FRT Ghosts for watermarking

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Acknowledgements and apologies

Acknowledgements :

- Imants Svalbe ;
- Nicolas Normand.

Apologies :

- Poor English level on those slides ;
- maybe some over-simplifications ... ;
- ... and some inaccuracies.

That being said ...

Plan

Correlation based watermarking

Objectives :

- Hide a mark in an image... ;
- ...with minimal image modification... ;
- ...that can be detected easily using correlation.

Here :

- **Mark** : binary ghost / pseudo-noised perfect arrays ;
- **Watermarking** : simple addition between motif and mark ;
- **Detection** : correlation peak between watermarked image and motif.

What is a good mark ? 2 properties :

- **Good auto-correlation** properties, for detection ;
- **Weak cross-correlation** with other marks to avoid false positive.

Plan

Ghosts

A ghost is a geometrical array that is 'invisible' along some angles

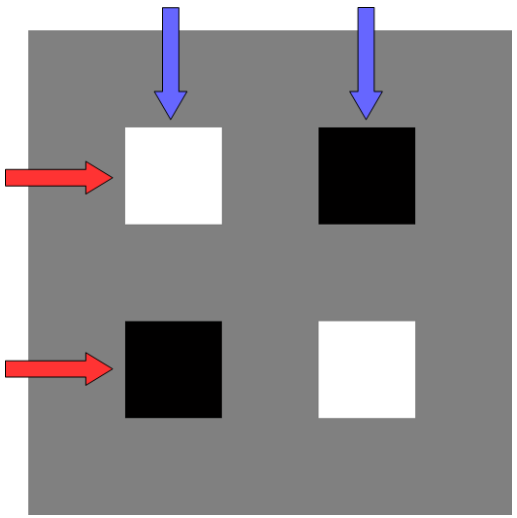


Figure: Ghost example
white$= 1$
black$= -1$
grey$= 0$

Ghosts presented here are of size $p \times p$ with p prime

Ghosts correlation

Main interests of ghosts (here) :

- Made with weak values [-1, 0, 1] $\rightarrow$ small image change ;
- good auto-correlation.

