing works.

2.1 Metaheuristics

The metaheuristics used in this work are the Tabu Search, proposed by Fred Glover in 1986 (Glover, 1986), and the Genetic Algorithm proposed by John Holland in 1975 (Holland, 1975).

The metaheuristics have been used in a variety of combinatorial optimization problems. Gendreau, Laporte and Potvin (2002) and Simas (2007) used metaheuristics for the Vehicle Routing Problem. Since Chung, et al. (2010), Gonçalvez and Mauricio (2004), Gonçalvez and Tiberti (2006) make use of metaheuristics applied to the Manufacturing Cells Formation Problem.

The utilization of metaheuristics for parameter optimization of data transmission for IPTV was approached by Weissheimer (2011), in this paper the author presents the development of a computational model based on the application of metaheuristics on an IPTV platform in order to find the best configuration of transmission parameters considering the types of users and receiving devices.

Link (2011) presents a system to configure parameters of video coding for digital TV using the H.264 standard. This search is based on metaheuristics Tabu Search and Genetic Algorithms. In this work was developed a hybrid algorithm, based on the utilization of these two metaheuristics, the Tabu Search was used to intensify the search in conjunction with the power of GA diversification**.**

2.2 Software Agents and Ontologies

In the context of digital television have been published several works using ontologies for the representation of programs, movies and sports metadata available to users.

In the paper of Araújo and Ricarte (2010) the authors proposed an integration of existing metadata in a transmission environment and reception of digital TV in open networks of terrestrial and satellite transmission. Once the open digital TV receiver device will have access to an interactive channel via Internet, was presented a methodology to integrate the metadata information of the broadcast industry using ontologies to describe the knowledge of specific areas in existing ontology repositories on Internet.

Fernández, et al. (2006), proposed an automatic content recommendation system for Digital TV broadcast programs based on the Web Semantic technologies like ontologies, OWL (Web Ontology Language) and software agents.

Figure 1 shows the ontology structure that was set up, can observe a similar structure to the ontology propused in this work, however, with a larger scope, because the authors encompassed different contents such as movies, series, entertainment, concerts, among others.

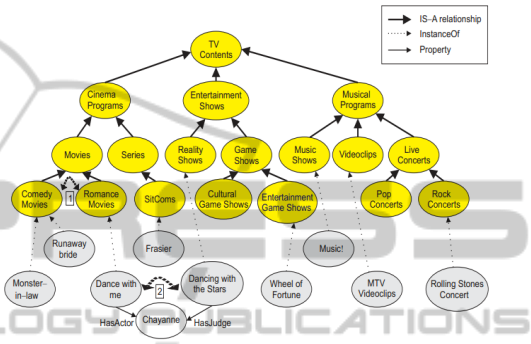

Figure 1: AVATAR ontology structure.

3 PROPOSED SOLUTION

The Brazilian Digital Television System supports an interactive channel, considering that exist an internet connection to make the communication with the television station. From this fact, were proposed two ontologies. The first one, that aims to make a classification of content in the multimedia application server, for example, classification of films by genre, film's authors, release year, etc. and other ontology to describe the users profile, for example, can be identified if the users that like to watch movies of action genre, comedy, suspense, among others.

Thus, with these two ontologies, it is possible to make a crossing of the user profile with the content available on the multimedia application server. To do it was created a software agent that reads the user's profile, to find the content available on the multimedia application server and to send this suggestion to the user. These suggestions will be sent in a time interval which can be determined by the television station.

After the user accepts the suggested content, a communication channel is established between the multimedia application server and the user. On the other hand, the optimizer agent, that is processed from time to time on the server, will determine the

most optimum way to deliver the content to end user. This agent will run a metaheuristic that will determine the parameters and the best policy for the transmission according to the profile defined by ontologies.

Figure 2 shows a practical example of the operation of the proposed architecture. At the content suggestion module there are the consultants agents, one for each user, they are responsible for analyzing user's profile, in this case we have two users, each one with a profile described by an ontology. After knowing the profile, each agent performs a search in the server's ontology to see the contents that are appropriate for each user. Suppose that user likes to watch action movies, the agent will search for contents related to action movies.

