A COMPLICATED AND IMPRESSIVE SOUNDING TITLE THAT IS TOO LONG

FOR A SINGLE LINE WHILE INCLUDING EVERYTHING

by

John Q. Engineer

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ABSTRACT

A Complicated and Impressive Sounding Title that is Too Long For a Single Line While
Including Everything

by

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Utah State University, 2016

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This is the abstract of the demonstration thesis. Hopefully the examples will be sufficiently clear that you will have few formatting problems.

(29 pages)

PUBLIC ABSTRACT

A Complicated and Impressive Sounding Title that is Too Long For a Single Line While

Including Everything

John Q. Engineer

The public abstract is to convey the purpose of the research to the PUBLIC, so layman's terms should be used.

To all the little people....

ACKNOWLEDGMENTS

I am so happy that my advisor helped me.....

John Q. Engineer

CONTENTS

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ACRONYMS

BFCS	body-fixed coordinate system
CEF	composite energy function (related to ILC)
CSOIS	Center for Self-Organizing and Intelligent Systems
CV	certainty value (related to HIMM)
DOF	degree of freedom
EKF	extended Kalman filter
FOG	fiber optic gyro
FOV	field of view of a camera
GAIC	geometric Akaike information criterion
GMDL	geometric minimum description length criterion
GRO	growth rate operator (related to HIMM)
HIMM	histogram in-motion mapping
HOSA	higher-order spectral analysis (related to Matlab toolbox)
IBO	identifier-based observer (related to PDS)
IIC	identical initial condition (related to ILC)
ILC	iterative learning control
ICS	inertial coordinate system
LAO	linear approximation-based observer (related to PDS)
LQG	linear quadratic Gaussian
LS	least squares
LTV	linear time-varying
NN	neural network
OCS	obstacle cluster strength (related to HIMM)
ODIS	omni-directional inspection system, a robot at the CSOIS center
ODV	omni-directional vehicle

CHAPTER 1

INTRODUCTION

Image compression or image coding is the process of reducing the redundancy in the image data that may result in some loss of information. Vector quantization (VQ)[1] is one such technique.

Binary splitting is illustrated in Fig. 1.1.

Indices — j_i^1 $\longleftarrow$ Indices $\longrightarrow$ j_k^2

Codebook Stage 1

Codebook Stage 2

X^1 — VQ Stage 1

$Y_{j_i^1}^1$

$X^1 - Y_{j_i^1}^1$

$+$ $-$

X^2 — VQ Stage 2

Fig. 1.1: Binary splitting.

