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A Critical Analysis of Design Flaws in the Death Star

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Report submitted in partial fulfilment of the requirements of the module Project (E) 448 for the degree Baccalaureus in Engineering in the Department of Electrical and Electronic Engineering at Stellenbosch University.

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Abstract

English

The English abstract.

Afrikaans

Die Afrikaanse uittreksel.

Contents

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Nomenclature

Variables and functions

$p(x)$	Probability density function with respect to variable x.
$P(A)$	Probability of event A occurring.
ε	The Bayes error.
ε_u	The Bhattacharyya bound.
B	The Bhattacharyya distance.
s	An HMM state. A subscript is used to refer to a particular state, e.g. s_i refers to the i^{th} state of an HMM.
$\mathbf{S}$	A set of HMM states.
$\mathbf{F}$	A set of frames.
$\mathbf{o}_f$	Observation (feature) vector associated with frame f.
$\gamma_s(\mathbf{o}_f)$	A posteriori probability of the observation vector $\mathbf{o}_f$ being generated by HMM state s.
μ	Statistical mean vector.
Σ	Statistical covariance matrix.
$L(\mathbf{S})$	Log likelihood of the set of HMM states $\mathbf{S}$ generating the training set observation vectors assigned to the states in that set.
$\mathcal{N}(\mathbf{x}\|\mu, \Sigma)$	Multivariate Gaussian PDF with mean μ and covariance matrix Σ.
a_{ij}	The probability of a transition from HMM state s_i to state s_j.
N	Total number of frames or number of tokens, depending on the context.
D	Number of deletion errors.
I	Number of insertion errors.
S	Number of substitution errors.

Acronyms and abbreviations

AE	Afrikaans English
AID	accent identification
ASR	automatic speech recognition
AST	African Speech Technology
CE	Cape Flats English
DCD	dialect-context-dependent
DNN	deep neural network
G2P	grapheme-to-phoneme
GMM	Gaussian mixture model
HMM	hidden Markov model
HTK	Hidden Markov Model Toolkit
IE	Indian South African English
IPA	International Phonetic Alphabet
LM	language model
LMS	language model scaling factor
MFCC	Mel-frequency cepstral coefficient
MLLR	maximum likelihood linear regression
OOV	out-of-vocabulary
PD	pronunciation dictionary
PDF	probability density function
SAE	South African English
SAMPA	Speech Assessment Methods Phonetic Alphabet

Chapter 1

Introduction

Chapter 2

Literature Review

2.1. Theory and applications of superconductivity

In order to understand and apply the methods described in [1] one must first understand the basic theory behind superconductivity as well as some examples of how this theory is used in practice.

2.1.1. Superconductivity

REVIEW NEEDED

Since the first discovery of superconductivity a couple of successfully theories have been put forth to explain the phenomenon. The London theory is a framework that describes the qualitative behaviour of superconductors and correctly describes perfect diamagnetic and zero resistance but fails to explain the effect on a microscopic level [2]. The London equations (equation 2.1 and equation 2.2) [3] is an addition to Maxwell's equations.

$$E = \frac{\partial}{\partial t}(\Lambda J_s) \tag{2.1}$$

$$h = -c\nabla \times (\Lambda J_s) \tag{2.2}$$

Here Λ is a phenomenological parameter determined through experimentation. The London equations allow us to calculate the current distribution in a superconductor which is very important to the objective of this project. BCS theory put forth a microscopic model of superconductors and explains the phenomenon as a quantum mechanical effect. The details are out of scope for this project but on a crude qualitative level BCS theory can be explained by the pairing of electrons in the crystal lattice of the superconductor allowing them to be considered one particle. These particles are known as cooper-pairs. At extremely low temperatures the formation of these cooper pairs are energetically favourable [4]. Electron pairs in this state can flow through the superconductor unimpeded. BCS theory is the most successful model of superconductivity discovered to date.