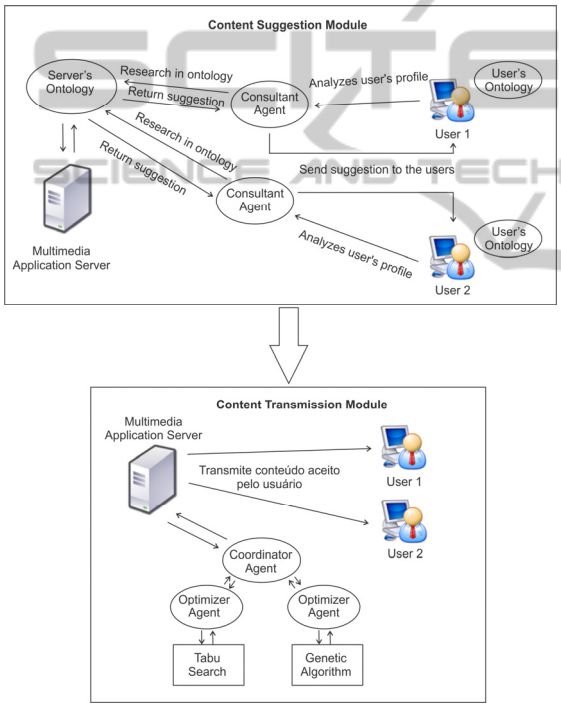

Figure 2: Proposed architecture.

After the acceptance of a suggested content, the control passes to the transmission content module. In this module we have the coordinator agent and the optimizers agents. The coordinating agent will trigger the other agents to run the metaheuristics to determine the best parameters and the best policy for transmission of the content. After ended this process, each optimizer agent will transmit the results found by the metaheuristic Tabu Search and Genetic Algorithm for the coordinating agent. The coordinating agent will analyze which of them had the best result. These parameters will be chosen for the transmission of content between the multimedia application server and the user. In this procedure, is considered that content streaming will occur over the IPTV. To finish the transmission the communication channel is closed.

3.1 Multimedia Application Server and User's Ontology

The multimedia application server ontology was created to describe the multimedia content that is stored on the server. Due to the great diversity of content that a server can store this work will restrict the scope of this ontology for movies.

The user's ontology was created to describe the user's profile that connects to the server. Due to the large amount of data that can be described on a user's profile, the scope was limited to some relevant information.

Figure 3 shows the multimedia application server's ontology together with the user's ontology. The light circles indicate the ontology classes and the dark circles indicate classes instances.

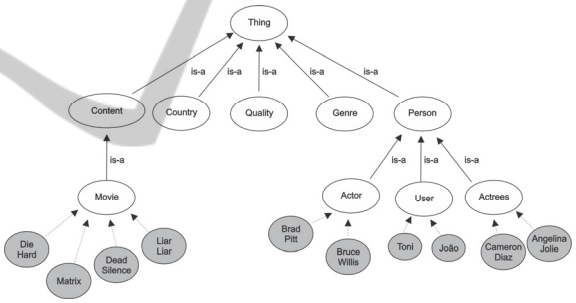

Figure 3: Ontology structure.

3.2 Mathematical Formulation

This section presents the objective function (OF) and restrictions related to the OF. For each decision variable of the OF will be presented the range of feasible values. The expected result of the formulation is to have the best possible utilization and distribution of bandwidth of the server in order to attend a varying number of clients connected to the service.

$$\text{MAX FO} = \alpha\left(\sum_{n=1}^{nLD} vLD_{[n]}\right) + \beta\left(\sum_{n=1}^{nSD} vSD_{[n]}\right) + \gamma\left(\sum_{n=1}^{nHD} vHD_{[n]}\right) + \delta\left(\sum_{n=1}^{nP1} vP1_{[n]}\right) + \omega\left(\sum_{n=1}^{nP2} vP2_{[n]}\right) + \theta\left(\sum_{n=1}^{nST} aST_{[n]}\right) + \rho\left(\sum_{n=1}^{n51} a51_{[n]}\right) \quad (1)$$

Restrictions:

$$0.01 \leq vLD \leq 1.00 \quad (2)$$

$$1.00 \leq vP1 \leq 2.00 \quad (3)$$

$$2.00 \leq vSD \leq 5.00 \quad (4)$$

$$5.00 \leq vP2 \leq 10.00 \quad (5)$$

$$10.00 \leq vHD \leq 18.00 \quad (6)$$

$$0.096 \leq aST \leq 0.256 \quad (7)$$

$$0.384 \leq a51 \leq 1.00 \quad (8)$$

$$LB = 500.00 \quad (9)$$

$$\alpha + \beta + \gamma + \delta + \omega + \theta + \rho \geq 0 \quad (10)$$

$$nLD, nSD, nHD, nP1, nP2, nST, n51 \in Z^{+} \quad (11)$$

$$\left(\sum_{n=1}^{nLD} vLD_{[n]}\right)+\left(\sum_{n=1}^{nSD} vSD_{[n]}\right)+\left(\sum_{n=1}^{nHD} vHD_{[n]}\right)+\left(\sum_{n=1}^{nP1} vP1_{[n]}\right)+\left(\sum_{n=1}^{nP2} vP2_{[n]}\right)+\left(\sum_{n=1}^{nST} aST_{[n]}\right)+\left(\sum_{n=1}^{n51} a51_{[n]}\right) \leq LB \quad (12)$$