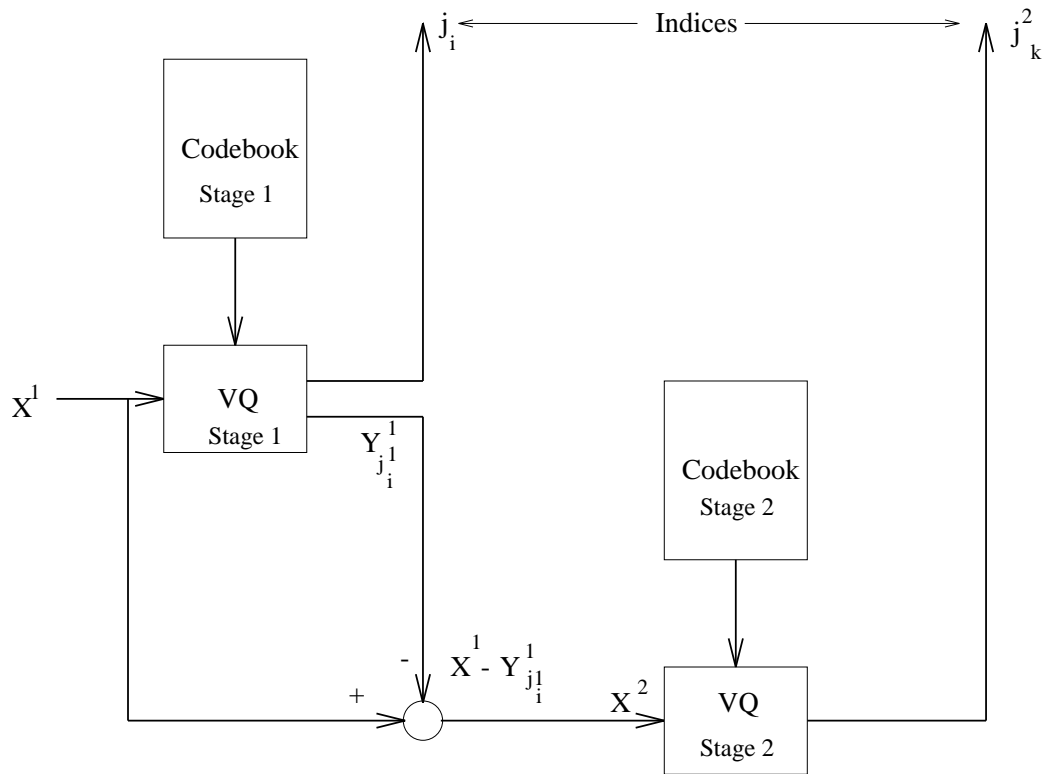[1]The acronym VQ is used as an abbreviation for both vector quantization and vector quantizer.
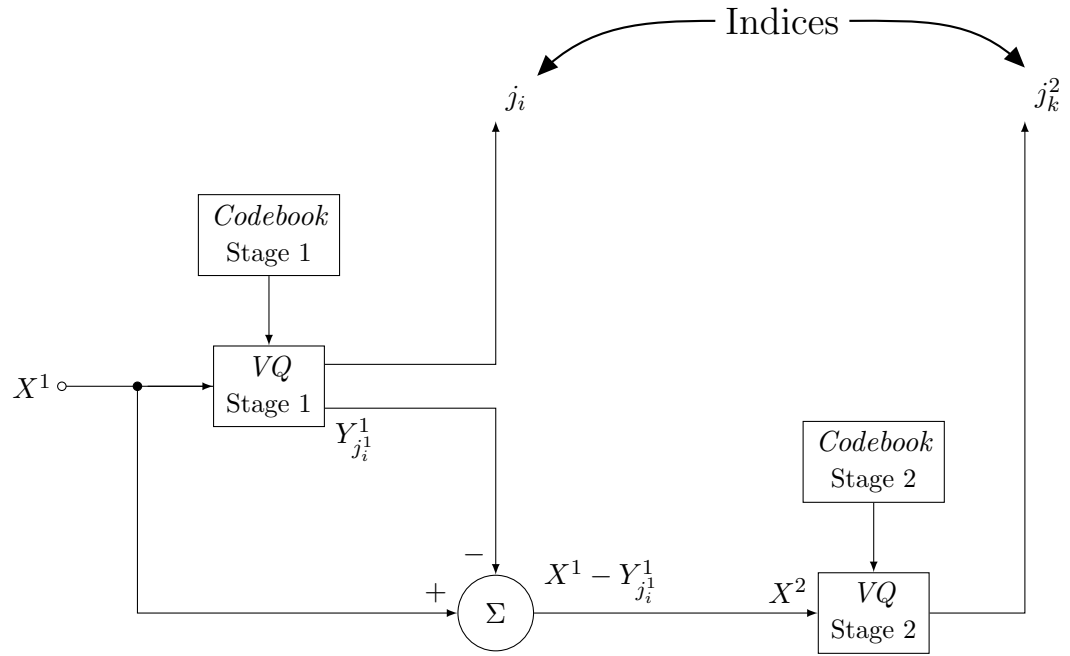
Fig. 1.2: Binary splitting (drawn with TikZ).
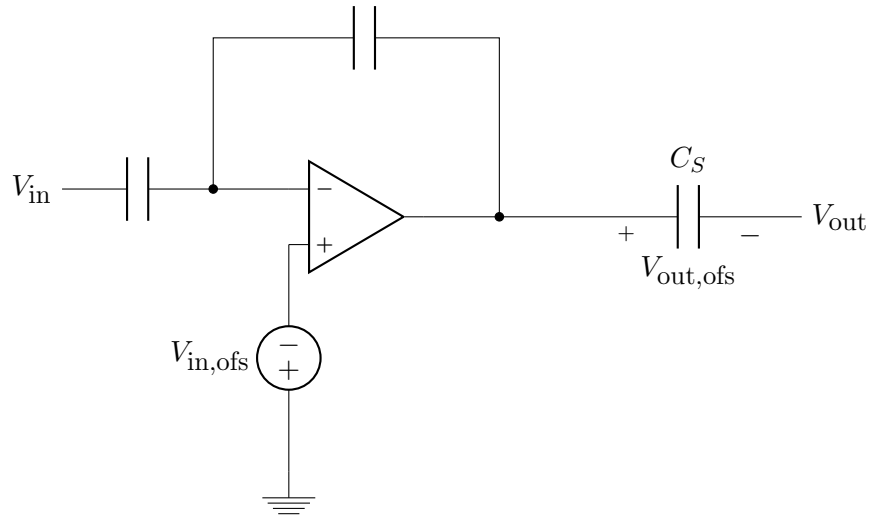
