Watermarking of Polygonal Lines

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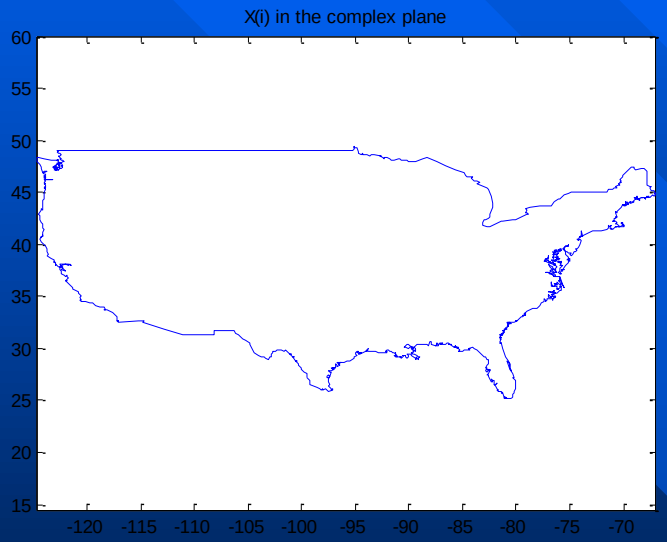
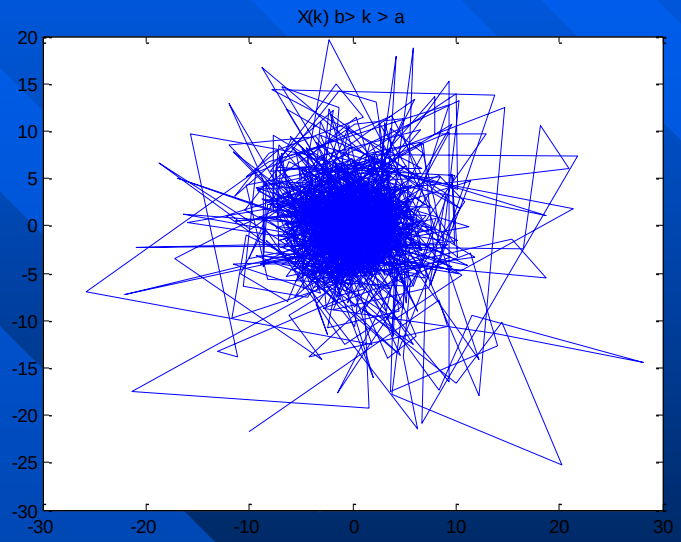
Introduction

- Polygonal line: sequence of vertices defining a polygon
- Polygonal lines in: GIS data, cartoons, segmented images (from video), CAD, general vectorial graphics
- Robust watermark system using Fourier descriptors

Watermark Embedding: 1

- Fourier descriptors: Fourier coefficients of the polygon considered as a function in the complex plane
- Sample: 1. USA 2. USA in the Fourier domain





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Watermark Embedding: 2

Watermark:

- Spread spectrum techniques
- W(k) A pseudorandom signal, generated with an integer key
- W(k) takes values of ±1 randomly, N length
- Watermark is multiplicative: $|X'(k)|=|X(k)|\ (1+pW(k))$
- Watermark is only embedded in medium frequencies

Watermark Detection: Correlator

- Correlation is calculated: $C=\Sigma |X'(k)|W(k)$
- Random variable with 0 mean if no key or wrong key provided
- Compared against a threshold
- For big N, it performs well (central limit theorem applies)

Watermark Detection: Optimal

- Signal Im and Re parts considered to be independent gaussian processes: Modulus amplitudes follows a Rayleigh distribution

