LSGENSYS - AN INTEGRATED SYSTEM FOR PATTERN RECOGNITION AND SUMMARISATION OF MULTI-BAND SATELLITE IMAGES

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Abstract: This paper presents a new system developed in Java® for pattern recognition and pattern summarisation in multi-band (RGB) satellite images. Patterns such as land, island, water body, river, fire in remote-sensed images are extracted and summarised in linguistic terms using fuzzy sets. Some elements of supervised classification are introduced in the system to assist in the development of linguistic summaries. Results of testing the system to analyse and summarise patterns in SPOT MS images and LANDSAT images are also discussed.

1 INTRODUCTION

The processes and techniques that comprise data mining, analyse raw data to discover implicit patterns that are useful for decision-making. Pattern recognition is another form of data mining because both concentrate on the extraction of information or relationships from data. A particular data mining technique may be successful with one type of multimedia such as images, but the same technique may not be well suited to many other types of multimedia due to varying structure and content.

A system that classifies and summarises patterns such as land, island, water body, river, and fire, was described in (Nair, 2004). The system utilised fuzzy logic to describe these patterns. (Nair, 2006) introduced some significant changes to the system. A few of these changes have been implemented in C.T.R.F.®'s LSGENSYS. LSGENSYS (Linguistic Summary Generation System) draws upon the earlier techniques of utilising fuzzy logic, but also adds a new significant element of user interaction via the blackboard architecture component (described in Section 2). This paper is organised as follows. Section 2 explains the architecture and design of the system. Section 3 explains the methodology and approach. Section 4 presents results of testing the system for image analysis, pattern recognition and summarisation on LANDSAT and SPOT MS satellite images. Section 5 presents the conclusions and future work.

2 SYSTEM ARCHITECTURE

LSGENSYS is an integrated system that allows the user to analyse images, extract feature descriptors such as area, length, location etc of patterns and then use these descriptors to form linguistic summaries of these patterns. This system also provides an interactive environment, wherein, the user may suggest some possible linguistic summaries for the image patterns. The system would evaluate the fitness of these user-summaries. Alternately, the system could, without user intervention, generate some possible summaries and evaluate their fitness and suitability with respect to the image patterns.

The system architecture is shown in Figure 1. The input image is analysed and some feature descriptors extracted. These descriptors are stored thereafter in a relational table in the database. The blackboard holds the current state in the process of developing summaries. This paper presents the system with the significant change where, presently, the user has the choice of suggesting concepts such as descriptions of area, length, location of patterns etc. The knowledge base uses geographic facts to define feature descriptors using fuzzy sets. It interacts with a built-in library of linguistic labels, which also

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interacts with the summariser as it supplies the necessary labels to it. The summariser receives input from these components and performs a comparison between actual feature descriptors of the image patterns stored in the database, the concepts suggested by the user, and the feature definitions stored in the knowledge base. After this comparison, the summariser uses the linguistic labels supplied by the library to formulate some possible summaries for each pattern/object in the database. These summaries are stored in the blackboard. From among these summaries, the most suitable one describing each pattern is selected by interaction with the engine (genetic algorithm). As the GA evolves through several generations, it generates better summaries (indicated by higher fitness, as defined in Section 4) which are then stored and indicated on the blackboard. Thus, the system has been improved and enhanced to include some elements of supervised classification and summarisation. The classification rules that classify land, island, water body, river, and fire are the same as in (Nair, 2006).

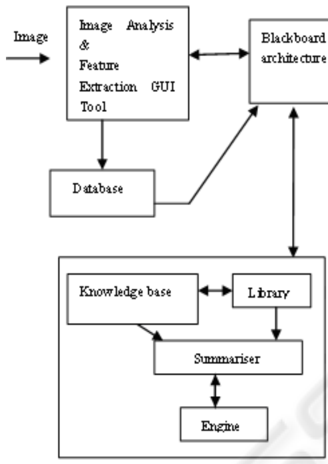

Figure 1: System architecture.

3 APPROACH

As in (Nair, 2006), area, length, location (X, Y pixel co-ordinates of centroid of pattern in image), Additional Information or Pattern Id, grey level intensity, are the attributes of the patterns/objects that are used to develop their linguistic summaries. These attributes are calculated/extracted automatically by the GUI tool. The linguistic summary of patterns/objects is evaluated as follows.

If $Y = y_1, y_2, ... y_p$ (1)

then

$truth(y_i isF)=\mu_F(y_i): i=1,2,...,p,$ (2)

where $\mu_F(y_i)$ is the degree of membership of y_i in the fuzzy set F and $0 \leq \mu_F(y_i) \leq 1$. The linguistic proposition y_i *is F* could be instantiated as for example, *River is relatively long*.

