

ROAD LINE SEGMENTATION FOR CARTOGRAPHIC GENERALIZATION: A WAVELET BASED PROCEDURE

José L. García Balboa (*); **Francisco J. Ariza López (*)**

(*) Grupo de Investigación en Ingeniería Cartográfica.
Dpto. de Ingeniería Cartográfica, Geodésica y Fotogrametría. Universidad de Jaén.
Campus "Las Lagunillas" s/n. 23071. Jaén (Spain).
e-mail: jlbalboa@ujaen.es. Tel.: (+34)953212844
e-mail: fjariza@ujaen.es. Tel: (+34)953212469

ABSTRACT

In automatic cartographic line generalization it is known that results depend on line type and properties. Line description and classification is an essential step prior to the decision-making process. Moreover, line characterization involves a segmentation task in different consecutive homogeneous sections, because each line could have a heterogeneous form and the description would not be applicable to all its length.

The possibility of using wavelets for cartographic line segmentation has been pointed out in Plazanet (1995) and in García and Ariza (2000). As a first approach, this work tests a method of line segmentation by applying different levels of wavelet filtering over a curvature representation of a set of lines. The method is simple to apply but intuitive. As a reference, the segmentation method presented in Plazanet (1995) is also applied, with encouraging results. Taking into account the sinuosity, directionality and granularity of the road lines, the proposed method seems to give a better location of the sections.

1. INTRODUCTION

In automatic line generalization it is known that the performance of any generalization operation depends on line type and properties. Therefore, line description and classification is an essential step in order to enrich data bases prior to decision-making. Moreover, this line characterization involves a segmentation task in homogeneous sections, because each line could have a heterogeneous form, and the description would not be applicable to all its length. The importance of this line segmentation has been underlined by different authors: Dutton (1999), Richardson and Mackaness (1999), Plazanet (1997), etc. Therefore, optimal segmentation and classification methodologies would be the first goals to achieve in order to adapt processes, algorithms and parameters to different line types, uses and scales.

The work presented is part of a large scheme (Ariza and García, 2004; Ariza, García and Reinoso, 2005; García, Ariza and López, 2005) that pursues the automatic segmentation and classification of road lines of a medium scale map (1:25.000 scale). This work is centred on the stage of automatic segmentation by means of a wavelet filtering. Wavelets are functions that satisfy certain mathematical requirements and are used to representing data or other functions (Graps, 1995), by means of a set of coefficients. The elimination of a subset of coefficients allows the employment of wavelets for data compression, and for this reason they have been employed in line generalization, for example by means of a curvature diagram simplification. Results of preliminary work on generalization by means of wavelets (Plazanet, 1995; García and Ariza, 1999, 2000) have pointed out that wavelets could be useful for line segmentation.

This paper summarizes a methodology for wavelet road line segmentation and shows results over a group of road lines from a map sheet. Contents are divided into three sections: i) methodology, describing all steps needed to perform the wavelet filtering and the section detection, ii) results, obtained from the analysis of the control parameters, applied over each road line of the sample and iii) general conclusions.

2. METHODOLOGY

This section is divided into three subsections. The first one presents, and solves in a simple way, the problem of the curvature computation in a polyline; the second subsection summarizes the process of a wavelet filtering of the length/curvature diagram, and the third subsection expounds a way of detecting critical points between consecutive sections in the simplified length/curvature diagram.

2.1. Curvature computation

The road line representation must be transformed into a length/curvature one. This representation is formed by two axes: a) the horizontal represents accumulated lengths from the beginning, along the curve, and the vertical b) the curvature evolution. In our case the road line is a polyline. There are several methods for obtaining the curvature from a polyline. A very simple method consists of adjusting circle arcs, and this can be called circle approximation for curvature estimation-

As an example, Figure 1 shows the absolute curvature distribution along a motorway, with vertical black lines for every kilometre. The minimum curvature value is 0, which matches the aligned points, the radius being infinite. Any value different to 0 comes from points from a curve, and the higher is this value, the smaller is the radius.