Fig. 1.3: Circuit example drawn using circuitikz.
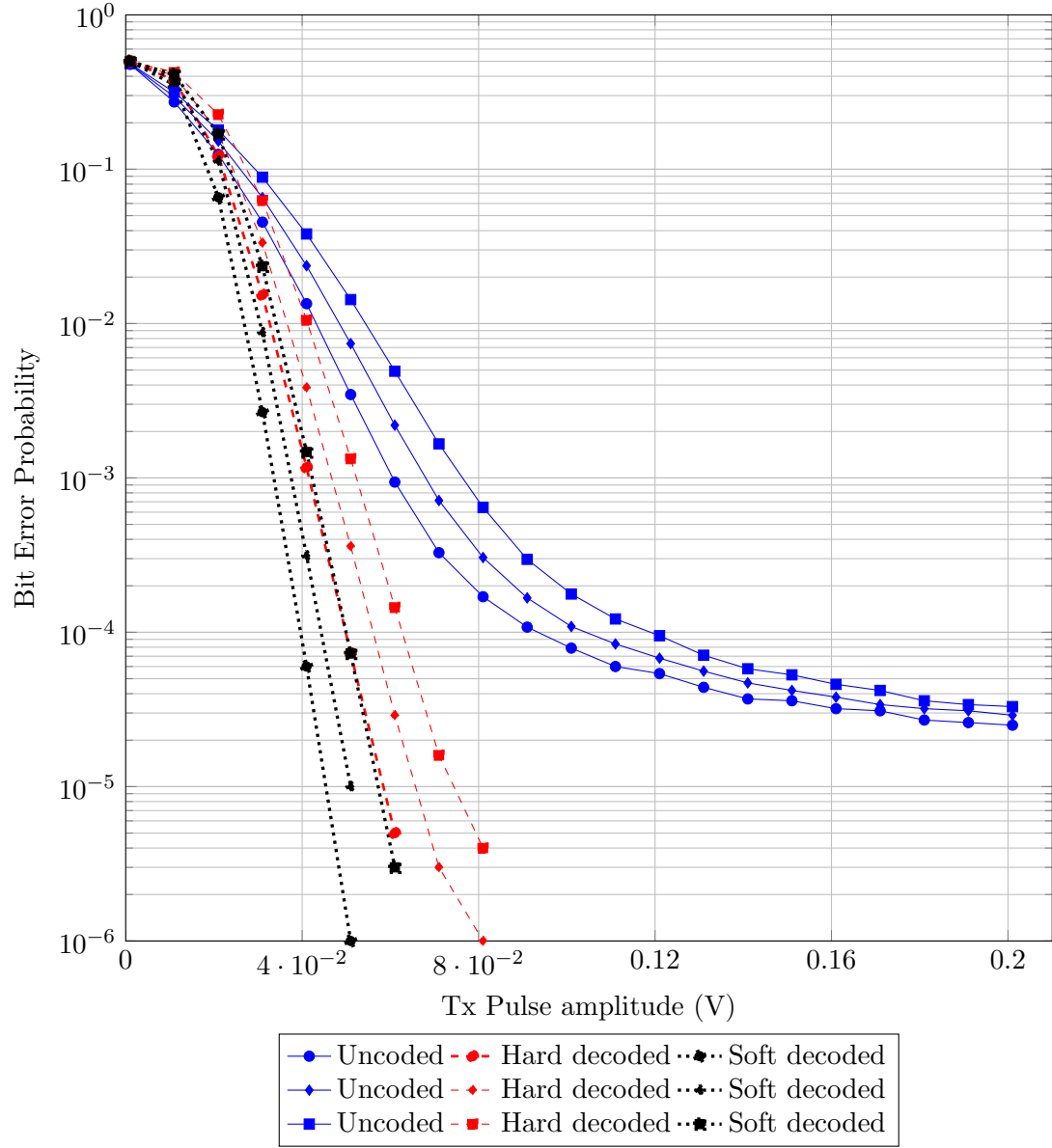
Fig. 1.4: Example figure made with PGFplots. Originally created in Matlab, then exported using the Matlab2TikZ script (available from Matlab Central). Then pasted into the LATEX document and edited for style.

