Research Project and Seminar

Informatik-Ingenieurwesen

Orthogonal Codes for Acoustic UnderwaterLocalization

by

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Acknowledgment

This is the place to thank all the people involved with your thesis / project. Examples would be your family, friends, and of course your supervisor. The acknowledgement will not have any influence on your grade; however, we think it is good style to have an acknowledgement in your thesis.

Abstract

The abstract of your thesis goes here. There may be formal requirements on it that can be found in the corresponding examination guidelines (Prüfungsordnung). If there are none, ask your supervisor. As a rule of thumb, the abstract should be concise and focused. It is not a shortened introduction to your work. We also suggest that—if an abstract is not required—only write one if it is really well done.

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List of Symbols

$\mathbb{N}, \mathbb{Z}, \mathbb{Q}, \mathbb{R}, \mathbb{C}$	Regular sets of numbers
$\mathcal{NP}, \mathcal{P}$	Complexity classes
$\mathcal{V} = \{v_0, \ldots, v_{N-1}\}$	Set of N nodes v_i belonging to a network with sink v_0
ϱ	Node density, i.e., the average number of nodes within another node's communication range
$(v_i, v_j) \in \mathcal{E}$	Set of bidirectional communication links in the network
$G = (\mathcal{V}, \mathcal{E})$	Graph representation of a wireless sensor network
$\mathcal{N}_i = \{v_j \in \mathcal{V} \mid i \neq j \wedge (v_i, v_j) \in \mathcal{E}\}$	The set of bidirectional communication partners of node v_i
$\mathcal{T} \subseteq \mathcal{E}, \quad \lvert\mathcal{T}\rvert = N-1$	Routing tree rooted in the sink
$\mathcal{T}_i$	Subtree rooted in (and including) node v_i
$\mathcal{C}_i, \quad C_i = \lvert\mathcal{C}_i\rvert$	The set and number of children of node v_i in $\mathcal{T}$
$\mathcal{F} = \{v_i \in \mathcal{V} \mid \mathcal{C}_i = \emptyset\}$	Set of leafs in $\mathcal{T}$ and the number of leafs
$\mathcal{F}_i$	Set of leafs in the subtree $\mathcal{T}_i$ of $\mathcal{T}$

List of Symbols

Chapter 1

PN and orthogonal sequences

There are two main goals need to be pursued for receiving higher localization accuracy.

First the code which is used for the under water localization needs its auto-correlation approaching a Dirac impulse. Thus one get advantageous detection capabilities.

The next factor are cross-correlation properties, which should meet certain criteria for improving the separation from other sequences. These will come in handy if noise, reflections and other artifacts emerge.

1.1 Pseudo-random codes

There are a couple of principles to generate PN sequences. Most of these methods use linear feedback shift registers to generate the codes by an initial condition. In this project I will concertize my research on gold codes, Kasami-Codes and the classical m-sequences which are also used for generating gold codes.

M-sequences are binary PN codes, which are generated by linear shift registers with feedback. The sequences are periodic and contain the same number of zeros and ones [PS08]. M-sequences need to fulfill certain criteria. First its length is defined by $N = 2^n - 1$ where n is the maximum degree of the generator polynomial $f(X)$ [SP80]. Second the cross-correlation between m-sequences needs to take three values only, which are $-1, -t(n), t(n) - 2$. With it $t(n)$ is defined by $1 + 2^{\lfloor 0.5(n+2) \rfloor}$ [SP80]. If every pair of m-sequences is a preferred pair, they form a maximal connected set and these sets have a limited cardinality. Experiments from Gold and Koptizke showed that the number of such connected pairs is limited. Between degrees

[GK65].

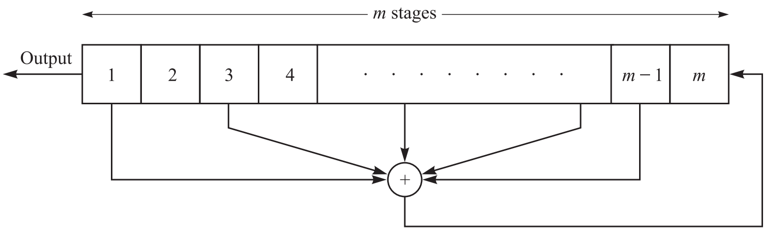

Figure 1.1: Basic structure of an LFSR (Linear Feedback Register). [PS08]