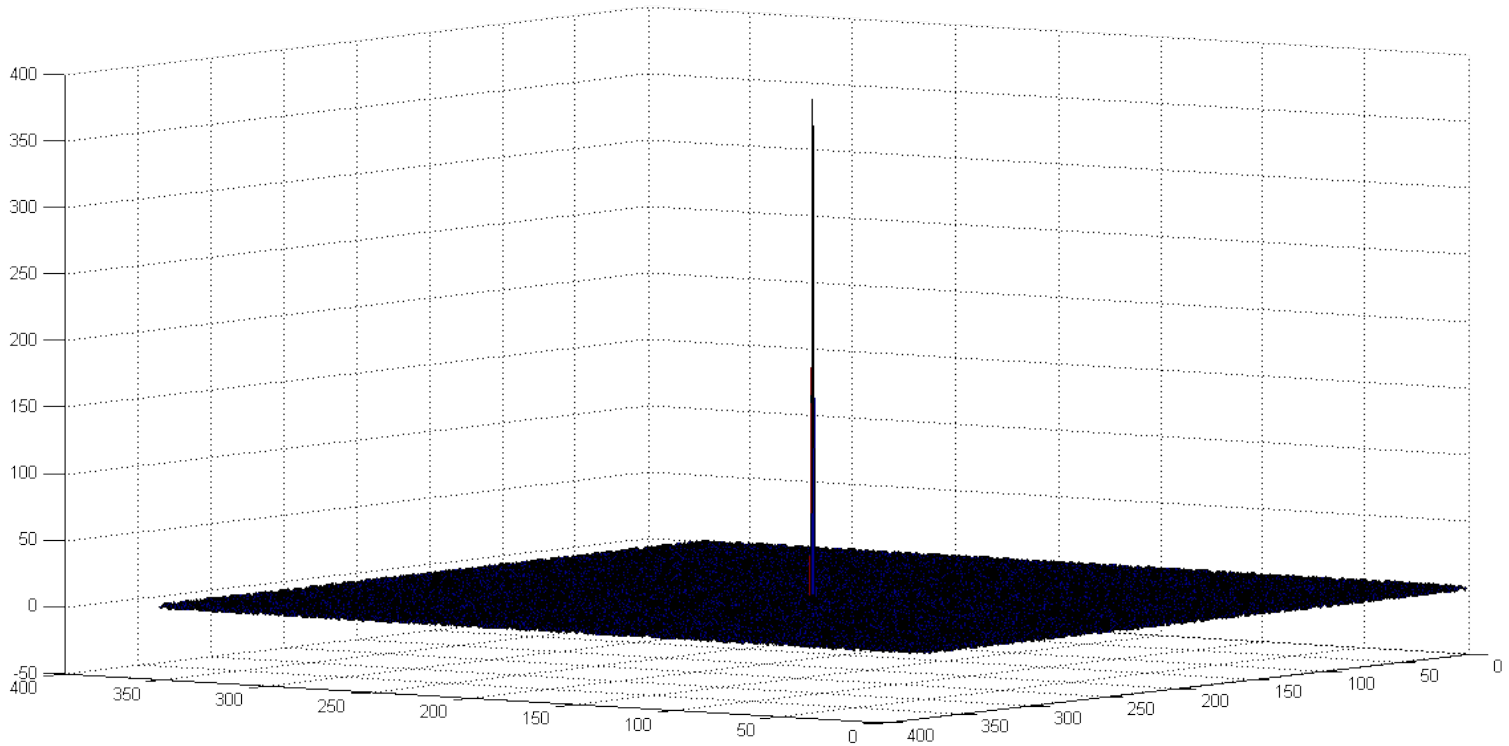
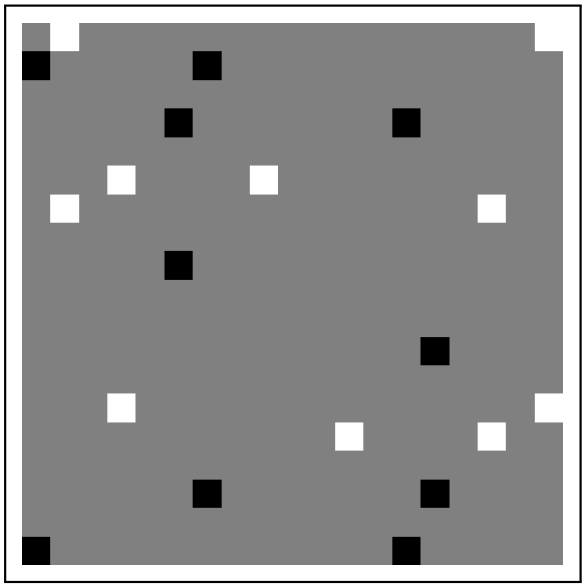


