A Computational Approach to Filipino Speech Rhythm

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ABSTRACT
Embedded in the human perception is the distinction of speech rhythm to discriminate between languages. The rhythm of Filipino speech is given empirical validation in this paper using the computational and statistical methods prescribed by Ramus, Nespor, and Mehler (RNM) implemented on the Filipino Speech Corpus of the Digital Signal Processing Laboratory. Following the two sub-grouped convention, syllable-timed and stress-timed, the Filipino language was shown to be syllable-timed, and in the extended classification system, it was shown to be Mora-timed. The study was intended for the comprehensive modeling of the prosodic parameters of Filipino Speech for a natural-sounding Filipino Text-to-Speech (TTS) system, and a robust Automatic Speech Recognition system. The paper was already published and presented in a digital speech processing conference, but it was recently brought to our attention that the study has major implications to the linguistic description of the Filipino language, and to the recently ratified mother-tongue based multilingual education. Similar to digital speech systems, a person studying a second language (L2) will decide on the segment units he or she will use. If not guided properly, the student will be segmenting speech according to the rhythm of the native tongue (L1). Proper awareness of such speech parameters is very important for the student to avoid confusion, and especially for the teacher who will need to come up with an appropriate program to facilitate effective language acquisition.

Keywords
First Language (L1), Second Language (L2), Mother-tongue based Multilingual Education (MLE)

1. INTRODUCTION
Speech rhythm is an important study in digital speech systems, psycholinguistics and multilingual education as a major component of prosody. Speech is composed of prosodic features or suprasegmentals that modify the meaning and information carried by a word. Intensity, duration, pitch, and rhythm are such features that vary among languages, which differentiate one prosodic unit from another. An accurate description of a language's prosodic model is essential in language preservation and documentation, and is essential in language education programming. In digital systems, an accurate description and classification of the rhythm of a language is fundamental for quality digital speech systems.

Pike (1946) proposed that speech rhythm might be classified into syllable-timed and stress-timed, based on temporal organization and regularity of certain intervals. Furtherance on the initial study by Pike became what is commonly known as the Isochrony theory. Though still inconclusive, Isochrony theory proposes that a stress-timed language have isochronous or near equal inter-stress intervals, regardless of the number of syllables in a stress unit or interval. Syllable-timed languages are observed to have near-equal syllable lengths regardless of the number of stresses in a morphological or syntactic construction Under this classification, linguists have traditionally classified Filipino speech as syllable timed. However, there are no empirical measurements to verify this classification and it is being challenged by another school of thought which we will refer to as the phonological account of rhythm. Proposed by Dasher and Bolinger (1982), the phonological account advocates a classification based on phonological properties which led to Dauer's proposition of a continuous uni-dimensional model of rhythm where syllable and stress timed classification is just a part of.

2. Classification of Speech Rhythm

Languages are classified according to speech rhythm, a complex relationship of the temporal information of speech. The traditional classification was proposed by Pike (1946) based on recurrence of speech elements in regular intervals, thus establishing a temporal organization. In this section are the major schools of thought in speech rhythm classification, and discussion on rhythm of Filipino and English as L1 and L2.

2.1 Classification Conventions
There are two major conventions on classifying speech rhythm. Isochrony theory postulates a constant interstress interval in stress-timed languages, and a phonological account which maps languages in a continuous distribution plane for rhythm.

2.1.1 Isochrony Theory
The underlying concept of the Isochrony theory is the principle that inter-stress intervals have near-equal length for a stress timed language (Abercrombie, 1967). This Isochrony of inter-stress intervals is said to be the difference between the "Morse-code" rhythm of stress-timed languages and the "machine-gun" rhythm

of syllable-timed languages. Syllable-timed language exhibits near-equal duration for each syllable. This is illustrated in a comparison between the stress-timed English word mathematics, and syllable-timed French word *Mathématique*. Mathematics ([mæ̀θəmǽtɪks]) has primary and secondary stresses on the first and second "ma" which is consistent to the Isochrony theory. On the other hand, the French word *Mathématique* ([maθəmatɪk]) is segmented into almost equal duration syllables.