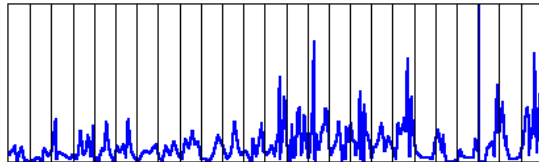


Figure 1 - Length/curvature diagram

2.2. Wavelet filtering

Wavelet theory is described in Graps (1995), Nievergelt (1999) or Goswami and Chan (1999). A short summary is also presented in García and Ariza (2000). Data wavelet filtering can be summarized as: data resampling, data codification in wavelet coefficients, elimination of high frequencies, and data reconstruction from wavelet coefficients. These consecutive steps are commented on below

a) Resampling of the curvature distribution

Wavelet representation needs 2^n initial values. It also needs an equally spaced distribution of sampled values. Of course, this is not the general case for polylines where the total number of vertices is any number and spaces between them are variable. Consequently, it is necessary to resample the polyline. A small resampling interval makes information lost negligible. For example, a value below the smallest length between any consecutive pairs of vertices of the polyline.

b) Wavelet decomposition

As soon as the 2^n samples of curvature have been obtained, the decomposition must be carried out. As a result, an average value of curvature and 2^{n-1} coefficients are obtained (see example in Figure 2).

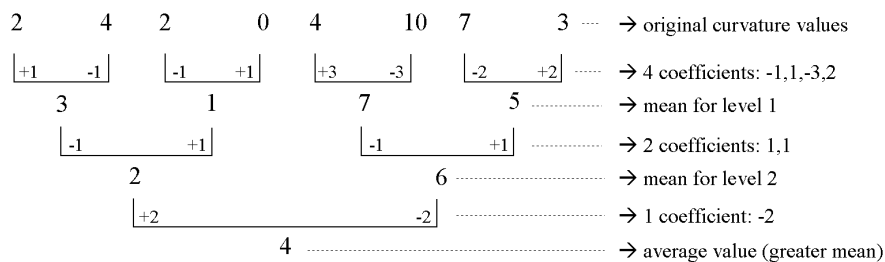


Figure 2 - 2^3 coefficients wavelet decomposition example

c) Arrangement and elimination of coefficients

Coefficient values are ordered in absolute value. A threshold is established, K , below which all the coefficients are set to 0. This threshold is a percentage obtained from the sum of squares of all the coefficients. The lowest values are eliminated until the sum of their squares reaches the threshold.

d) Reconstruction from the wavelet coefficients

As the highest frequencies have been eliminated, the reconstruction allows us to obtain a set of curvature values that are a simplified or filtered version of the original. Thus, length/curvature diagram is a function consisting of a series of constant curvature values, each of different length (from now on “curvature piece”). Figure 3 shows a length/curvature simplified diagram with $K = 40\%$, from the original diagram of Figure 3.

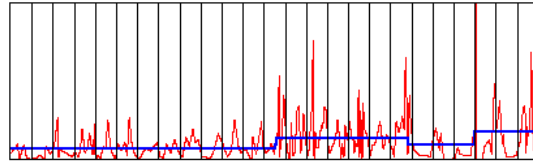


Figure 3 - Length/curvature simplified diagram

2.3. Sections detection

Once the filtered curvature diagram has been derived, sections detection is easier. One simple procedure is the selection of the longer curvature pieces, beginning and ending with critical points that mark a change between consecutive sections. Thus, an L parameter is established as a threshold. Given a series of curvature pieces, only those with length higher than L are considered in order to find critical points.

For example, watching Figure 3, any number of sections from 1 up to 4 could be derived. The number of curvature pieces is 4, but the L parameter allows us to choose only those pieces with a minimum length. Knowing that black vertical lines are spaced at 1 km, we can see that if L is 3 km or less there are 4 sections, if L is from 3 to 6 km there are 3 sections, if L is from 6 km to 12 km there are 2 sections and if L is 13 km or higher the whole road is a section (see Figure 4).