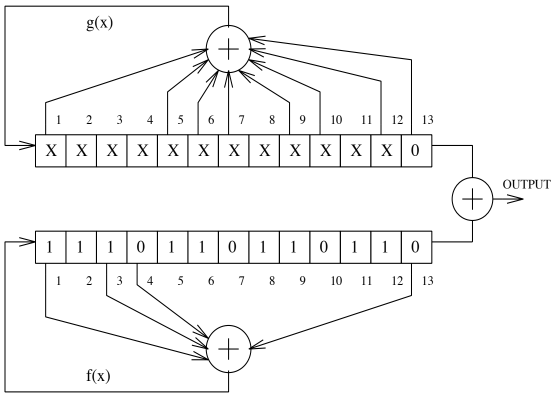

Figure 1.2: LFSR structure of preferred generator polynom of degree 13). [MD]

1.1.1 Gold Codes

Because of not optimal cross-correlation properties m-sequences alone are not applicable for the project. But if these type of codes are combined their correlation qualities can change. Gold Codes are m-sequences where two of them with same length are modulo-2 summed. [PS08]

The gold code which has the highest similarity to Gaussian random variable has a degree of 13. Thus, a generator polynomial pair of $x^13 + x^4 + x^3 + x + 1$ and $x^13 + x^12 + x^10 + x^9 + x^7 + x^6 + x^5 + x + 1$ is chosen [MD] .

1.1.2 Kasami Codes

Kasami sequences are constructed in the same fashion by using m-sequencs. But now the second sequence which is used in the modulo sum is formed by decimating the default m-sequence by $2^{m/2}$ [PS08] [SP80] [PPWW72].