A third rhythm type, Mora-time, was proposed by Bloch (1950). Morae are syllable sub-units consisting of a short vowel and any preceding onset consonants. Successive Morae are said to be near-equal in duration. Mora-time, as exemplified by Japanese, is more similar to syllable-timed languages than to stress-timed languages. Under the two-classification scheme, Mora-timed languages may be classified as under syllable-timed. . In itself, having a very strict Consonant-Vowel (CV) characteristic, one syllable in the English language can be composed of more than one Mora. As an example the word Honda when segmented using Mora will become /ho/ /nə/ /da/, which is most apparent in their borrowed words (e.g. McDonald's /ma/ /ko/ /do/ /na/ /ru/ /do/).

While there are studies proposing that syllable and stress-timing are dictated by the Isochrony or rigidity of inter-stress intervals, our study will distance from such discourse based on the following findings presented by RNM (1999):

- For the stress-timed which is postulated to have constant or isochronous inter-stress intervals, duration of inter-stress intervals were found to be directly proportional to the number of syllables in the utterance (Bolinger, 1965; Lea, 1974; O'Connor, 1965; Shen & Peterson, 1962 cited by Ramus et. al).
- Duration of inter-stress intervals depends on its position and contained syllable types within the utterance. Thus, there is reason to believe that inter-stress intervals do not seem to have a constant duration.
- In a study of six languages (Abercrombie, 1967; Roach, 1982) which includes syllabled-timed French Telegu and Yoruba, and stress-timed Arabic, English and Russian, variation in syllable duration is similar in all six languages and that stress pulses are not more evenly spaced in the second group of languages than they are in the first one.
- Mean duration of inter-stress intervals for all the analyzed languages is proportional to the number of syllables in the interval, stresses do not recur more regularly in English than they do in the other languages. (Dauer, 1983)
- Borzone de Manrique and Signorini (1983) have shown Spanish syllable duration is not constant and that inter-stress intervals tend to cluster around an average duration

These findings do not debunk the theory of Isochrony completely but adheres to the possibility of Isochrony being more related to principles inherent to the beats and surface rhythm of music (Benadon, 2009).

2.1.2 Phonological Account of Rhythm

This alternate theory to Isochrony points out that different types of rhythm depend on phonological elements of the language, and is a product of respective phonological properties. This extends the traditional syllable and stress timed dichotomy of rhythm, to the possibility of having other types of rhythm classes. In contrast to the rigidity of Isochrony to interstress intervals, Dauer (1983) proposes that there are multiple phonological properties that are independent and cumulative, from which two of the most important are the syllable structure, and vowel reduction characteristics of a language. This method allows us to describe languages, depending on their properties, to have various degrees of likeness to a stress-timed or a syllable-timed, vis-à-vis a continuous uni-dimensional model of rhythm.

Dauer's continuously-distributed model of rhythm postulates that a characteristic typical to stress-timed languages is a wider syllable inventory resulting to heavier syllables. Also important in this model of rhythm is vowel reduction in the unstressed syllables. These elements are consistent to stress-timed language's underlying concept of syllable stress that places some syllables to be more salient than the others. For languages that seem to be more syllable-timed and Mora-timed, it's just the opposite of the stress-timed with simplicity of syllables and lack of vowel reduction. Consistent to the phonological account of rhythm, Fenk and Fenk-Oczlon was able to come up with the following observation in the phonological account of rhythm.