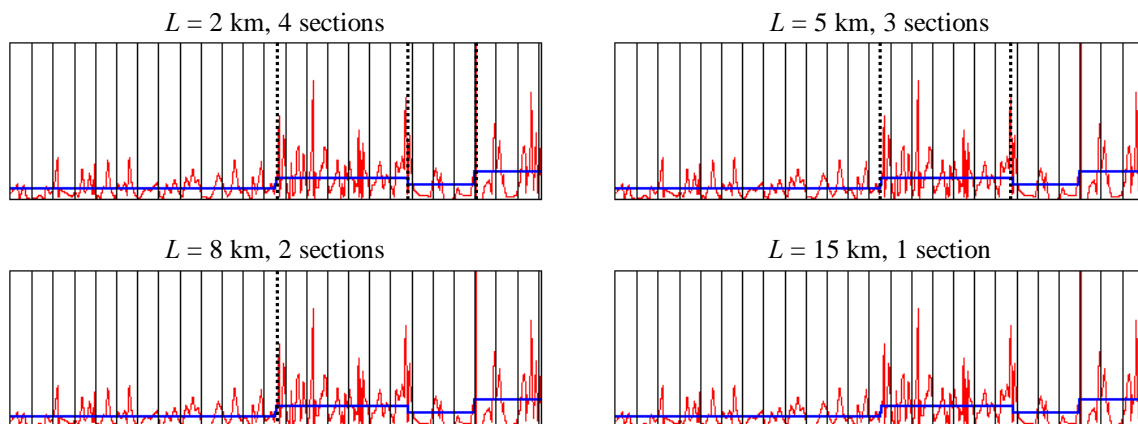


Figure 4 - Sections detection by means of L parameter

3. RESULTS

3.1. Parameters analysis

There are two parameters which control the wavelet segmentation process presented above: the percentage of loss of information K , and the section length threshold L . With K the intensity of the filtering performed over the length/curvature function can be adjusted. The higher the K value, the stronger the filtering, allowing a higher variability in the set of original curvature values that form a curvature piece.

Figure 5 shows a series of wavelet filterings of a length/curvature function, modifying K from 0% (no filtering) to 50% (when filtering results in a constant function). Wavelet filtering must allow the detection of different curvature behaviour of the road line, favouring section detection. In Figure 5, the existence of 4 sections when $K = 40\%$ is obvious. Therefore, a good election of the K value allows a immediate segmentation of the road line.

On the other hand, the parameter L fixes the minimum length of a section to be considered. Also with L parameter we avoid the situation where small local details of the road are considered as a section or divide a section into two consecutive sections. In short, with L the detail level of the segmentation process is fixed (see Figure 6), and furthermore the solution is more robust, because it is less probable that local details will change the final segmentation (see Figure 7).

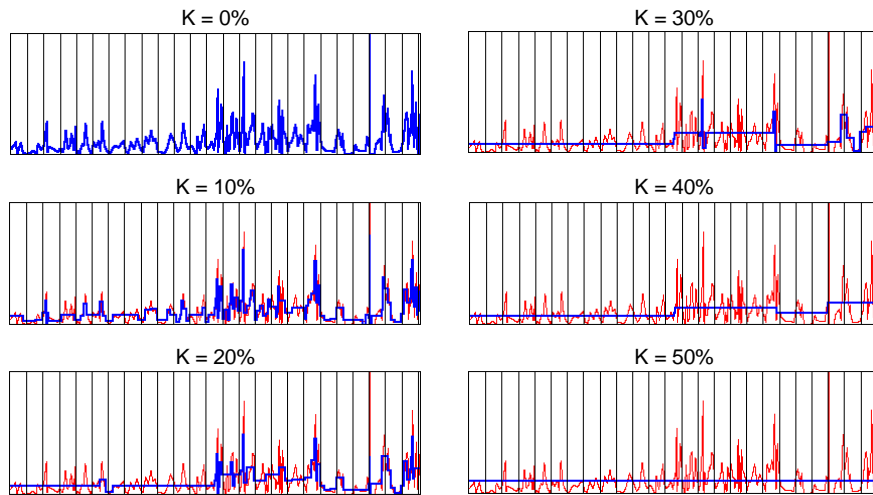


Figure 5 - Length/curvature diagrams of road A-44. Red is the original and blue the filtered diagram.