1.1.3 Comparison

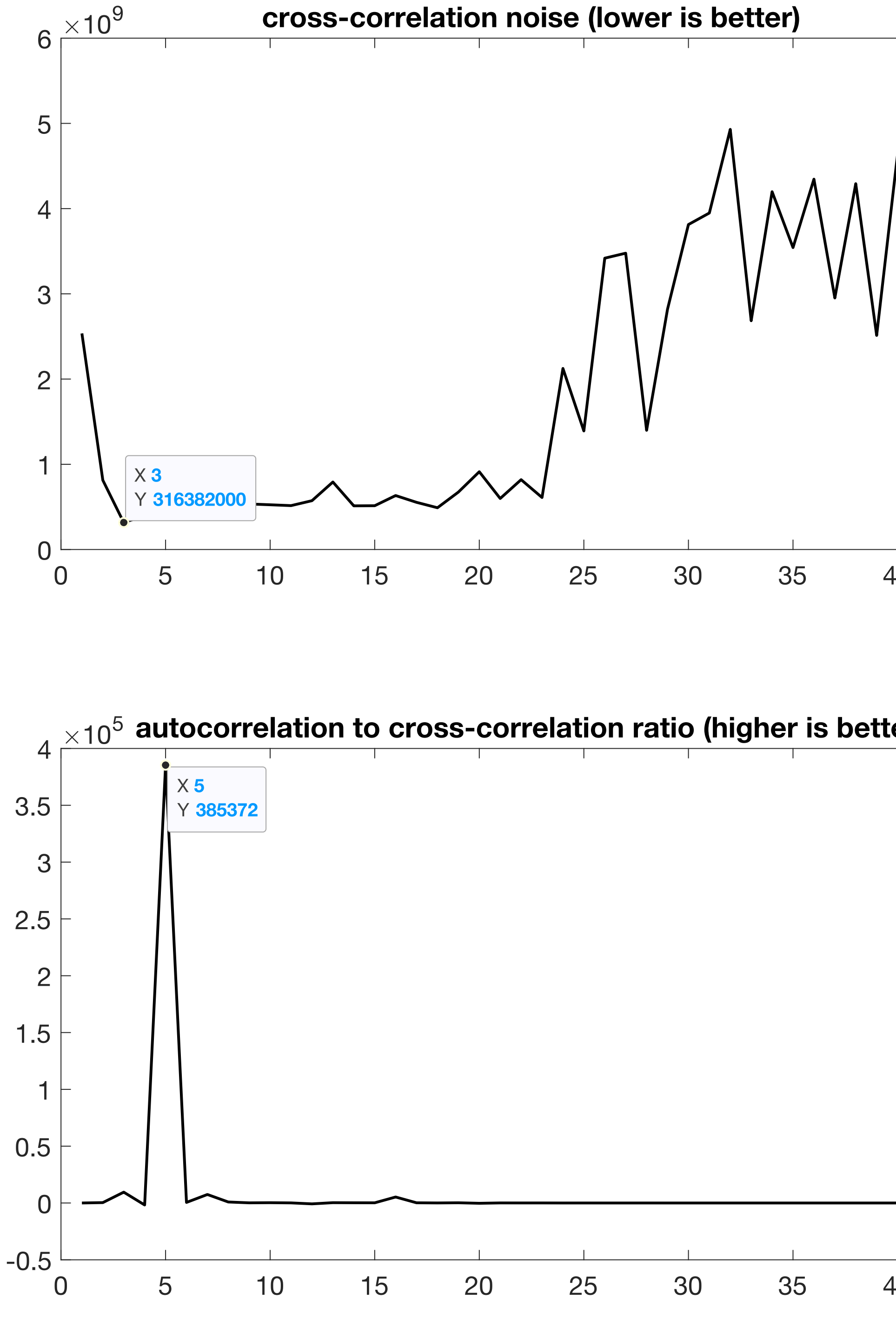

Figure 1.3: Basic structure of an LFSR (Linear Feedback Register). [PS08]

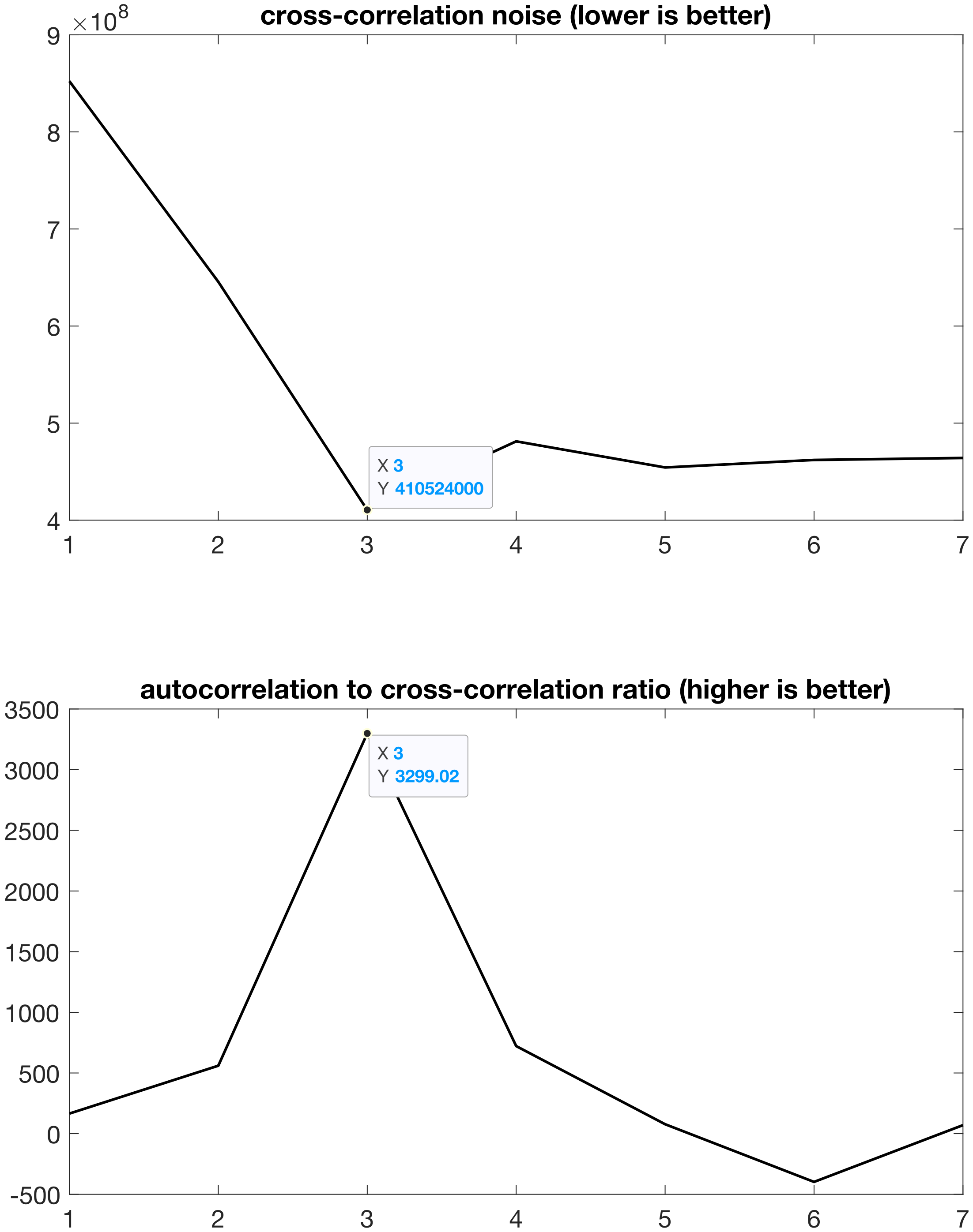

Figure 1.4: Basic structure of an LFSR (Linear Feedback Register). [PS08]