Table 1. An Idealized pattern based on correlational model of phonological properties. *Source: Fenk and Fenk-Oczlon (2006)*

stress-timed rhythm	syllable-timed rhythm
metric properties:	*metric properties:*
high n of phonemes per syllable	low n of phonemes per syllable
low n of syllables per clause	high n of syllables per clause
low n of syllables per word	high n of syllables per word
high n of words per clause	low n of words per clause
non-metric properties:	*non-metric properties:*
VO order	OV order
tendency to prepositions	tendency to postpositions
low n of cases	high n of cases

2.2 The Difference in Filipino Rhythm and English Rhythm

2.2.1 Tendencies in the Multilingual Context

Narayan wrote that infants, and adults to some degree, recognizes and identifies languages by tracking the rhythmic patterns of speech. It enables the infant to recognize one language from another despite having no prior knowledge of the phonemic set of languages. As a person matures, the person reinforces the sounds and rhythm of the L1. It becomes evident when a person tries to learn a second language, where he or she favors the rhythm and sounds of the L1. That is the reason why students of the same L1 would have similar tendencies in speaking an L2.

Traditionally, multilingual education focuses on the teaching of sounds: vowels and consonants of the L2. For English learners, many of them also believe that if they want to get good pronunciation, they just need to work on individual sounds(Chen

et. al. 1995). However, often neglected is the subtle difference in speech rhythm which causes English speech to sound unnatural and metrical for Filipino speakers. Exposure to the L2 alone doesn't guarantee mastery and proper acquisition of the language, proper timing and exposure is necessary. This is the reason why there are numerous ways the Filipino language could sound regionally, and also the reason why there is a distinct sound for English spoken by Filipinos.

When the misspoken rhythm is not corrected, the incorrect rhythm is reinforced and once the unaware student encounters speakers of linguistic familiarity, the communication process may become hampered or impeded

2.2.2 Adaptation to the Mother Tongue

The most notable characteristic in the Filipino English is the rhythm (Thompson). Instead of speaking English in the stress-timed manner, Filipinos have the tendency to adapt English to their own syllable-timed rhythm.

Understanding the difference in speech rhythms is very important in speech and reading, since it will be the student's basis on segmenting one's speech. Speech rhythm is a very important prosodic feature, which can cause inadvertent ambiguity and confusion once an unaware speaker converses with a person of different rhythmic acquaintance.

This phenomenon is not only crucial in Filipino – English L1 and L2 tandem. With 170 regional languages in the country, it would be interesting to see how Filipino emerges as an L2 considering the wide variation between the regional languages and Filipino.

Below is an example of sentences where ambiguity could arise in the absence of proper rhythm.

Ibaun mo yang pagkain sa skwelahan.

The sentence above can be interpreted two ways, depending on the rhythm of the word "baunin."

- [i b**a** on] = bury
    - Bury that food at school.
- [I ba **o** n] =to bring
    - Bring that food to school.

Below is another example of possible ambiguity arising from inadvertent improper rhythm for a Filipino(L1) speaker.
Source:Chi et. al. (1995)

(a) Is it ele**men**tary?

(b) Is it a **le**mon tree? .

(a) Is that **Eu**rope?

(b) Is that your **rope**?

3. Acoustical Measurements for Speech Rhythm Classification

Ramus Nespor and Mehler (RNM, 1999) analyzed the acoustic signal of sentences of the following languages: English, Polish, Dutch, Catalan, Spanish, Italian, French and Japanese. The chosen sentences were segmented into vocalic and consonantal intervals. For each language, the sample standard deviation of the durations of the consonantal intervals (ΔC) and the proportion of time spent on the vocalic intervals (%V) were computed.

Figure 1 illustrates the distribution of languages over the (%V, ΔC) plane. The eight languages appear to be clustered into three groups. The groupings correspond to the intuitive notion of rhythmic classes. English, Polish and Dutch, conjectured to be stress-timed languages, are in one cluster, French, Spanish, Catalan and Italian, conjectured to be syllable timed languages, appear in a separate group. Japanese which is considered to be on a separate classification on its own appears isolated. Linear regression analysis shows that the %V and ΔC data have a correlation coefficient of –0.926, indicating a strong negative correlation