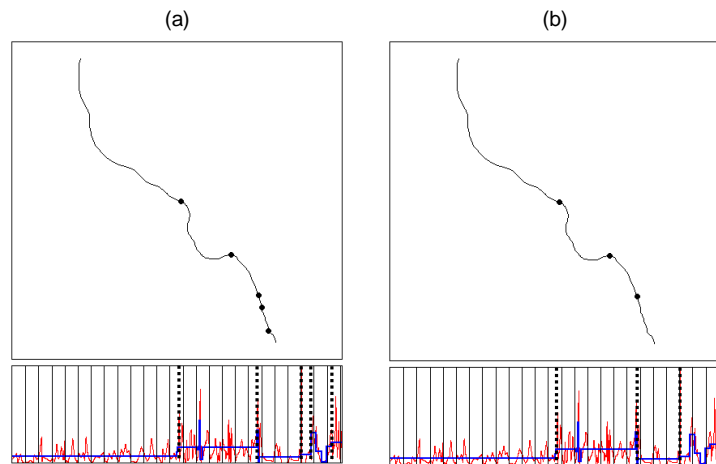


Figure 6 - Wavelet segmentation of road A-44, with $K = 30\%$ and $L = 500$ m (a) or 1000 m (b).

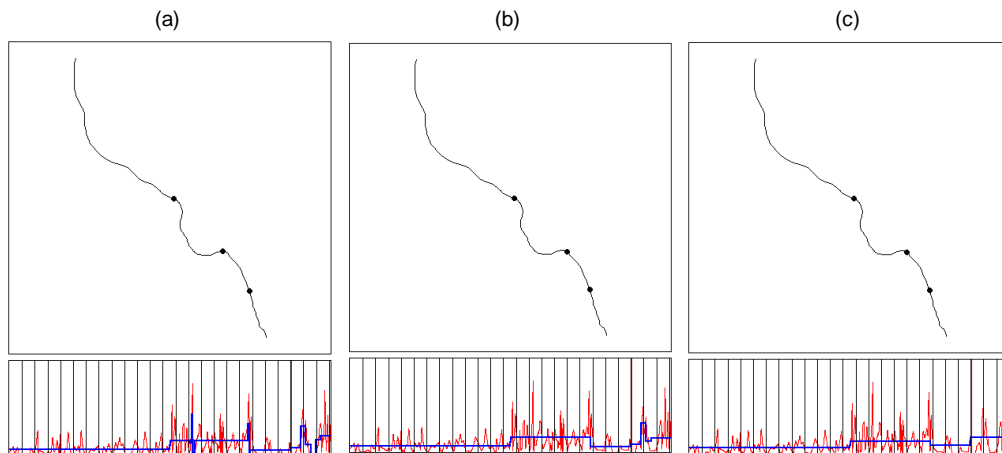


Figure 7 - Wavelet segmentation of road A-44, with $K = 30\%$ (a), 35% (b), 40% (c), and $L = 2000$ m.

The sample of road lines is the same as García, Ariza and López (2005). This work uses all tarmac road lines and tracks in the four 947 sheets of the MTN25 (Topographic National Map 1:25.000) with a length over 4 kilometres. Figure 8 summarise the selected sample.