Figure: 373*373 ghost auto-correlation

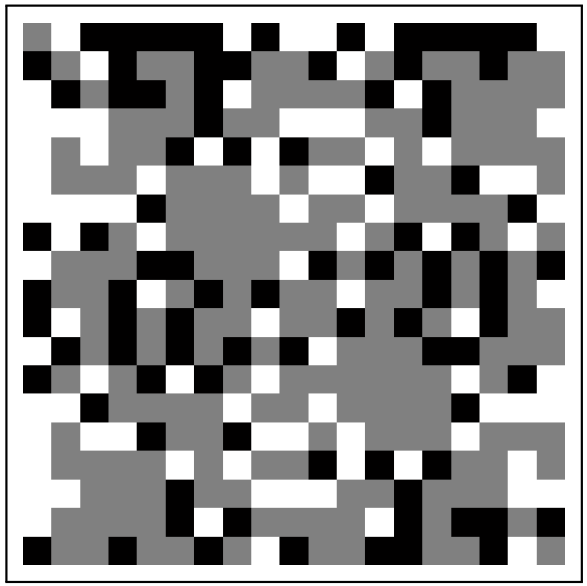
Minimal and compounds ghosts

Minimal ghost : ghost that is invisible along n angles with $n \times 2$ points

Compound ghost : duplication of a minimal ghost in order to obtain a new motif

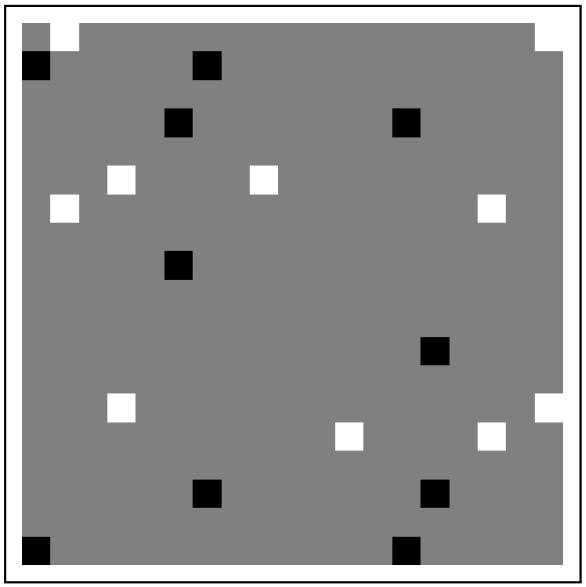


(a) Minimal ghost

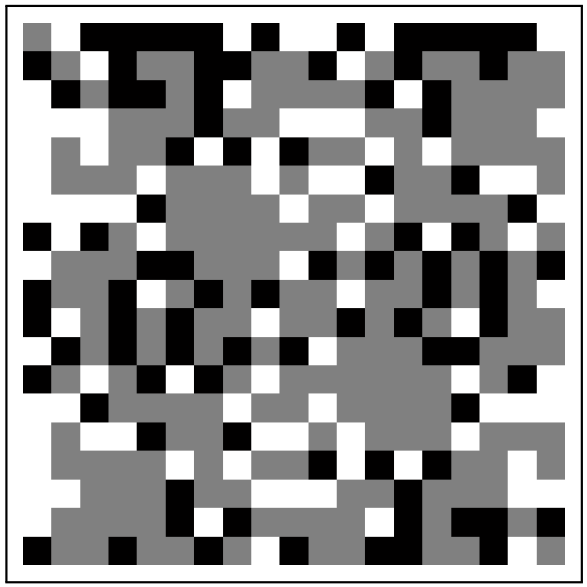


(b) Compound ghost

Why do we use compound ghosts ?