CHAPTER 2

RESIDUAL VECTOR QUANTIZATION AND ITS PROBLEMS

2.1 Residual Vector Quantization (RVQ)

A P-stage RVQ consists of a sequence of P single stage Vector Quantizers. Let us assume that the RVQ is made up of ESVQ stages. Each ESVQ is fully described by the set $\{ A^\rho, Q^\rho, P^\rho \}$. The method for designing the ESVQ is given in Algorithm 2.1. Note that this is the "usual" codebook design algorithm.

Throw in some citations [1–4].

Algorithm 2.1 LBG

Input:

      Training vectors (V_t),

      Distortion measurement rule d,

      Codebook size N,

      Threshold ε

Output:

      Codebook Vectors, Cb_i

Begin

      Select N initial codevectors, Cb_i

      Do

          Begin

              Partition V_t

              $Dist_{prev} = Dist_{current}$ /* Dist is the average */

              Calculate $Dist_{current}$ /* distortion of all the */

              Calculate Centroids of N groups of V_t /* training vectors when */

              $Cb_i =$ Centroid of that group   /* partitioned or encoded */

          End

      while $\{(Dist_{prev} - Dist_{current})/Dist_{prev} \geq \varepsilon\}$

End

2.2 Reasons for the Poor Performance of RVQs

$$d(X^\rho, Y_i^\rho + A^{\rho+1} + \cdots + A^P) \leq d(X^\rho, A^\rho + A^{\rho+1} + \cdots + A^P) \qquad (2.1)$$

It can be noticed from the above equation that while the traditional RVQ partitions are based on the stagewise residues, the optimal RVQ partitions are based on the final residues. As is evident from (2.1), the optimal codevectors are unique. The equivalent codevectors are obtained by summing all possible combinations of the codevectors of all stages. These represent the set of reconstruction vectors possible at the decoder.

2.3 Methods to Improve RVQ Performance

The various methods either suboptimal or optimal used in codebook generation and in the quantizer (RVQ) implementation are dealt with here. The common goal of all these methods is to improve the performance of the RVQ.

