# COMPUTER-BASED MALAY STUTTERING ASSESSMENT SYSTEM

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*To my dearest parents, siblings and friends*
*for their love and support to make the journey*

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## ABSTRACT

Stuttering has attracted extensive research interests over the past decades. However, far less effort has been done on the computer-based stuttering assessment system. Stutterers respond in unique ways to different therapy techniques. The technique that works so dramatically for one stutterer does not necessarily work dramatically, or at all, for other stutterers. Stuttering is so variable and so highly individualized that, few would disagree, no one method works for all stutterers. Normally, 2 to 3 months are required to determine suitable techniques for each client. The effectiveness of each approach depends on the receptiveness of the client. This thesis explains the development of a computer-based Malay stuttering assessment system. The system assists Speech-Language Pathologist (SLP) in determining suitable therapy techniques for each client. The software was developed based on fluency shaping techniques used in fluency rehabilitation regimen. Digital Signal Processing techniques were implemented to analyze speech signals. The maximum magnitudes of the clients' and the SLPs' speech signals, corresponding to the Average Magnitude Profiles (AMPs), were determined and compared. The maximum magnitude was determined where a total of 15 neighbouring samples were summed to obtain a maximum value. Start location, end location, maximum magnitude and duration were compared between clients' and SLPs' AMPs to generate scoring, the computational analyses help SLP to determine suitable techniques in a faster way. The software has been developed using Microsoft Visual C++ 6.0 to run under Window XP. Three therapy techniques were introduced in the proposed computer-based method. These techniques consisted of Shadowing, Metronome and Delayed Auditory Feedback. Ten test subjects were selected from 6 primary schools located at Skudai. Measurements of percent syllables stuttered on test subjects were made by SLP from Hospital Sultanah Aminah. The experimental results showed that SLP agreed with the result analyses generated by the software.

# ABSTRAK

Masalah gagap telah menarik perhatian para penyelidik sejak beberapa dekad yang lalu. Namun demikian, kerja penyelidikan melalui implementasi sistem penilaian masalah gagap berdasarkan komputer adalah amat terhad. Pesakit gagap memberi reaksi yang berlainan terhadap teknik terapi yang berbeza. Satu teknik terapi yang berkesan terhadap seorang pesakit gagap tidak semestinya memberi kesan yang sama kepada pesakit yang lain. Biasanya, dua hingga tiga bulan diperlukan untuk mengenalpasti teknik terapi yang paling sesuai untuk seseorang pesakit gagap. Keberkesanan sesuatu teknik bergantung kepada tahap penerimaan individu. Tesis ini menerangkan proses pembinaan dan implementasi sistem penilaian gagap berdasarkan komputer. Sistem penilaian ini membantu Patologis Pertuturan (SLP) dalam mengenalpasti teknik terapi yang paling sesuai bagi pesakit gagap. Perisian ini direka berdasarkan teknik penajaman kelancaran pertuturan yang digunakan dalam proses pemulihan pertuturan. Teknik pemprosesan isyarat digital diaplikasikan untuk menganalisis isyarat pertuturan. Magnitud maksimum isyarat pertuturan bagi pesakit dan SLP, iaitu "Profil Purata Magnitud" (AMP) dikenalpasti dan dibandingkan. Magnitud maksimum dikira dengan menambah 15 sampel untuk mendapatkan satu nilai maksimum. Titik permulaan, titik akhir, magnitud maksimum dan tempoh dibandingkan di antara AMP pesakit dan SLP untuk menghasilkan pemarkahan yang dapat membantu SLP mengenalpasti teknik terapi yang sesuai dengan lebih cepat. Perisian direka dengan menggunakan Microsoft Visual C++ 6.0 dalam platfom Window XP. Tiga teknik terapi dibangunkan berdasarkan komputer iaitu Shadowing, Metronome, Delayed Auditory Feedback. Sepuluh subjek ujian dipilih dari enam buah sekolah di Skudai. Pengukuran peratusan sukukata yang gagap dibuat oleh SLP dari Hospital Sultanah Aminah terhadap sampel subjek ujikaji. Hasil ujikaji telah menunjukkan bahawa SLP bersetuju dengan analisis keputusan perisian.