(a) Minimal ghost

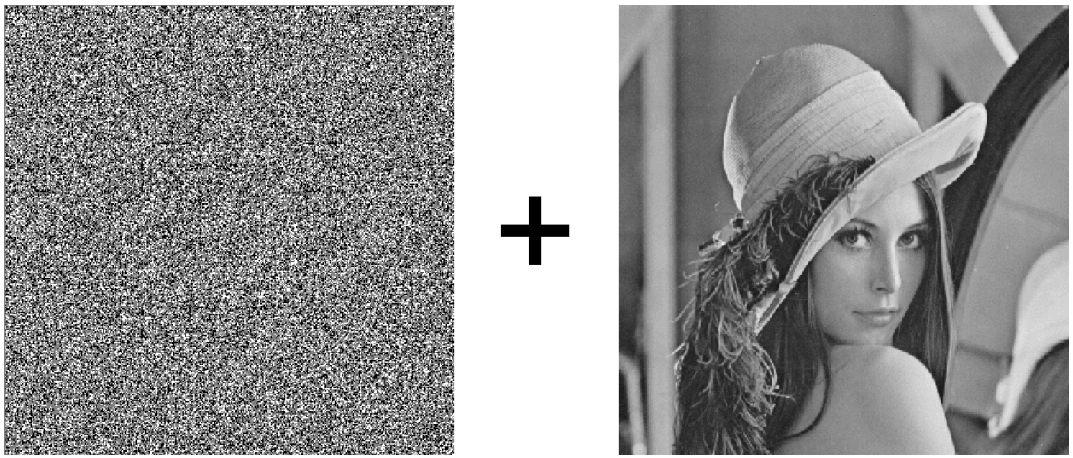


(b) Compound ghost

Worse theoretical auto-correlation
but better detection one embedded in an image

Plan

Insertion

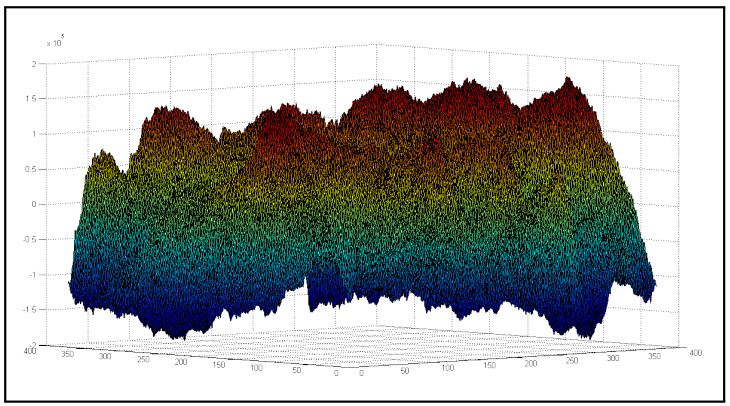


(a) Marking by simple addition

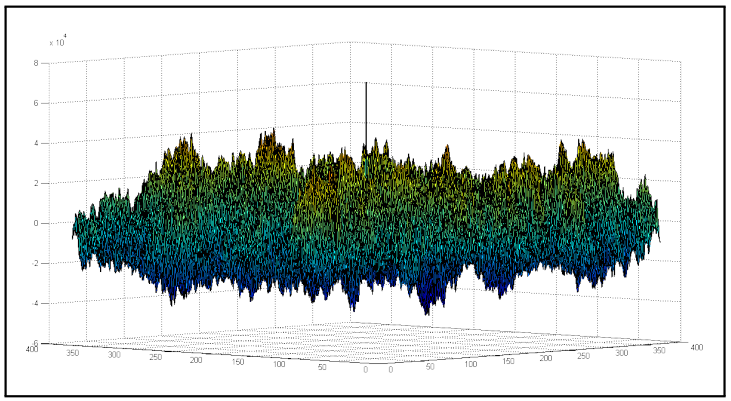
(b) Watermarked image

Extraction

By looking for a peak in correlation between watermarked image and mark



(a) No possible extraction



(b) Possible extraction

Decision could use a threshold (peak to second peak ratio, merit factor, ...)

Plan

Zero cross-correlation

It's possible to generate odd and even symmetry ghosts with zero cross-correlation (i.e. 0 everywhere)