2.3.1 Brute Force RVQ or Stagewise RVQ (SRVQ)

The new codevectors are obtained by adding the centroids of the stagewise residues to the old codevectors. This can be done using a random splitting technique or a selective splitting technique.

2.3.2 Exhaustive Search RVQ (ESRVQ)

ESRVQ is the optimal RVQ described in the previous section. ESRVQ, as the name suggests, exhaustively searches all the *equivalent* codevectors as shown in (2.1). Centroids of the final residues are added to the codevectors during each iteration of the codebook design, to obtain the new optimal codevectors for the given partition.

2.3.3 Deep Search RVQ

Although ESRVQ is optimal, it needs an exhaustive search encoder. We must be able to create the encoder using an optimal method.

2.3.4 Comparison of SRVQ, DSRVQ, and ESRVQ Encoders

This section compares the different encoders presented previously. The different encoders have different performance and complexity, and so must be compared using a common basis. This is difficult to do, since we must first establish the criteria we will use.

2.3.5 Algorithm for Generating Jointly Optimized Codebooks

The ESRVQ is not instrumentable and the DSRVQ does not use a tree-structured encoder. Hence Barnes et al. proposed the reflection symmetric RVQ or the rRVQ [5]. The rRVQ uses a tree-structured encoder similar to SRVQ although it differs from the traditional RVQ or the SRVQ encoder in that it is slightly more complex. The rRVQ codebook is also more structured than the traditional RVQ.

Some other citations are in [3, 6–14].

2.3.6 Reflection Symmetric RVQ (rRVQ)

The ESRVQ is not instrumentable and the DSRVQ does not use a tree-structured encoder. Hence Barnes et al. proposed the reflection symmetric RVQ or the rRVQ [5]. The rRVQ uses a tree-structured encoder similar to SRVQ although it differs from the traditional RVQ or the SRVQ encoder in that it is slightly more complex. The rRVQ codebook is also more structured than the traditional RVQ.

The structured nature of the rRVQ codebook allows for a reduction of the complexity of the the implementation.

Binary rRVQ

It was already stated that for the optimal performance of the RVQ, an exhaustive search encoder must be used. To avoid this in rRVQ the codebook is constrained in such a way that the nearest neighbor stagewise equivalence classes are simply connected and convex [5]. A reflection symmetry is forced between the stagewise codevectors of the binary rRVQ to obviate the suboptimality caused by *entanglement* and *overlapping* discussed in the previous

chapter. Barnes et al. derived the optimality conditions for the rRVQ quantitatively [5]. They stated their results as follows [5, pp. 3–4]:

> "The difficulty in achieving optimality is that it is difficult. We observed that it was necessary to look at the conditions for optimality before we could proceed. We then proceeded with caution.
>
> Having proceeded, we applied the conditions for optimality. To our amazement, we found our results were optimal."

2.3.7 Distortion Results and Analysis

Table 2.1 gives the PSNR in dB of the reconstructed test image, compressed (encoded and decoded) using the codebooks generated by SRVQ.

The ESRVQ is not instrumentable and the DSRVQ does not use a tree-structured encoder. Hence Barnes et al. proposed the reflection symmetric RVQ or the rRVQ [5]. The rRVQ uses a tree-structured encoder similar to SRVQ although it differs from the traditional RVQ or the SRVQ encoder in that it is slightly more complex. The rRVQ codebook is also more structured than the traditional RVQ.

It is important to recognize at this point, that rRVQ is a suboptimal method for covering the vector space. It is therefore important to make sure that the best possible vectors are chosen for the codebook.

Table 2.1: Performance results of ESRVQ, rRVQ, SRVQ, and DSRVQ of 4x4 vectors (PSNR in dB).

No. of		SRVQ		DSRVQ		ESRVQ		rRVQ	
Stages	bps	Unopt	JO	Initial	JO	Initial	JO	Initial	JO

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APPENDICES

Appendix A

List of Edge Vectors

A.1   Definition of an Edge Vector

Before we list the table of edge vectors, we need to describe what an edge vector is. In this section we will describe in detail the theory that results in the edge vectors. The first set of edge vectors is given in Table A.1.