Where:

- LB = total bandwidth of the television station;
- vLD = LD (low definition) video quality;
- vP1 = P1 (between LD and SD definition) video quality;
- vSD = SD (standard definition) video quality;
- vP2 = P2 (between SD and HD definition) video quality;
- vHD = HD (high definition) video quality;
- aST = Stereo audio quality;
- a51 = multichannel 5.1 audio quality;
- nLD = number of clients connected as LD;
- nSD = number of clients connected as SD;
- nHD = number of clients connected as HD;
- nP1 = number of clients connected as P1;
- nP2 = number of clients connected as P2;
- nST = number of clients connected as Stereo audio quality;
- n51 = number of clients connected as multichannel 5.1 audio quality;
- α = importance level of the LD transmission;
- β = importance level of the SD transmission;
- γ = importance level of the HD transmission;
- δ = importance level of the P1 transmission;
- ω = importance level of the P2 transmission;
- θ = importance level of the Stereo Audio transmission;
- ρ = importance level of the multichannel 5.1 transmission;
- All decision variables accept real numbers.

It can be seen, through the mathematical formulation of the equations, that the system bottleneck is the bandwidth available at the multimedia application server. Because this feature is limited and has a high cost, it should be used as best as possible.

4 EXPERIMENTS AND RESULTS

The validation of the experiments for the content suggestion module was made through simulations and analysis of requirements to verify if the system is suggesting content according to the user profile. There were created three profiles of users with different tastes about movies, were also registered a number of movies and genres in order to crossing the user's profile with the movies database.

For the content transmission module experiments were evaluated by the decision variables vLD, vSD, vHD, vP1, vP2, aST and a51 through the results obtained by metaheuristics GA and TS.

4.1 Results Obtained by Content Suggestion Module

Algorithms related to the content suggestion module could be found in the literature as in Fernandez et al. (2006), De Paula, Villaça and Magalhães (2011). The following are presented the steps and the pseudo-code of the algorithms developed to authenticate the users and to suggest content using SPARQL (SPARQL, 2008).

Step 1: The following shows a SPARQL pseudo-code to authenticate the user. In the case of the password, we chose to encrypt using MD5.

```
SELECT  ?o
  WHERE {
    ?s w:hasNameValue ?o .
    ?s w:hasPasswordValue :password .
    ?s w:hasLoginValue :login
  }
```

Step 2: The following query is run in the user's ontology to find out what their preferred genres.

```
SELECT  ?o
  WHERE {
    ?s w:hasPreferedGenre ?o .
    ?o w:hasGenreNameValue ?n .
    ?s w:hasLoginValue :login
  }
```

Step 3: Once having the list of user's preferred genres, we selected in the ontology server, the films that are available and they are ordinated by the viewing rate.

```
SELECT  *
  WHERE {
    ?s w:hasNomeValue ?o .
    ?s w:hasTaxaVisualizacaoValue ?t .
    ?s w:hasGenero ?g .
```

```
    ?g w:hasNomeGeneroValue ?n .
    filter (?n = :listaGeneros)
  }
  order by desc(?t)
```

Step 4: The suggestion is sent to the user. Since it can accept one of the suggestions, in case of acceptance the film is transmitted to the user and the user ontology is updated with the watched film.

```
INSERT DATA {
  w: :user
  w:hasWatchedMovie
  w: :movie
}
```

It may be noted that whenever a user accepted a suggestion, the ontology is updated. Thus, the system can adapt and evaluate the films that the user are watching, and so improve the suggestions.

4.2 Results Obtained by Content Transmission Module

This module runs in an interval of time on the multimedia application server and contains software agents that will coordinate the metaheuristics to optimize the content to be transmitted according to the number of users connected to the server and according to the user's profiles.