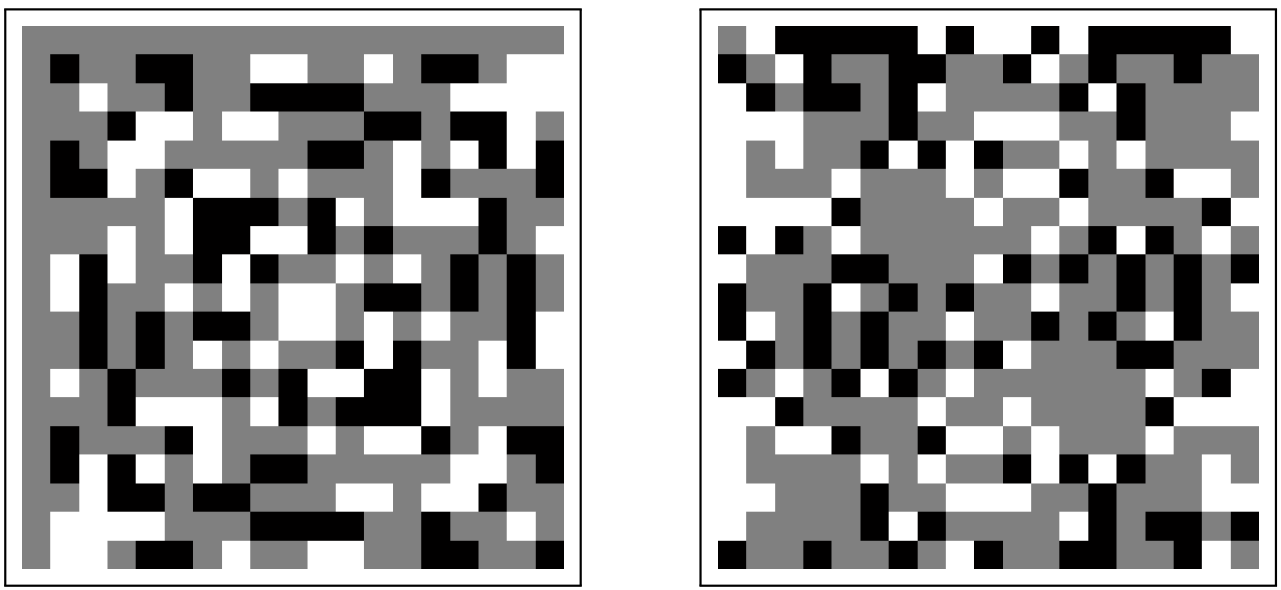


Figure: Two ghosts that have zero-cross correlation

Merging without overlapping

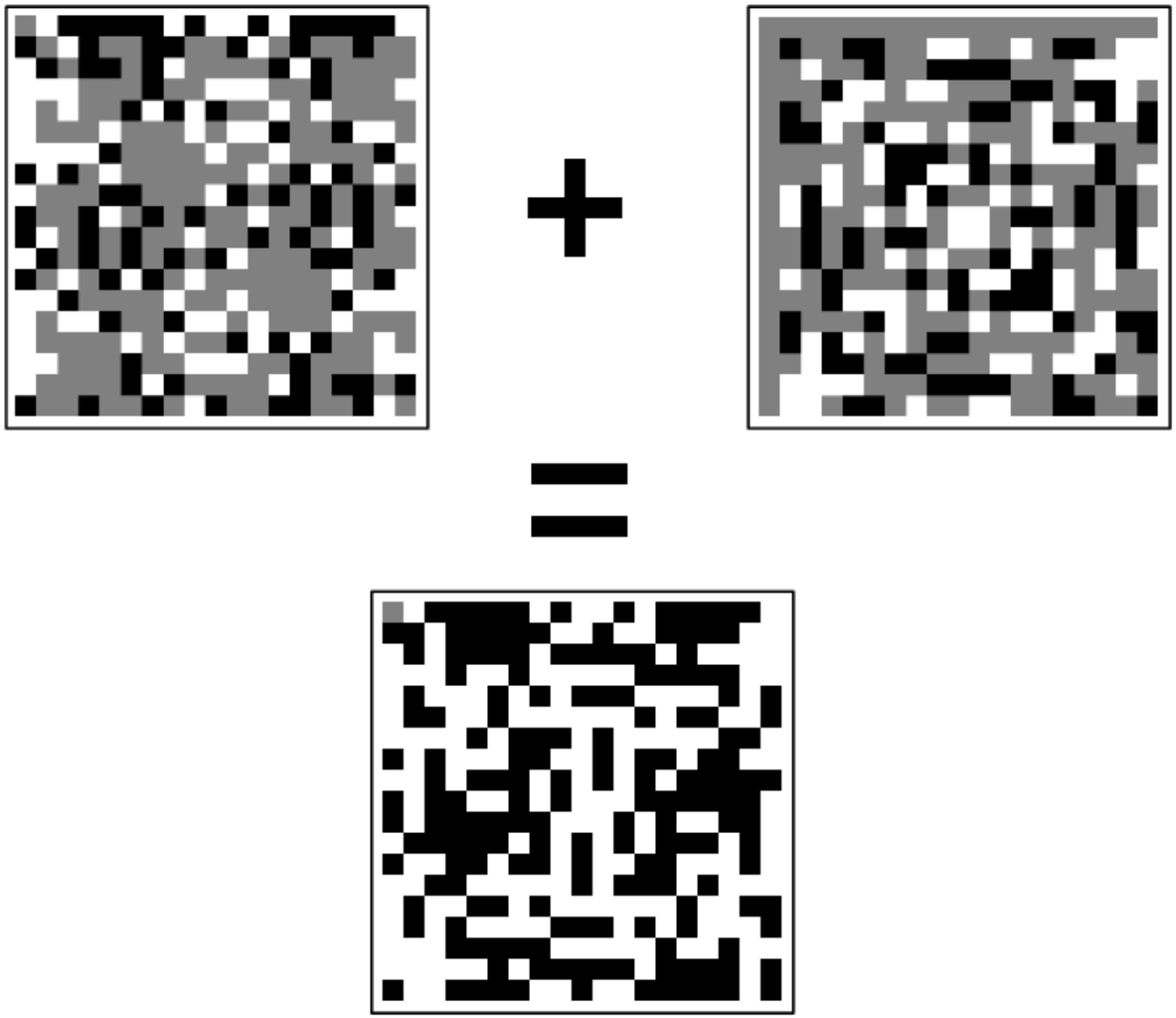


Figure: Merged ghosts : no overlapping !

Practical application : double watermark

Consequence of two previous points : possible to add two mark in a single image