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## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| ADC | - | Analogue to Digital Converter |
| AMP | - | Average Magnitude Profile |
| API | - | Application Programming Interface |
| ASHA | - | American Speech-Language-Hearing Association |
| AWS | - | Adults Who Stutter |
| CAT-R | - | Communication Attitude Test-Revised |
| CBR | - | Constant Bit-Rate |
| CODEC | - | Compression Decompression |
| CPU | - | Central Processing Unit |
| CWS | - | Children Who Stutter |
| DAC | - | Digital to Analogue Converter |
| DAF | - | Delayed Auditory Feedback |
| DC | - | Direct Current |
| DMA | - | Direct Memory Access |
| DSP | - | Digital Signal Processing |
| EBP | - | Evidence-Based Practice |
| FS | - | Fluency Shaping |
| GDI | - | Graphics Device Interface |
| GUI | - | Graphical User Interface |
| ISA | - | Industry Standard Architecture |
| LCB | - | Locus of Control Behaviour |
| LPF | - | Low Pass Filter |
| MFC | - | Microsoft Foundation Class |
| OS | - | Operating System |
| PC | - | Personal Computer |
| PCI | - | Peripheral Component Interconnect |
| PCM | - | Pulse Code Modulation |

| | | |
|---|---|---|
| PS | - | Prolonged Speech |
| PSI | - | Perception of Stuttering Inventory |
| PWS | - | Person Who Stutter |
| RB | - | Regulated Breathing |
| RIFF | - | Resource Interchange File Format |
| S-24 | - | Modified Erickson Scale of Communication Attitudes |
| SLP | - | Speech-Language Pathologist |
| SM | - | Stuttering Modification |
| SS | - | Stuttered Syllables |
| SSI-3 | - | Stuttering Severity Instrument |
| SSMP | - | Successful Stuttering Management Program |
| SW/M | - | Stuttered Words per Minute |
| USD | - | United State Dollar |
| VBR | - | Variable Bit-Rate |
| WPM | - | Words Per Minute |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background and Motivation

Stuttering has attracted extensive research interests over the past decades. Stuttering research is exploring ways to improve the diagnosis and treatment of stuttering as well as to identify its causes. Emphasis is being placed on improving the ability to determine which children will outgrow their stuttering and which children will stutter the rest of their lives.

Recent research has been focused on the therapy program such as Lidcombe Program, Camperdown Program, Prolonged Speech-based Stuttering Treatment and others. Many classical manual inventories, scales, and procedures have been developed for assessing the quality of both the surface as well as the deep structure of stuttering such as Stuttering Severity Instrument (SSI-3), Modified Erickson Scale of Communication Attitudes (S-24), Perception of Stuttering Inventory (PSI) and so on. However, far less effort has been done on the computer-based stuttering assessment system.

Studies [1] indicated that stuttering therapy was eventually helpful in reaching goals of successful management for person who stutter (PWS). However, PWS had difficulty in identifying specific therapy techniques to which they could attribute their success. Findings [2] suggest that a system that can identify suitable therapy techniques is important because any rational and empirically informed procedure that enables the PWS to systematically modify speech behaviours and the associated cognitive features may be likely to successfully facilitate fluency.

Numerous therapy techniques exist to treat stuttering, yet there remains a paucity of empirically motivated stuttering treatment outcomes research. Despite repeated calls for increased outcome documentation on stuttering treatment, the stuttering literature remains characterized by primarily ‘‘assertion-based’’ or ‘‘opinion-based’’ treatments, which by definition are based on unverified treatment techniques and/or procedures [3].

Conversely, ‘‘evidence-based’’ treatments, based on well-researched and scientifically validated techniques, remain relatively rare in the field of stuttering and are usually limited to behavioural and fluency shaping (FS). The objective assessment of specific stuttering treatment approaches is also important to elucidate therapy techniques that contribute to desired outcomes. However, identifying the appropriate therapy techniques manually can be difficult, given the multidimensional nature of stuttering [4].

A study [5] consisted of 98 children who stutter (CWS) ranged from 9 to 14 years old were divided into four groups:

1. The first group was treated by speech-language pathologist (SLP) in a speech clinic.
2. In the second group, the parents were trained to administer the stuttering therapy to their children, but the children did not see a SLP.
3. In the third group, the children used speech biofeedback computers designed for treating stuttering. They were not treated by SLPs, and their parents were not involved.
4. The control group received no therapy.

One year after the therapy program ended:

1. 48% of the children treated by SLPs were fluent.
2. 63% of the children treated by their parents were fluent.
3. 71% of the children treated by computers were fluent.
4. The control group's speech did not improve.

The results showed that computers were the most effective, the parents were the next most effective, and the SLPs were the least effective. At the 1% disfluency

level, the computers and the parents were about four times more effective than the SLPs and this encourages the implementation of a computer-based stuttering assessment system to improve clients' fluency.

Computer-based stuttering assessment system implements the function of complicated and expensive acoustic equipment available only at well-equipped speech-language pathology clinics.