The Table 1 shows the first experiment with the Tabu Search with a small instance of the problem, in this case are three connected clients of every type (LD, P1, SD, P2 and HD), a total of 15 clients. From these clients, 5 receive stereo audio and 10 receive 5.1 audio. The server's bandwidth was limited to 70 Mbit/s. The value of the objective function (OF) is 70.00 Mbit/s and the harmonic mean is 0.507 Mbit/s.

Table 1: Tabu search results.

Tabu Search						Harmonic	Nr. Clients
LD	0,710	0,460	0,470			0,525	3
P1	1,140	1,420	1,520			1,340	3
SD	3,610	2,010	3,390			2,805	3
P2	6,130	5,380	5,070			5,492	3
HD	10,030	12,560	10,160			10,801	3
ST	0,180	0,100	0,100	0,110	0,150	0,117	5
A51	0,390	0,500	0,410	0,410	0,490	-	5
A51	0,470	0,390	0,740	0,750	0,750	0,495	5
				OF =>	**70,000**	**0,507**	**15**

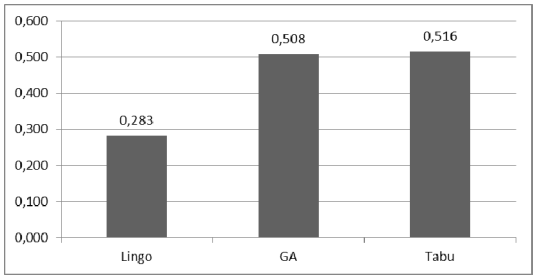

Figure 4: Metric comparing Lingo, GA and TS.

Figure 4 shows on a graph the metric value, the harmonic mean of the results obtained by the Lingo software (Lingo, 2012), AG and BT of the same instance of Table 1. It can be observed that the worst results were obtained by the Lingo. GA and TS obtained similar results of 0.508 and 0.516 Mbit/s.

The graph of Figure 5 shows the standard deviation obtained for each metaheuristic. The TS obtained the best result 0.091 Mbit/s and the GA obtained 0.107 Mbit/s.

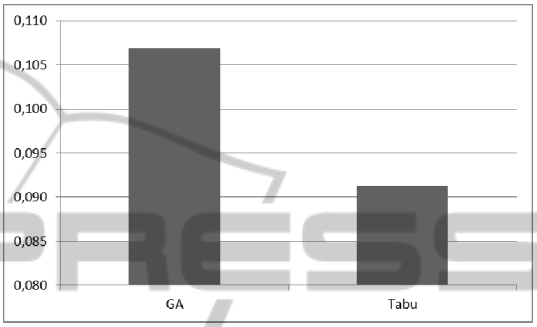

Figure 5: Standard deviation.

The metaheuristics were also tested with 15,000 connected customers: 3,000 of each type (LD, P1, SD, HD and P2). Of these 15,000, 7,500 received stereo audio quality and 7,500 received 5.1 audio quality. Figure 6 shows the harmonic mean of GA and TS. Both have had very close results with transmission rates of 0.407 Mbit/s (GA) and 0.406 Mbits/s (TS).

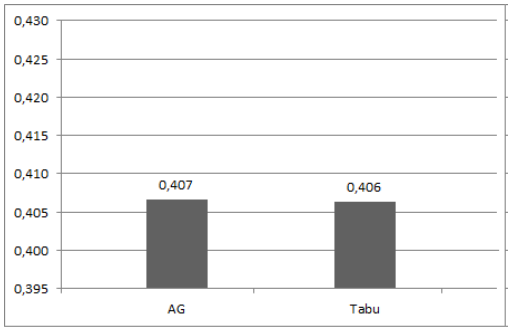

Figure 6: Ontology Structure.

5 CONCLUSIONS

This paper presented an architecture based on ontologies, software agents and metaheuristics applied to the multimedia service of the Brazilian Digital television System divided into two modules. The suggestion module, that suggests content to the users, and the content optimization module that has

the function to optimize the content that will be transmitted to the user.

Through the implementation and the experiments that were performed, is observed that it is possible attend the specified requirements. The experiments showed that the content suggestion was made according to the user's profile. The content optimization module that includes the metaheuristics GA and TS has obtained good solutions. The validation showed that the metaheuristics obtained results of good quality making it possible to obtain a fair distribution of available bandwidth on the multimedia application server.

In future works the application of the ontology for other topics will be extended. Will be included content that represent music shows, music genres like jazz, rock, pop, dance, among others. Also it will be developed a hybrid algorithm to perform the optimization and the obtained result will be compared to the current results of the Lingo software, GA and TS.

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