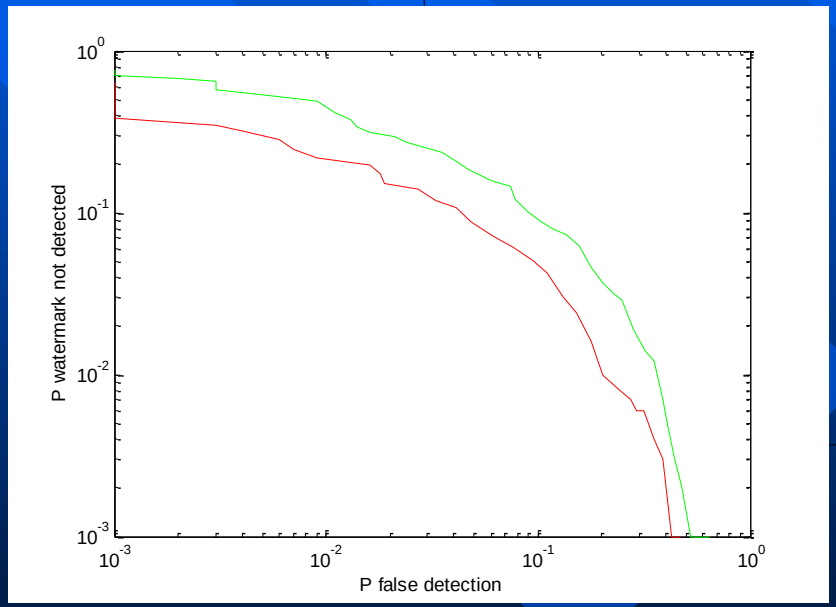
- Every sample is expected to have a value according to the watermark for that point, different if watermark not present.

- Likelihood for every sample is considered.

- Better results than the correlator, but slower

Watermark Detection: Comparison

- Correlator is faster but has higher error probability
- Example for a very small embedding power (0.1)
- In the ROC shown, correlator in green, optimal in red



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Watermark Detection: Improvements

- Non-idealities happen in real life data.

- Variance is not stationary along the spectrum. Improvements have to be done in the variance estimation.

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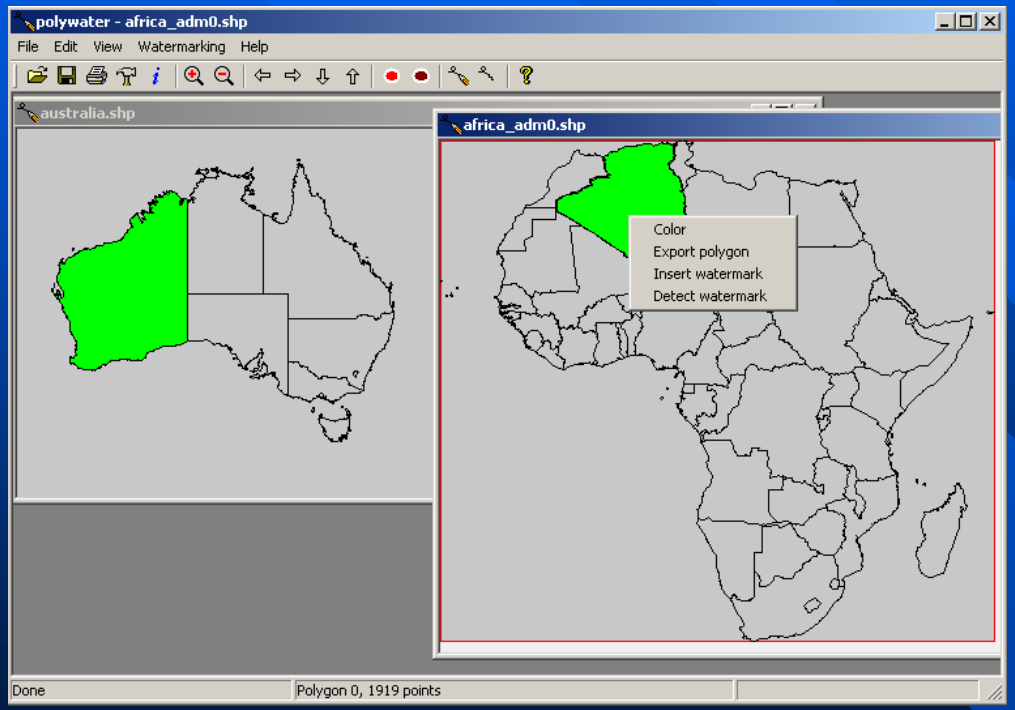
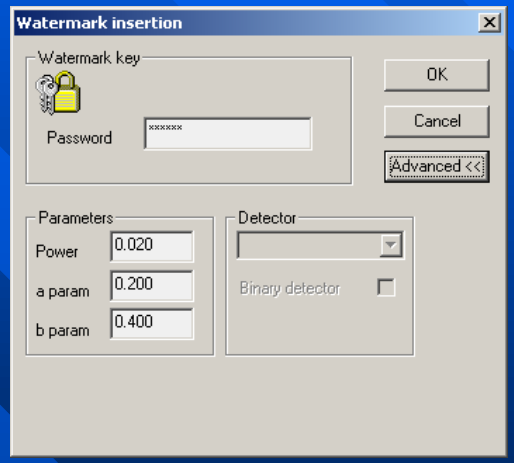
Practical work: PolyWater