## 1.2 Problem Statement

Why computer-based stuttering assessment system should be implemented to replace the classical manual assessment approach? What is possible during clinical session is often determined by treatment variables such as the availability, setting, and cost of services. The drawbacks and insufficiencies of classical manual stuttering assessment include:

a) **Time -** There were at least 115 therapy techniques that decreased stuttering markedly [6]. Each of the PWS exhibits a unique response to different therapeutic approaches. The technique that works so dramatically for one stutterer does not necessarily work dramatically, or at all, for other PWS. Stuttering is so variable and so highly individualized that, few would disagree, no one method works for all PWS.

Without computer-based system, SLP has to try every single therapy technique depending on the needs and response of the client, which may take months of repeated procedures that are costly and overly generalized. The fact is, the longer a SLP takes to assess a client, the more tedious and troublesome will be for a client. For PWS, practice with therapy techniques must take place for many months and years before the techniques become functional. The uniqueness of each individual PWS prevents any specific recommendations of therapy techniques from being universally applicable [7]. Being able to move systematically and persistently toward distant goals is essential since treatment with PWS takes a considerable length of time.

b) **Cost** - Due to the typical length of treatment and the usual lack of reimbursement by insurance companies, the cost of successful treatment can quickly become prohibitive for many clients [8]. The longer the SLP takes to assess a client, the higher the cost of diagnosis. The cost of clinical session is a major consideration for nearly every client. Some individuals simply cannot afford professional help unless the services are covered by insurance (which is not typically the case for fluency disorders) or are available at a reduced rate. A computer-based stuttering assessment is capable to reduce the diagnosis duration and thus reduce the costs of clinical session for client.

c) **Effectiveness** - The success of treatment is closely tied to the ability of an experienced SLP to determine a client's readiness for change and adjust treatment techniques accordingly. Thus the utility of the techniques depends on the SLP's ability to apply the right technique (s) at the right time. Often, an approach is chosen because it coincides with the personality of the SLP and her view of reality. The SLP's perception of the client should be as accurate as possible. If SLP apply the wrong therapy technique on a particular client, not only the client will not show any improvement, the client may need longer time for assessment process.

One of the features of stuttering is that it tends to change with time. This requires SLP to give full attention to each client's progress. This is impossible in sole traditional clinical treatment without the assistance of a computer-based diagnosis tool. Research [5] indicates that computers were the most effective, the parents are the next most effective, and the SLPs were the least effective.

d) **Uniformity** - The scores from manual measures provide quantitative information that is very subjective due to different human perception. This quantitative measurement may vary from one SLP to another which leads to the scoring inconsistencies. Scoring generated by computer-based system enables SLPs in different locations to be on "the same page" regarding the general severity, suitable therapy techniques and the overall characteristics of clients.

e) **Motivation** - PWS often finds traditional clinical session to be a very tedious and undesirable process. Successful intervention also requires continued

commitment and motivation by the client. The problem could be eliminated if SLPs use a "user-friendly" stuttering relief approach where this could be enhanced by the use of a computer-based system. An experienced and interesting guide such as computer-based scoring analyses can show the way or, at the very least, make the journey more efficient and often more pleasant. It is essential that the child enjoys the assessment process and finds it to be a positive experience.

## 1.3 Research Objectives

The objectives of the research work are to develop a computer-based Malay stuttering assessment system and to verify its operation in a real clinical session. The computer-based assessment system is able to assist SLP in determining suitable stuttering therapy techniques for each client. The application is capable to reduce time consumption required to determine suitable therapy technique for each client.

The effectiveness of stuttering assessment process is improved as computer-based approach has been proved to be the most effective in treating PWS. Scoring generated by the computer-based system ensures the consistency and uniformity regarding the general stuttering severity of a particular client. Computer-based system provides interesting guide which motivate client to enjoy the assessment process.

## 1.4 Scope of Work

The scope of this research work includes the development of a computer-based Malay stuttering assessment system working on Window-based operating platform. This research work focuses on school-age children because stuttering should be treated as early as possible, primarily because it becomes less tractable as children get older. The application is developed and coded to run in the graphic user interface (GUI) to provide a user-friendly environment. Digital Signal Processing

(DSP) techniques are implemented to analyze speech signals. Software is designed based on standard speech FS techniques that can be easily incorporated into current fluency rehabilitation regimen. Three stuttering therapy techniques are introduced in computer-based. They are Shadowing, Metronome and Delayed Auditory Feedback (DAF). These three techniques are chosen because they are the most commonly used therapy techniques in Malaysia based on discussion with SLPs in Malaysian hospitals. Once the computer-based stuttering assessment system is developed, it is verified in the real stuttering clients through clinical trial carried out among primary school's students. Hospital Sultanah Aminah assisted in the clinical trials, as well as giving professional feedback.