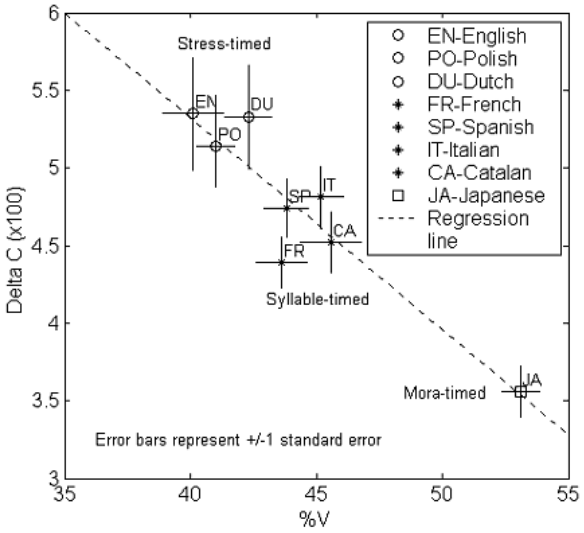

Figure 1: Distribution of Languages over the (*%V, ΔC*) Plane

3.1 Method

The study involved close implementation of the procedure presented by Ramus, Nespor and Mehler (RNM) so that our calculations can be directly compared with previous results. RNM was able to map the following languages: English, Polish, Dutch, French, Spanish, Italian, Catalan, and Japanese. Twenty sentences were recorded for each language, for a total of 160 utterances for the 8 languages.

Recorded sentences were labeled, segmented and classified as vowels and consonant. A computer program was written to

automatically take the duration from the transcription files, and compute the sought variables for each sentence.

3.2 Material

Recorded sentences by 4 speakers were taken from the DSP Filipino Speech Corpus. For each speaker, five sentences were chosen. Three sentences are declarative, one is interrogative, and another imperative-exclamatory. That is 20 sentences for 4 speakers, averaging 2.5 seconds in duration with minimal mid-sentence pause. The recording was done in the DSP sound room at 44.1 kHz sampling frequency.

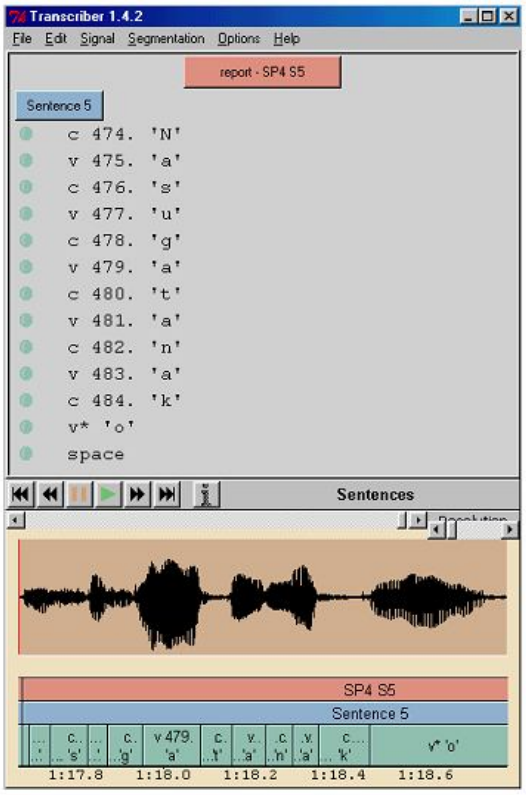

Figure 2: A sample transcription of "nasugatan ako" using the transcriber tool.

3.3 Transcription

The sentences were phonemically transcribed with a software called Transcriber 1.4.2, using visual and auditory cues. A computer program was written to classify the phonemes as vowels and consonants, with the following exceptions: Pre-vocalic glides (as in Filipino /wa/: "wa·lâ" or /yâ/: "kan·yâ") were treated as consonants, whereas post-vocalic glides (as in Filipino /áw/: "i·káw" or /áy/: "ka·máy") were treated as vowels.