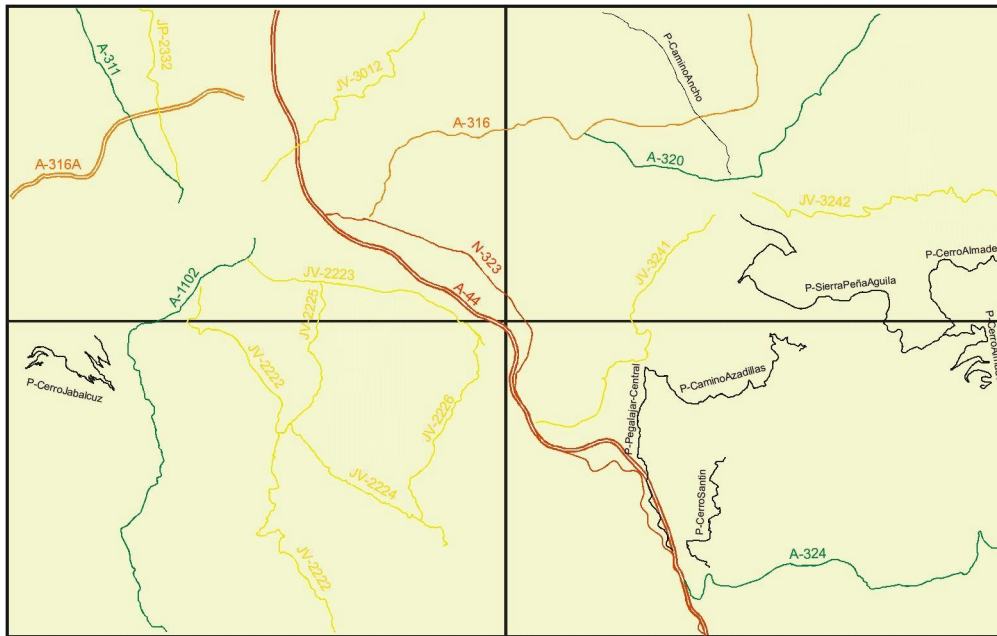


Figure 8 - Sample of road lines extracted from the 947 sheets of the MTN25 (Instituto Geográfico Nacional, 1996a, 1996b, 1996c, 1997).

Wavelet segmentation has been tested over all linear elements of the sample, searching for K and L values that provide a suitable solution. K has been modified in 5% steps from 30% to that value at which the length/curvature diagram is a constant function. L has been tested with 1000 and 2000 m. We have found that a lower value can give local details an excessive importance in the segmentation process.

Table 1 - Number of sections of each road line after wavelet filtering. In green the best solutions, in red the worst.

K (%)	L = 1000 m										L = 2000 m							
	30	35	40	45	50	55	60	65	70	30	35	40	45	50	55	60	65	
A-44	4	5	4	2	1	1	1	1	1	1	4	4	4	2	1	1	1	1
N-323	9	10	8	8	3	2	1	1	1	1	4	3	4	5	2	2	1	1
A-316A	3	4	3	2	2	1	1	1	1	1	3	3	3	2	2	1	1	1
A-316	5	5	4	5	4	3	2	1	1	1	2	2	4	4	3	3	2	1
A-311	2	3	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
A-320	5	4	4	3	4	3	1	1	1	1	1	3	4	3	3	1	1	1
A-324	3	3	2	4	4	4	4	2	1	1	3	3	2	2	3	3	3	2
A-1102	3	5	4	6	6	4	3	1	1	1	1	1	2	2	2	3	3	1
JV-2222	4	5	7	5	5	4	4	1	1	1	1	2	2	3	4	3	3	1
JV-2223	3	3	3	2	2	3	1	1	1	1	1	1	2	2	2	2	1	1
JV-2224	1	1	2	4	3	2	1	1	1	1	1	1	1	2	2	1	1	1
JV-2225	1	4	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1
JV-2226	3	3	3	3	3	3	2	1	1	1	1	1	1	1	1	2	2	1
JV-3012	3	3	6	6	4	3	1	1	1	1	2	2	2	3	1	1	1	1
JV-3241	4	4	5	5	4	4	3	3	1	2	2	2	2	4	3	3	3	3
JV-3242	5	4	4	3	3	3	2	1	1	1	1	1	2	3	2	2	2	1
JP-2332	2	2	2	2	2	2	3	3	1	2	2	2	2	2	2	2	2	2
P-CaminoAncho	3	3	3	3	3	3	3	3	2	1	1	2	2	2	2	2	2	1
P-CaminoAzadillas	2	3	4	3	3	3	4	1	1	1	1	3	3	3	3	3	3	1
P-CerroAlmadén	4	4	6	6	2	1	1	1	1	2	2	2	2	2	3	1	1	1
P-CerroJabalucz	3	5	5	5	5	1	1	1	1	1	1	2	2	3	1	1	1	1
P-CerroSantín	1	2	2	2	3	3	1	1	1	1	1	2	2	2	2	1	1	1
P-Pegalajar-Central	1	1	1	3	2	1	1	1	1	1	1	1	1	1	2	1	1	1
P-SierraPeñaDelÁguila	6	5	5	5	1	1	1	1	1	1	3	3	3	2	1	1	1	1