## 1.5 Research Approach

The development process can be broken into six phases as shown in Figure 1.1. During the first phase, hardware and software required for computer-based stuttering assessment system are identified. Hardware includes microphone, earphones and desktop equipped with sound card, while software means Operating System (OS), the development tools and the necessary drivers. Window XP OS is chosen due to its availability and familiarity. Sound card must be able to work with Window XP.

Prior to the designing and coding stage, basic principles and strategies of stuttering assessment systems are analyzed. Both the FS and stuttering modification (SM) treatment approaches are reviewed and compared. Digital audio processing theories and principles are studied in detail. Algorithm selection and analysis are made for the recording and playback procedures such as windowing, and filtering.

Next, the program flowcharts of stuttering assessment operation are constructed for each module. Coding is done by Microsoft Visual C++ language on Window-based platform. Clinical trials on control data and test subjects are carried out to make sure that the system runs properly before its practicality was verified.

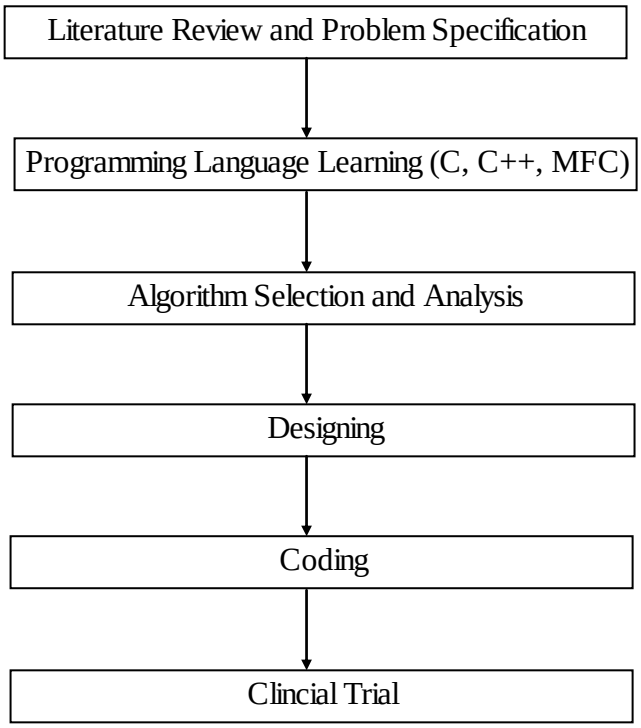


**Figure 1.1:** Research Development Process

## 1.6 Significance of Research Work

Implementing a stuttering assessment in a computer-based system is very important because the use of computer technology in stuttering assessment is still new in Malaysia and currently no computer-based assessment tool is available to assist SLPs in determining suitable therapy technique for each client. Coming up with a clean implementation not only helps better understanding of the available stuttering therapy techniques, but also allows extensions to the introduction of more stuttering therapy techniques in computer-based.

The implementation of computer-based Malay stuttering assessment system aids SLP to determine suitable therapy techniques for each client during the clinical assessment process. Each client exhibits a unique response to the treatment strategies. The uniqueness of each individual PWS prevents any specific recommendations of therapy techniques from being universally applicable.

Without the use of computer-based assessment system, normally 2 to 3 months are required to determine suitable technique for each client. The computer-based assessment system is capable to reduce the amount of time needed for the determination of therapy techniques and the possibility of error occurrence in the manual calculation of percentage of stuttered syllables (SS).

The algorithms involved in the design of assessment procedures and the introduction of three therapy techniques in computer-based are our original ideas.

## 1.7 Thesis Layout

The content of the thesis is organized as follows. Chapter two describes the generic characteristics of stuttering assessment system and survey of current assessment systems used in clinical sessions. Not all systems are mentioned here, but rather those systems that are intuitively relevant for our case of computer-based assessment system.

Chapter three depicts the problem formulation and underlying design principles of computer-based Malay stuttering assessment system, by pointing out some relevant topics such as the basic stuttering treatment approaches including FS and SM, and the criteria for selection of scoring parameters.

Clinical trials on control data and test subjects have been carried out to make sure that the system runs properly before its practicality was verified. The details of the development of computer-based Malay stuttering assessment system are presented in Chapter four while Chapter five portrays the results obtained during the clinical evaluation of the developed assessment system. Chapter six presents the conclusions of the thesis and identifies some areas for future work.