$\rightarrow$ every mark can be detected as if it was alone

Plan

By shifting previous array in a particular way, it's possible to obtain pseudo-noised perfect arrays

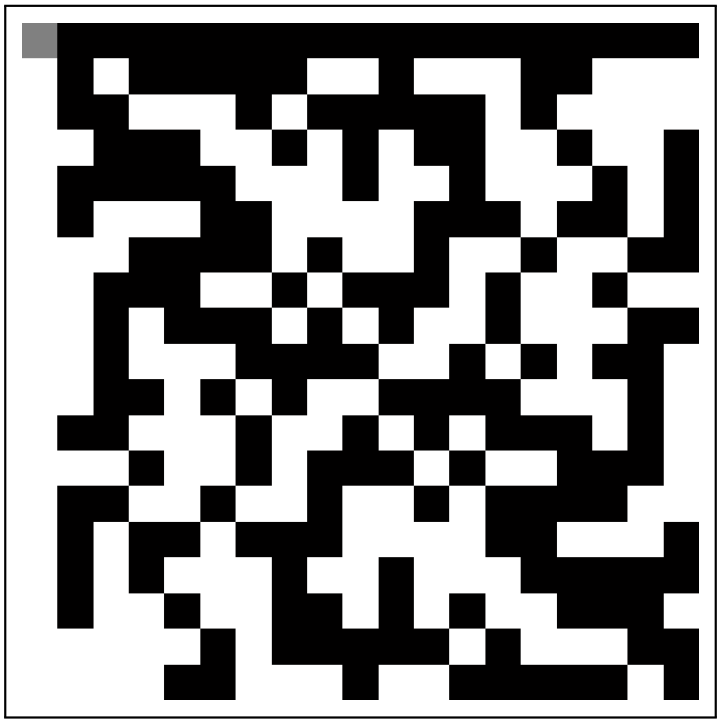
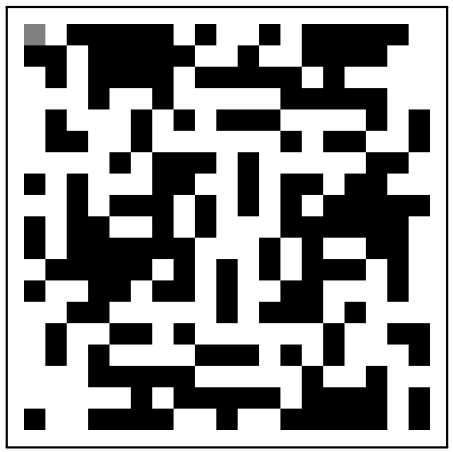