A.2   Next Codebook Size Description

In this section we do the next size codebook. This is different from the previous case in that the codebook size is different. The next set of edge vectors is given in Table A.2.

A.3   Final Set of Codebook Size Descriptions

The following three tables contain the data for codebook sizes that are different than the previous sizes. We note that the differences in the tables are due to the differences in the sizes of the codebook edge vectors. Note the values given in Table A.3 – Table A.5.

Table A.1: List of edge vectors for a codebook with b=8 and d=3, for a 4×4 vector size.

Level	Edge Vectors
L1	(5)
	(6)
	(7)
L2	(3,1)
	(3,2)
	(3,5)
	(4,0)
	(4,2)
	(4,3)
	(4,4)
	(4,5)
	(4,6)
L3	(3,4,1)
	(3,4,2)
	(3,7,0)
	(3,7,2)
	(3,7,4)
	(4,1,0)
	(4,1,1)
	(4,1,2)
	(4,1,3)
	(4,1,4)
	(4,1,5)
	(4,1,6)

Table A.2: List of edge vectors for a codebook with b=4 and d=3, for a 4×4 vector size.

Level	Edge Vectors
L1	(1)
	(2)
	(3)
L2	(0,3)
L3	(0,2,0)
	(0,2,2)
	(0,2,3)

Table A.3: List of edge vectors for a codebook with b=16 and d=3, for a 4×4 vector size.

Level	Edge Vectors
L1	(11)
	(12)
	(13)
	(14)
	(15)
L2	(7,0)
	(7,1)
	(7,2)
	(7,6)
	(8,4)
	(8,5)
	(8,6)
	(9,6)
	(9,14)
	(10,1)
L3	(4,6,14)
	(5,6,6)
	(6,14,0)
	(6,14,3)
	(6,14,4)
	(6,14,5)
	(7,7,0)
	(7,14,7)
	(9,5,3)
	(9,5,10)
	(9,5,11)

Table A.4:   List of edge vectors for a codebook with b=16 and d=3, for a 2×2 vector size.

Level	Edge Vectors
L1	(9)
	(10)
	(11)
	(12)
	(13)
L2	(6,0)
	(6,3)
L3	(2,2,8)
	(6,5,1)
	(6,5,4)
	(6,5,6)
	(6,5,7)
	(6,5,8)
	(6,5,15)
	(7,0,14)
	(8,0,1)
	(8,15,3)
	(8,15,4)
	(8,15,10)

Table A.5:   List of edge vectors for a codebook with b=16 and d=3, for a 6×6 vector size.

Level	Edge Vectors
L1	(6)
	(7)
	(8)
	(9)
	(10)
	(11)
	(12)
	(13)
	(14)
	(15)
L2	(2,8)
	(2,13)
	(4,1)
	(4,6)
	(4,7)
	(4,8)
	(4,10)
	(4,11)
	(4,13)
	(4,15)
L3	(1,7,0)
	(1,7,1)
	(1,7,2)
	(1,7,3)
	(1,7,4)
	(1,7,6)
	(1,7,9)
	(1,7,12)

Appendix B

Another Example Appendix

B.1   Background

Some random appended text for this section of the appendix....

B.2   Meat of the Appendix

Here we have the data that is so important to be included in this appendix.

CURRICULUM VITAE

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Published Journal Articles

- Rational Radial Distortion Models of Camera Lenses with Analytical Solution for Distortion Correction, Lili Ma, YangQuan Chen, and Kevin L. Moore, *International Journal of Information Acquisition*, *Accepted.*

- A Small Mobile Robot for Security and Inspection Operations, N.S. Flann, K. L. Moore, and Lili Ma, *Control Engineering Practice*, vol. 10, pp. 1265-1270, 2002.

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