The sentences are then segmented into vocalic and consonantal intervals, instead of measuring each individual phoneme. This convention is based on the assumption that infants rely on a coarse segmentation of speech, where the infant only distinguishes clusters of vowels and non-vowels. A vocalic interval is located between the onset and offset of a vowel, or a cluster of vowels. Similarly, a consonantal interval is located between the onset and offset of a consonant, or a cluster of consonants. As an example, the phrase "sa isang malayong lugar" which was pronounced as /sa'ísaŋmaláyoŋlugár/ has the following vocalic and consonantal intervals: /s/ /a/ /'i/ /s/ /a/ /ŋm/ /a/ /l/ /á/ /y/ /o/ /ŋl/ /u/ /g/ /á/ /r/. Words such as "huwag" commonly syllabicated into two syllables as /hu·wág/ but which were pronounced as a single syllable were segmented as /hw/ /a/ /g/. In order to process more data efficiently, a computer program was written to automatically segment the vocalic and consonantal intervals from phoneme transcriptions that are readily available in the DSP Filipino Speech Corpus.

3.4 Statistical Variables

RNM derived three essential variables that take one value in each sentence:

- Proportion of Vocalic Interval (%V)
- Standard Deviation of Vocalic Interval (ΔV)
- Standard deviation of the consonantal intervals within each phrase (ΔC)

The most definitive for the rhythm classification are the relationship of the %V and ΔC.

Proportion of Vocalic Interval **(%V)**, the proportion of the sum of the vowel duration and the total duration of the phrase. %C can be disregarded because it's proportional to %V, and therefore an isomorph.

$$\%V_i = \frac{\sum_{n=1}^{N_i} V_{i,n}}{\sum_{n=1}^{N_i} V_{i,n} + \sum_{m=1}^{M_i} C_{i,m}} \qquad (1)$$

- $V_{i,n}$ is the duration of n-th vocalic interval of the i-th sentence.
- $C_{i,m}$ is the duration of the m-th consonantal interval of the i-th sentence.
- N_i is the number of vocalic intervals in the i-th sentence
- M_i is the number of consonantal intervals of the i-th sentence

Standard deviation of the vocalic intervals within each phrase **(ΔV)**.

$$\Delta \mathrm{V}_i = \sqrt{\frac{1}{N_i - 1} \sum_{=1}^{N_i} \left(\mathrm{V}_{i,n} - \overline{\mathrm{V}}_i \right)^2}$$

Standard deviation of the consonantal intervals within each phrase(**ΔC**)

$$\Delta C_i = \sqrt{\frac{1}{M_i - 1}\sum_{m=1}^{M_i}\left(C_{i,m} - \overline{C}_i\right)^2}$$

4. Results and Analysis

Table 2. Vocalic intervals (%V), Standard deviation of consonantal intervals over a sentence (ΔC), averaged for each language and their respective standard deviations[a] *Source: Adapted from* RMN (1999)

Languages	%V (SD)	ΔC (SD) (x100)
English	40.1 (5.4)	5.35 (1.63)
Polish	41.0 (3.4)	5.14 (1.18)
Dutch	42.3 (4.2)	5.33 (1.5)
French	43.6 (4.5)	4.39 (0.74)
Spanish	43.8 (4.0)	4.74 (0.85)
Italian	45.2 (3.9)	4.81 (0.89)
Catalan	45.6 (5.4)	4.52 (0.86)
Filipino	**50.01(5.2)**	**4.06(1.23)**
Japanese	53.1 (3.4)	3.56 (0.74)

[a]**ΔC and the respective SDs are shown multiplied by 100 for ease of reading**

For the 20 Filipino sentences, the vocalic intervals have an average %V of 50.01% with a standard deviation of 5.2%. The consonantal intervals have an average ΔC of 0.0406 ms, with a standard deviation of 0.0123 ms.

In the 2-grouped syllable-stress timed convention, French, Spanish, Italian, Catalan and Japanese are considered to be syllable-timed. Filipino falls on the side of the syllable-timed languages and maintains close proximity to the regression line from the previous result. This validates our result with the negative correlation of (%V, ΔC) in any language.