In order to generate such summaries, it is necessary to formulate fuzzy sets that quantify area/length attributes of the object/pattern. Triangular and trapezoidal fuzzy sets (totally twenty nine sets) have been formulated. The linguistic description is calculated as follows:

$$T_j = m_{1j} \wedge m_{2j} \wedge ... m_{nj} \quad , \qquad (3)$$

where m_{ij} is the matching degree (Kacprzyk, Ziolkowski, 1986) of the *ith* attribute in the *jth* tuple. $m_{ij} \in [0,1]$ is a measure of degree of membership of the *ith* attribute value in a fuzzy set denoted by a fuzzy label. The logical AND ($\wedge$) of matching degrees is calculated as the minimum of the matching degrees (Kacprzyk, Ziolkowski, 1986).

$$T = \sum_{j=1}^{k} T_j \quad \forall m_{ij} \neq 0, \qquad (4)$$

T in equation (4) is a numeric value that represents the truth of a possible set of summaries of the k objects in the database. The next section discusses how the GA evolves the most suitable linguistic summary for all the objects by maximising T.

4 IMPLEMENTATION ISSUES

This section explains the implementation of the system, including the genetic algorithm approach and then discusses the results from applying this approach to analysing images.

4.1 GA Approach

Biological evolutionary theories are emulated by the genetic algorithm (GA) as it attempts to solve optimisation problems (Filho et al., 1994), (Goodman, 1996), (Smith et al., 1994). Each binary chromosome string in a population represents a possible linguistic summary for a pattern. Such a population of strings is manipulated by selection, cross-over and mutation operators in the GA (Filho et al., 1994) such that as the GA evolves through several generations, only those strings with highest fitness survive. The evaluation or fitness function for the linguistic summaries or descriptions of all objects in the table is

$$f = max(T), \quad (5)$$

where T is evaluated as shown in the previous section.

4.2 Results and Discussion

Image objects/patterns are classified at the highest level into land, water or fire. Land is further classified into island and other land. Water is further classified into river and other water body. The fuzzy sets that quantify area or length are defined with reference to geographic facts such as:

- Largest continent is Asia with area of 44579000 km^2
- Largest freshwater lake is Lake Superior with area of 82103 km^2
- Smallest continent is Australia/Oceania with area of 7687000 km^2

In (6), the triangular fuzzy set for *considerably large expanse of water* is shown.

$$\mu_{\text{considerably large expanse of water}}(x) = \begin{cases} 1-(55068.66-x)/27034.33, & \text{for } 28034.33 \le x \le 55068.66 \\ 1-(x-55068.66)/27034.33, & \text{for } 55068.66 \le x \le 82103 \\ 0, & x < 28034.33 \\ 0, & x > 82103 \end{cases} \quad (6)$$

An example SPOT MS satellite image to be analysed is shown in Figure 2. Figure 2 shows the image analysis tool of the system as it extracts area and length attributes of three patterns in the image. These attributes are calculated and displayed in the data table in the figure. Pattern id attribute denotes numbers as follows: 0= River, 1=Water Body, 2=Island, 3=Land, 4=Fire. Location is indicated by X, Y pixel co-ordinates of centroid of pattern/object. For river, its length is the most significant attribute for calculation, whereas for all other patterns, area is the most significant attribute for calculation.

The user may choose, at this stage, to interact with the system and suggest some possible summaries. The system can evaluate the fitness of the user-summaries and inform the user if they are most suitable to describe the image patterns in the table. After the user chooses triangular fuzzy sets in the knowledge base, the system displays triangular fuzzy set definitions (lower-left window in Figure 3) in order to guide the user to select the appropriate fuzzy set for area or for length of different patterns such as land, island, water body, river etc. With the aid of these fuzzy set definitions, the user then constructs some possible pattern summaries as shown in Window 1. The fitness value (1.0) of these possible summaries is calculated and displayed in Window 1. Thereafter, the user may verify the correctness of these summaries and their suitability with respect to the image patterns by running the GA Inference Engine.

Figure 4 shows a snapshot of the GA Inference Engine as it runs (in the top left window) and evolves the most suitable summaries with higher fitness, over several generations.

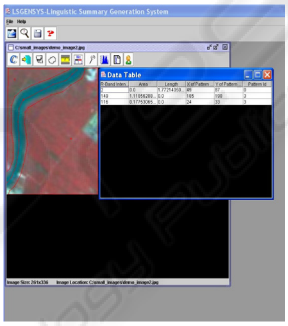

Figure 2: The image analysis tool of the system as it extracts area and length of patterns in a SPOT MS image. Approximate scale of image 1: 0.000019.

The summaries generated by the engine are captured in a text file as displayed in the top right window of Figure 4. The user may also chose to bypass the summary construction process, and directly invoke the inference engine (by pressing the Run button in Figure 3) to construct and generate the most suitable summaries. This would resemble unsupervised classification and description.

The GA is run with following input parameter set. These parameter values are set after several trial runs.