- Reads ESRI's shapefile format GIS data
- Extracts polygons and applies/read watermarks





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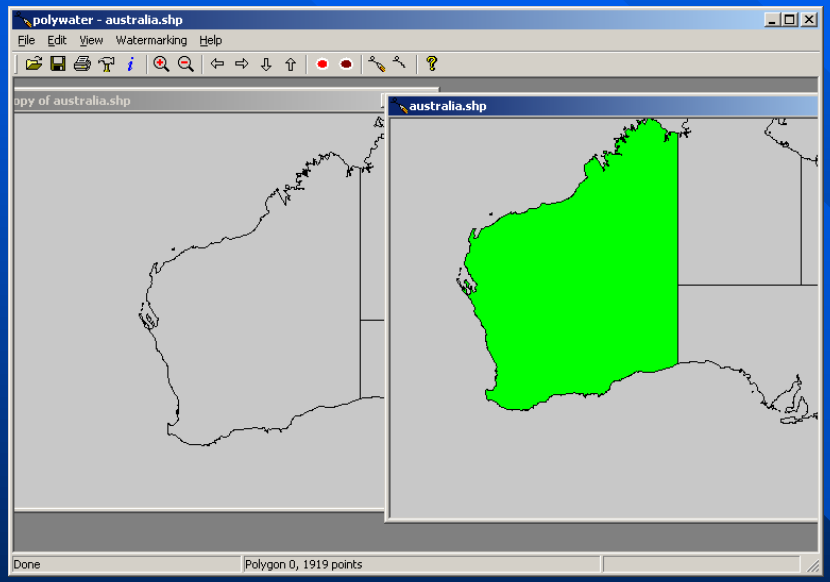
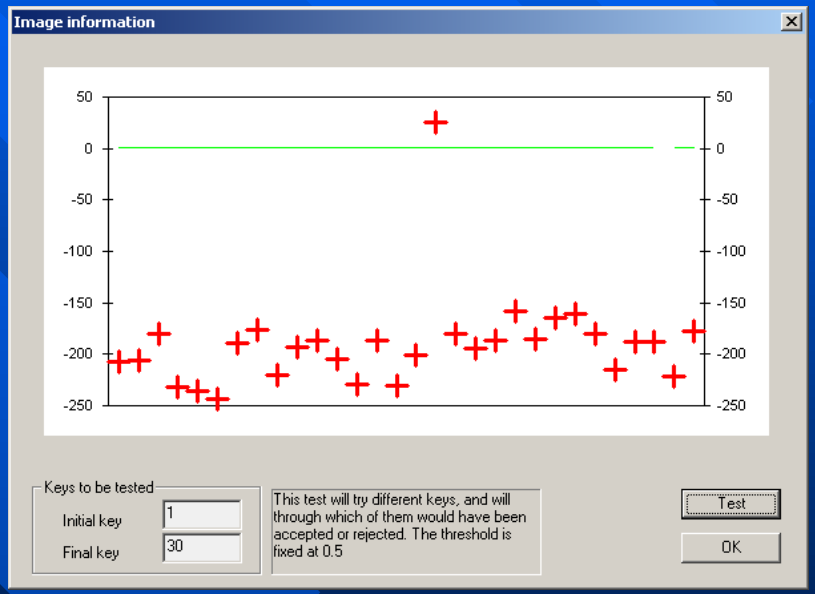
Practical work: sample