Table 1 summarizes the number of detected sections for each road line, K value and L value. The usual case (see line *JV-2224*) is that the number of sections first rises and then decreases (down to 1) when the K value rises. For McMaster (1993, 1995), people seem to judge a line shape attending to two criteria: directionality and sinuosity. Thus, a visual analysis has been performed on all the segmentation cases, observing whether the limit points between consecutive sections corresponded with a clear change in sinuosity. This has allowed us to mark the best solutions (in green) and the worst (in red) in the table. In this visual evaluation it is important to say that more heterogeneous lines are easier to evaluate; but when a more homogeneous line is difficult to be manually segmented, it is also difficult to evaluate the result of the automatic segmentation.

The results in Table 1 show that, in general, a 1000 m value for L is preferable to a 2000 m value. Only the smoothest lines, like those from the state or regional network, seem to work well with the 2000 m. value. Therefore, L is fixed in 2000 m for these lines and in 1000 m for the remaining (provincial network and tracks).

As for the K values that show more suitable solutions, these vary between 30% and 45%, 40% being the more frequent value. It is recommendable to opt for this value and modify it upwards or downwards if the solution is not satisfactory. However, the segmentation process is robust and in many road lines the result is the same for several consecutive K values. This is the case of lines *A-316*, *A-3166*, *JV-2223*, *JV-2226*, *JP-2332*, *P-CerroJabalruz*, etc.

Preliminary results of the wavelet segmentation method (see Figure 9) show intuitive solutions that are sensitive to the sinuosity, granularity, and directionality of the line, which is in accord with the usual visual judgement discussed by McMaster (1993, 1995). The method is simple in its operation but suitable for the purpose.

3.2. Plazanet's method comparison

Corinne Plazanet (Plazanet 1995, 1996, 1997; Plazanet *et al*, 1995, 1998) proposed a hierarchical segmentation method for a linear element, taking into account several analysis levels, trying to imitate the human perception of a line. This method has its starting point in the work of Bittenfield (1986, 1989, 1991) and in the artificial vision work of Mokhtarian and Mackworth (1986, 1992), who put the suggestion of a multiscale description of a line according to the curvature.

Plazanet carried out a specific proposal for a preliminary global segmentation of a line, that is, for a global segmentation. She proposed a homogeneity definition based on the maintenance of the distance between consecutive inflection points. Starting with a binarization (value is 1 for distances higher than the mean and 0 for smaller ones) the runs of this binarization point to the sections detected. A hierarchy is supposed for the inflection points, related to the prior smoothing. Thus the smoothing parameter (sigma in a gaussian filtering) controls the segmentation process.

In this work inflection point segmentation procedure has been applied, in order to perform a comparison with our method. The sigma parameter has been modified in order to obtain the same number of sections, or the most similar possible. As Plazanet's method searches section changes in the set of principal inflection points of the line, differences are expected because our method does not constrain that search to any subset of points of the line.

Figure 9 shows different examples of global road segmentation, both by means of our wavelet proposed method and by Plazanet's inflection point detection method. In general, it can be said that wavelet segmentation allows a better adjustment of the section change location, that is, this location is nearer to the change in line sinuosity or granularity. This can be observed in lines *A-44*, *A-320*, *JV-2226*, *P-CaminoAzadillas* or *P-SierraPeñaÁguila*. However, a similar result can be found in line *A-324*, and in lines *JV-3241* and *P-CerroJabalruz* it is difficult to choose the better solution. Therefore, results for the wavelet segmentation procedure are encouraging enough to continue the research with a refinement of the method.