No: of bits in a chromosome string of the population = 10

Generations per cycle = 27

Population size = 200 strings

Probability of cross-over = 0.535

Probability of mutation = 0.001

After 216 generations, the linguistic summaries generated for the data in Table 1 are:

- A short river at the top left
- A small area of land at the top left
- A small area of land at the right

Thus, the possible summaries formulated by the user compare well with the summaries generated by the inference engine.

Figure 5 and Figure 6 show the same procedure as applied to a LANDSAT image. Table 2 shows the data calculated from the image patterns. In Figure 5, the system evaluates and displays the fitness of the summaries formulated by the user. In this case, the fitness value calculated is 0.778, which is considered by the system to be too low. Therefore, the system rejects the summaries and the user re-formulates some possible summaries as shown in Figure 6. The fitness of this set of summaries is higher at 0.888, and the system accepts this possible set of user summaries.

The GA Inference Engine is invoked by the user to verify and validate the suitability of the possible set of summaries. The resulting summaries from the inference engine are enumerated below. The GA is run with the same input parameter set as before, with the exception that cross-over probability is set to 0.538.

After 216 generations, the linguistic summaries generated for the data in Table 2 are:

- A small area of land at the top right
- A small area of land in the lower part
- A moderately large expanse of water at the centre.

These summaries match the user-formulated summaries in Figure 6.

The blackboard architecture component of the system has been implemented via the user interaction process. The sequence of windows such as Fuzzy Set Type selection window, Fuzzy Set Definitions window, Window 1, Run Inference Engine Window, and the Outpt window are programs integral to the blackboard architecture component. The Data Table and possible set of user-formulated summaries in Window 1 are part of the blackboard data structure. Control in the blackboard architecture directs the order in which the programs are invoked depending on the user-formulated summaries stored in the blackboard.

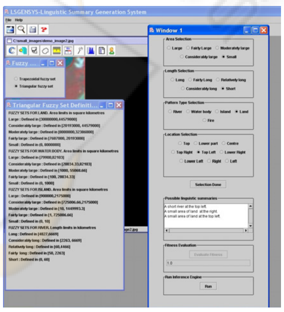

Figure 3: The user icon on the second horizontal menu bar is clicked in order to start the user interaction process.

Table 1: Data calculated from image in Figure 2.

R-band grey level	Approx Area	Approx Length	X	Y	Id
2	-	1.772	49	87	
149	1.1186	-	185	190	
116	0.1775	-	24	33	

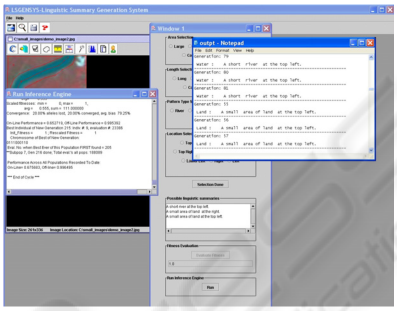

Figure 4: Snapshot of the GA Inference Engine as it runs and evolves the most suitable summaries that fit all the patterns extracted from the image.

5 CONCLUSIONS AND FUTURE WORK

This paper has presented a new system developed in Java for image analysis and pattern recognition in multi-band satellite images.

Table 2: Data calculated from image in Figure 5.

R-band grey level	Approx Area sq km	X	Y	Id
5	18979.83	88	71	1
91	2565.61	135	10	3
36	2317.14	97	133	3

The system architecture and design have been described. The system has been tested successfully with a SPOT MS image and a LANDSAT image and the results have been presented and discussed. Some directions of future work include: adding the provision to upload ground data in order to help classify more patterns such as vegetation in satellite images using supervised classification techniques, adding enhancements to image analysis functions, adding a scripting feature that allows the user to program a sequence of image analysis instructions in a user-friendly language.

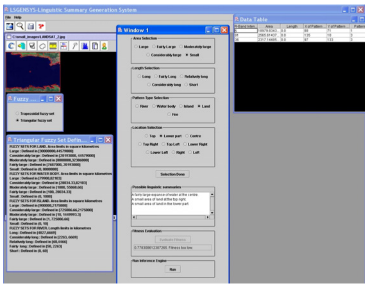

Figure 5: A LANDSAT image is analysed by the system and some possible summaries formulated by the user. Approximate scale of image is 1: 0.952 sq km.

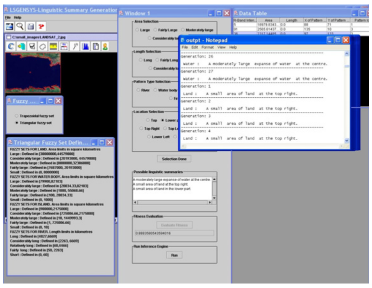

Figure 6: For the image in Figure 5, a different set of summaries as formulated by the user and fitness re-evaluated by the system.

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