- 1. Original and watermarked polygon: very small difference
- 2. Rigth vs. wrong keys test: clear detection





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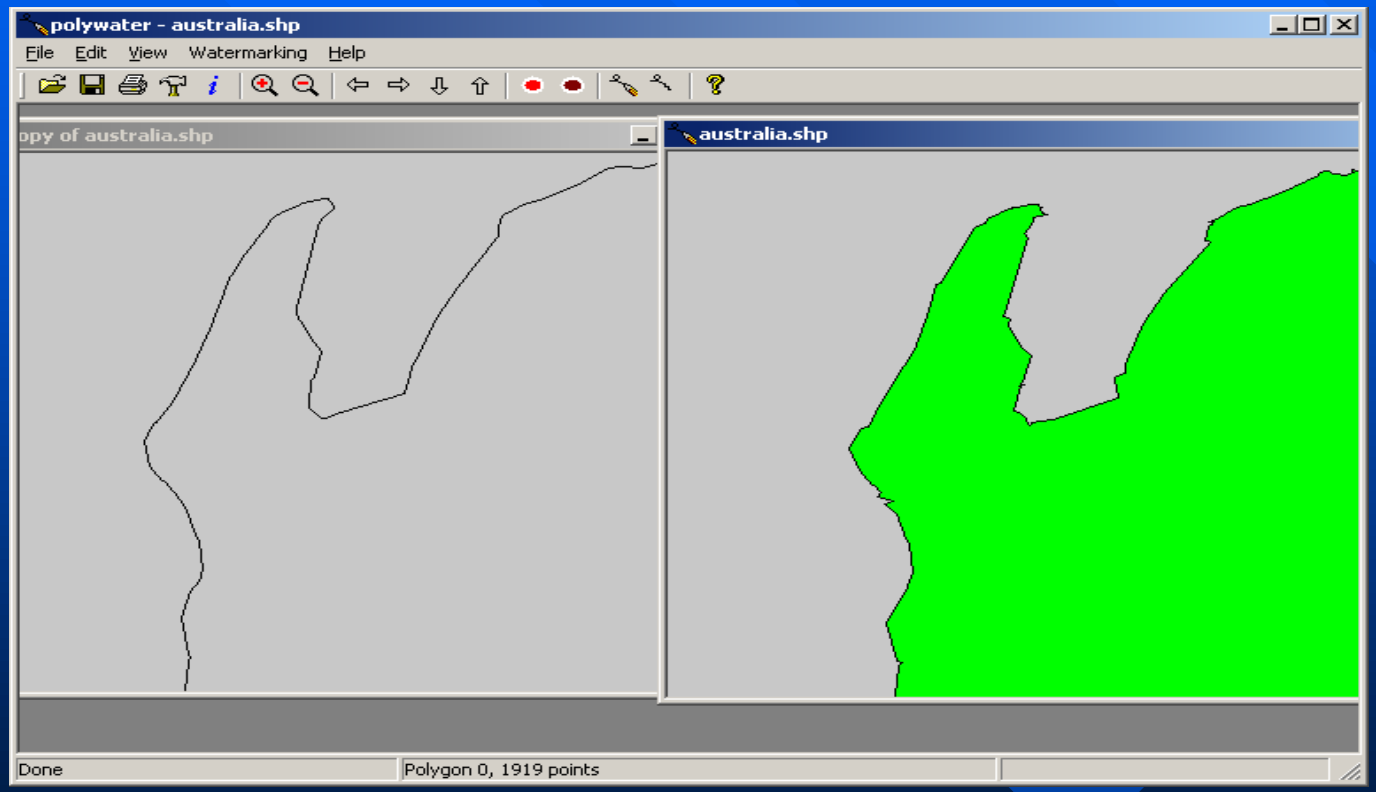
Practical work: sample (2)

- 1. Slight differences are visible when zooming in.



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Conclusion

- Watermark for polygons robust against attacks
- Good performance for N > 1000 points
- When multiple contours, fusion techniques have to be developed to avoid mismatching between borders

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