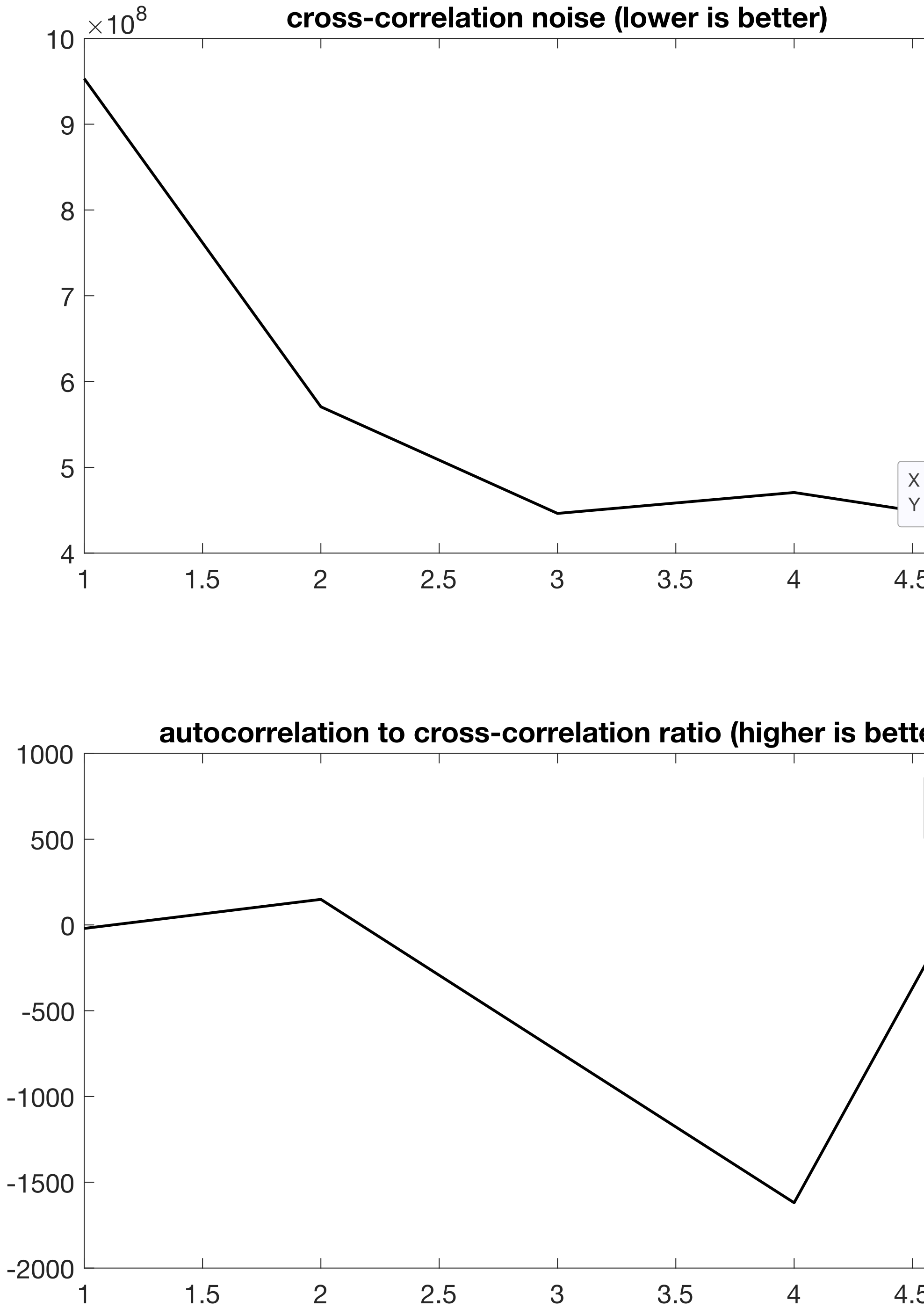

Figure 1.5: Basic structure of an LFSR (Linear Feedback Register). [PS08]

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[PPWW72] William Wesley Peterson, Wesley Peterson, Edward J Weldon, and Edward J Weldon. *Error-correcting codes*. MIT press, 1972.

[PS08] John G. Proakis and Masoud Salehi. *Digital Communications*. McGraw-Hill Higher Education, New York, 2008.

[SP80] Dilip V Sarwate and Michael B Pursley. Crosscorrelation properties of pseudorandom and related sequences. *Proceedings of the IEEE*, 68(5):593–619, 1980.

Appendix A

Content of the DVD

In this chapter, you should explain the content of your DVD.