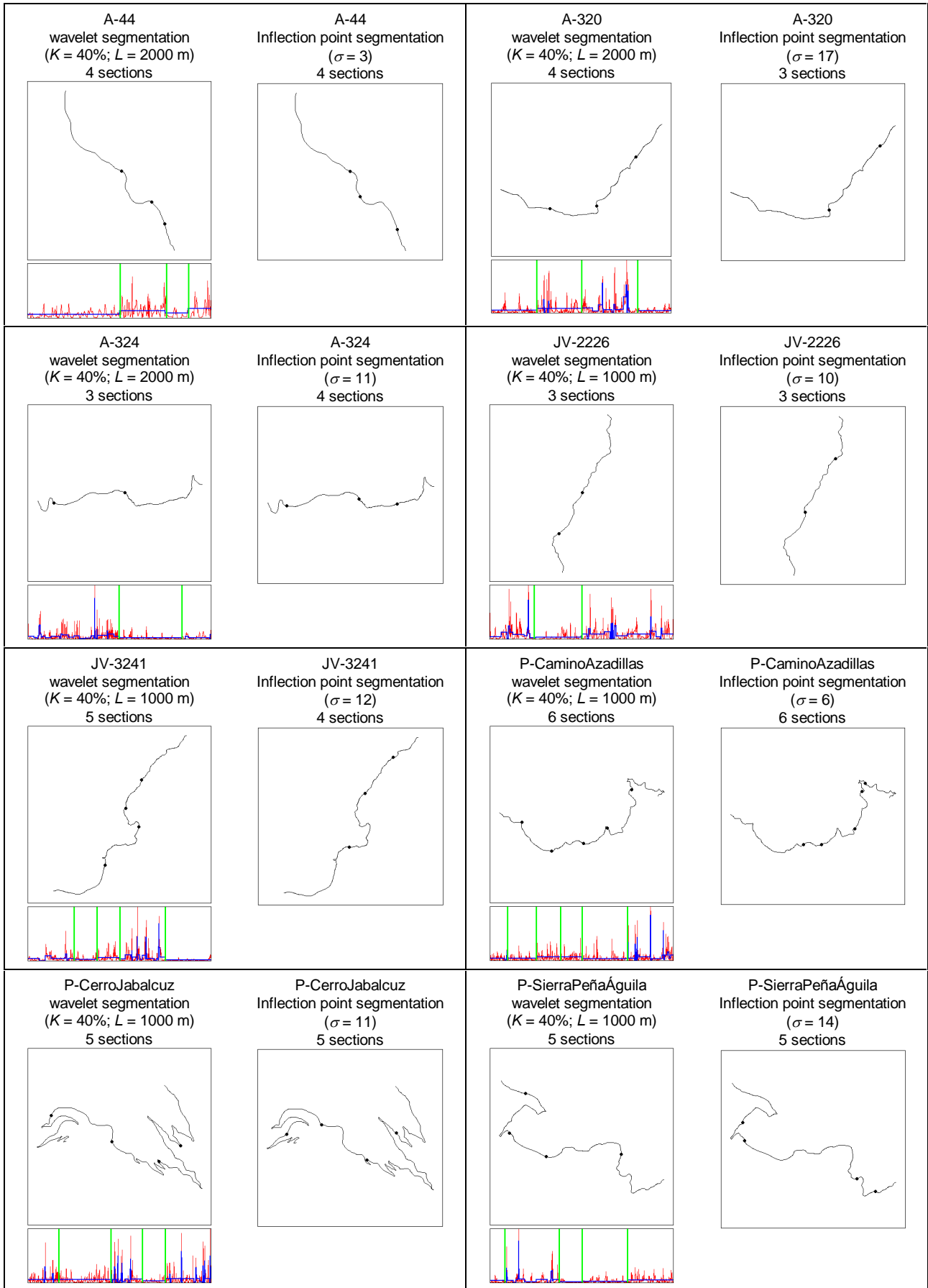


Figure 9 - Segmentation examples with wavelet filtering and Plazanet's inflection points detection.

4. CONCLUSIONS

The segmentation of curves is one of the more interesting aspects of automatic generalization because it is supposed that a good segmentation facilitates the adaptation of generalization algorithms (or its controlling parameter) to each section of a curve.

In this work we have obtained preliminary results from wavelet based segmentation. Wavelet filtering is applied over the curvature distribution of a road line. The method presented here is simple in its operation, but robust, suitable for the purpose and intuitive. Visual analysis of results seems to be quite encouraging for the continuation of this work. Our results have been compared with those obtained by the segmentation method proposed by Plazanet. In general, section change location is better with the wavelet segmentation procedure.

In future modifications and improvements of the method, new rules for segmentation detection are to be introduced. Also a bidimensional wavelet can be tested.

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