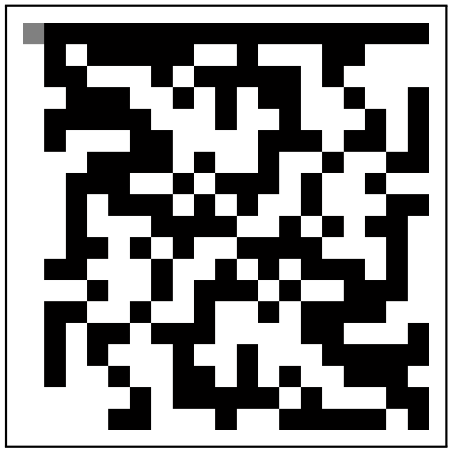
Figure: 19×19 pseudo noised perfect array

Pseudo-noised perfect arrays

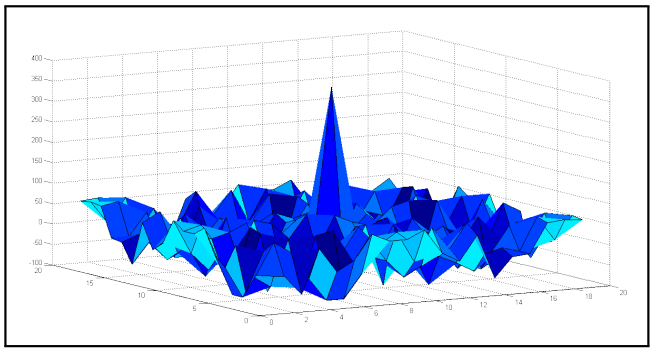
Pseudo-noised perfect sequences have superior auto-correlation properties

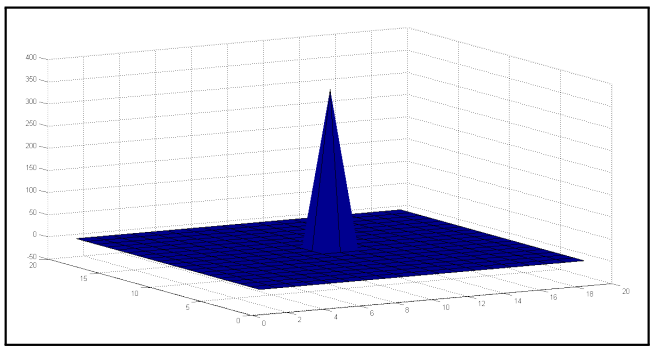


(a) 'Classic' compound ghost



(b) Pseudo-noised perfect arrays





Pseudo-noised perfect array vs ghosts

- Auto-correlation is better than for ghosts ;
- a simple generation method exists ;
- many $(C^{p+1}_{(p+1)/2})$ possibilities for $p * p$ sequences.

Plan

Cross-correlation of pseudo-noised perfect arrays

There is few cross-correlation patterns between pseudo-noised perfect arrays of size p
On of these patterns is very interseting

7	-7	-7	7	7	-7	-7
-7	7	-7	7	-7	-7	7
-7	7	7	7	-7	-7	-7
7	7	7	0	7	7	7
-7	-7	-7	7	7	7	-7
7	-7	-7	7	-7	7	-7
-7	-7	7	7	-7	-7	7

Figure: Cross correlation of two 7×7 pseudo-noised perfect arrays 'best case'

No peak at all : no false positive risk

Cliques

Cliques are sets of pseudo-noised perfect arrays with this good cross-correlation pattern

Maximum clique size seems to be p for $p \times p$ arrays

$\rightarrow$ for 373×373 pseudo-noised perfect arrays, it's possible to find sets of 373 of those arrays with this good cross-correlation pattern !

Plan

Conclusion

We achieved arrays with the two needed properties for correlation based watermarking

- **Good auto-correlation** : using ghosts, and pseudo-nosed perfect arrays ;
- **Poor cross-correlation** : with cliques.

Moreover we found zero-cross correlation arrays, allowing us to mark images twice.

Thank you for your attention !

Any question ?