2.1.2. The Josephson junction

In superconducting electronics the active component is the Josephson junction [5]. The Josephson junction refers to a situation where two superconductors are connected through a thin non-conductive barrier. If this barrier is thin enough one can observe what is known as the Josephson effect. This phenomena is can be explained by considering the effect of quantum tunnelling of cooper pairs through the non-conductive boundary. For a sufficiently large barrier one can express the ensemble average wave function in each superconductor independently [5]:

$$\Psi = |\Psi(\mathbf{r})| \exp\{i\theta(\mathbf{r})\} \tag{2.3}$$

This is due to the fact that it is energetically favourable for cooper pairs in proximity to one another to lock phases [5] allowing one to express a large collection of these cooper pairs as one ensemble wave function. The idea that it is energetically favourable for cooper-pairs in proximity to one another extends to the situation where the superconductors are separated by an insulating boundary. When the barrier is sufficiently small the energy of the system can be reduced by the coupling of wave functions in their respective superconductors [5]. This results in cooper-pairs being able to move across the boundary without energy loss. Following the derivation in [4] one can describe the system behaviour using Schrödinger's equation when a voltage is applied to the junction [4]:

$$i\hbar\frac{\partial\Psi_1}{\partial t} = U_1\Psi_1 + K\Psi_2 \tag{2.4}$$

$$i\hbar\frac{\partial\Psi_2}{\partial t} = U_2\Psi_2 + K\Psi_1 \tag{2.5}$$

Here $U_1 = qV/2$ and $U_2 = -qV/2$ [4] refer to the energy of the two wave functions and K refers to the coupling energy between each wave function. By taking 2.3 and setting $|\Psi(\mathbf{r})|$ to $\sqrt{\rho}$ where ρ refers to the cooper pair density in the super conductor one can substitute the result into equations 2.4 and 2.5. From this substitution one can find that the rate of change of electron density on either side of the junction to be described by the following equation [4]:

$$\dot{\rho}_1 = \frac{2}{\hbar}K\sqrt{\rho_1\rho_2}sin(\delta) \tag{2.6}$$

Where ρ_1 is the electron density on one side of the junction. The rate of change of charge on the other side of the junction is simply $\dot{\rho}_2 = -\dot{\rho}_1$ [4]. The rate of change of charge is the current and therefore the current through the junction can be expressed as follows [6]:

$$I = I_0 sin(\theta_2 - \theta_1) \tag{2.7}$$

Equation 2.7 is known as the current-phase relation of the DC Josephson effect. The phases of the currents on each side of the boundary is described by equation 2.8 [4].

$$\dot{\theta}_2 - \dot{\theta}_1 = \frac{qV}{\hbar} = \dot{\delta} \tag{2.8}$$

Integrating on both sides yields equation 2.9:

$$\delta(t) = \delta_0 + \frac{q}{\hbar}\int V(t)dt \tag{2.9}$$

It is important to note that 2.7 is only valid for a limited number of cases and the actual current-phase relation is often more complicated [6]. The applications of equation 2.7 is limited to analysing analogue and digital devices based on Josephson junctions [6].

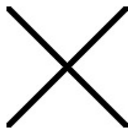

Figure 2.1: The circuit symbol for a Josephson junction

2.1.3. SQUID's

An application of the Josephson effect is the superconducting quantum interference device (SQUID). In essence a SQUID refers to a superconducting ring that contains one or more Josephson junction. This interference effect is analogous to interference one might encounter in the field of optics [7]. The SQUID is a highly sensitive device that can in some cases measure fields as weak as $5 \times 10^{-14}T$ [8].

Flux quantisation

To understand the basic operation of a SQUID, one must first understand the concept of flux quantisation. To do so we consider a superconducting ring in the presence of a uniform magnetic field. The ring is superconducting, so it exhibits the Meissner effect and thus the current density inside the ring is zero. Recall that the flux through a ring is:

$$\Phi = \oint \mathbf{A} \cdot d\mathbf{s} \tag{2.10}$$

Now consider the equation for the current density in a superconductor [4]:

$$\mathbf{J} = \frac{\rho\hbar}{m}(\nabla\theta - \frac{q\mathbf{A}}{\hbar}) \tag{2.11}$$

The current density inside the ring in the superconducting state is zero so equation 2.11 becomes:

$$\nabla\theta = \frac{q}{\hbar}\mathbf{A} \tag{2.12}$$

Integrating on both sides around a curve deep inside the superconductor such that the assumption that the current density is zero holds we can express equation 2.12 as:

$$\oint \nabla\theta \cdot d\mathbf{s} = \frac{q\Phi}{\hbar} \tag{2.13}$$

Recognizing $\nabla\theta$ as vector field with potential function θ, we can simply write the left-hand side of equation 2.13 as $\theta(\mathbf{r_1}) - \theta(\mathbf{r_1})$. One might assume that the left-hand side of the equation 2.13 must be equal to zero. This is incorrect because the absolute phase, meaning the potential function θ cannot be determined and can only be determined up to some constant because the gradient of the scalar potential function will take any constant to zero. Therefore, the phase can only be determined relative to some point. According to [4] the only limitation we can place on the phase of the wave function is that the wave function must be singularly valued. This is intuitively understood as the fact that a particle cannot have two different amplitudes to be in a certain quantum state as that would imply that it has two probabilities associated with the exact same quantum state [4]. From equation 2.3 one can conclude that the phase can change by any integer multiple of 2π as this results in the exact same wave function. Equation 2.13 then becomes:

$$2\pi n = \frac{q\Phi}{\hbar} \tag{2.14}$$

Clearly equation 2.14 implies that the flux through the superconducting loop must be quantized as n can only take on integer values.

The DC SQUID

Spurred on by developments in reliable manufacturing processes of Josephson junctions the DC SQUID has become the dominant device in the field of niobium based sensors [8]. The initial discovery of the DC SQUID by [7] in 1964 came shortly after the discovery of the Josephson junction in 1962 [9]. The simplest realisation of the DC SQUID consists of two Josephson junctions connected in parallel as depicted in figure 2.2.

A relationship between the current and the flux through the loop of the SQUID would like to be derived. The current through each Josephson junction is denoted as I_1 and I_2 for junction 1 and 2 respectively. From figure 2.2 one can easily see that there are 2 possible paths through the SQUID. Following the derivation of [4] one can write the change in phase through each branch of the squid using equations 2.15 and 2.16 [4].

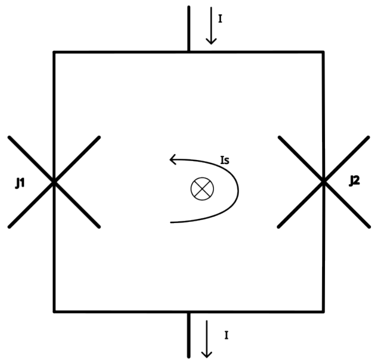

Figure 2.2: A circuit schematic depicting the configuration of a simple DC SQUID. The current I is the bias current and the current I_s is the screening current developed by an external magnetic field

$$\Delta\theta_1 = \theta_1 + \frac{2q_e}{\hbar}\int_{\text{left branch}} \mathbf{A}\cdot d\mathbf{s} \tag{2.15}$$

$$\Delta\theta_2 = \theta_2 + \frac{2q_e}{\hbar}\int_{\text{right branch}} \mathbf{A}\cdot d\mathbf{s} \tag{2.16}$$

Where θ_1 and θ_2 is the change in phase across their respective junctions. Similarly, $\Delta\theta_1$ and $\Delta\theta_2$ refer to the change in phase through the left and right branch respectively. As previously discussed, the integral of the phase gradient around a closed loop must be an integer multiple of 2π. As a consequence, subtracting equation 2.16 from 2.15 must yield $2\pi n$. Using equation 2.13 we derive equation 2.17.

$$\theta_2 = \theta_1 - 2\pi n + \frac{2q_e}{\hbar}\Phi \tag{2.17}$$

Using equation 2.7, 2.17 and a KCL at the top or bottom node, the relation between the current going into the loop and the flux through the loop is derived and equation is found. Here the $2\pi n$ term can be neglected as a $2\pi n$ shift in phase does not change the value of the function.

$$I = I_2 sin(\theta_2) + I_1 sin(\theta_2 - \frac{2q_e}{\hbar}\Phi) \tag{2.18}$$

Equation 2.18 describes the general behaviour of the DC SQUID. The current voltage characteristics are shown in the figure below Get figure

2.2. Noise in SQUIDS

List connection between Noise and squid sensitivity here aka - Why it is useful to know the noise figure ie the low frequency performance also list the characteristics of 1/f noise also why is low frequency performance important

2.2.1. Origin of noise in SQUIDS

proposed model for noise specifically 1/f noise

2.2.2. Models for noise in SQUIDS

this is basically steven antons work as well as some other people he links to observations made through measurements dependance on temp dependance on geometry some work on improving low frequency performance

2.2.3. Techniques for predicting mean square flux noise

go through methods previously used and explain Steven Antons work and discuss results for his noise modelling

2.3. InductEx and tetrahenry

Should this even be here?

Chapter 3

Solution development

asd

Chapter 4

Results

Chapter 5

Summary and Conclusion

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Appendix A

Project Planning Schedule

This is an appendix.

Appendix B

Outcomes Compliance

This is another appendix.