French, Spanish, Italian and Catalan may be considered to form a single cluster with a (%V, ΔC) centroid of (44.55%,4.615 ms). Euclidean distance measurements reveal that Filipino (50.01%,4.06ms) is closer to Japanese (53.1,3.56ms), than to the centroid of the syllable-timed cluster. This shows that in the three-grouped convention, Filipino would be classified as Mora-timed.

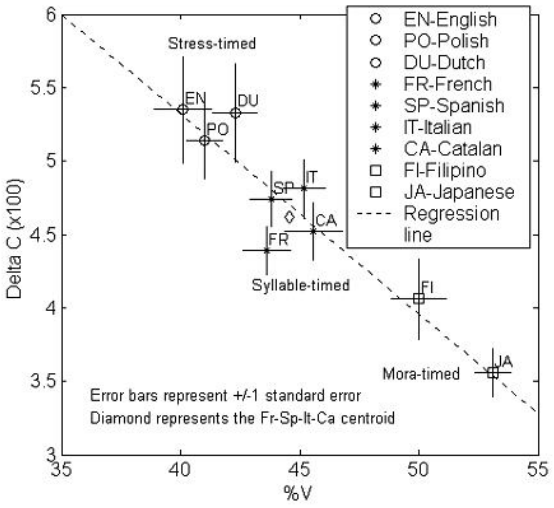

Figure 3: Distribution of Languages over the (*%V, ΔC*) Plane (with Filipino)

RNM compared language distributions on the (%V, ΔC), (ΔV,%V), and (ΔC,ΔV) planes. The %V and ΔC turns out to be the most definitive, in the variance perspective. The (%V, ΔC) is shown to be more definitive for the 3-grouped convention including Mora-timing using Analysis of Variance (ANOVA).

5. Conclusion

Under the two-classification scheme for speech rhythm, Filipino may be considered as syllable-timed. This result empirically validates the traditional views that Filipino is syllable-timed. Under an extended classification scheme which includes Mora-timing, Filipino may be considered as Mora-timed. These results also validate the phonological approach to rhythm classification.

The results allow us to infer that the rhythm models of syllable-timed and Mora-timed languages may be more similar to that of Filipino. Hence, works on speech rhythm on these languages may be more applicable to the speech rhythm model being developed for Filipino.

6. Recommendations

6.1 Mother-tongue Based Multilingual Education

To know the rhythmic typology of languages is very important, especially in a multilingual context. There are studies that support the importance of rhythm and knowledge of such rhythmic typology of a language in language discrimination, acquisition of syllable structures and segmentation of fluent speech .

6.1.1 Language Documentation of Filipino Languages

The initial stage of the DepEd order was preliminary research on the regional languages and the official language. The method used in this paper can be extended to the other regional languages in the Philippines, to come up with a standardized documentation and classification for the regional languages. The information can then be used for the planning of effective and contextualized MLE curriculum that is able to bridge the regional and the national languages.

On Intermediary Languages

There are propositions that there are more than three classes of rhythm. These studies aim to resolve the more complex syllabication or the stricter CV languages beyond Japanese. RMN postulated that it is possible for more rhythm clusters to be present in the continuous distribution model when it is populated with enough data. Drawing from his postulate, the position of the Filipino language in the distribution plane may indicate that Filipino belongs to an intermediate group, or to a group belonging to itself and other yet unclassified languages. With the sense of urgency in documenting the Filipino language, the need of preliminary information for the MLE, and relevance of rhythmic patterns to other linguistic properties, further studies to do the computational classification on the rest of the 170 regional languages should be encouraged.

6.1.2 Language Programming

With certainty on the rhythmic classification of Filipino as syllable-timed and Mora-timed, our educators may come up with contextualized education programs that are based on models that are more applicable to the Filipino speech. There are proven and tested models prescribed for learner-centered education in our academically-competitive neighbors which can be more applicable and effective for the Philippine context (Chen et. al. 1995; Lin et. al. 1994; Lan, 2000).

6.1.3 Identity and Intellectualization of Philippine Languages

"The language problem of the Philippines, according to most Filipino sociolinguists, is the problem of reconciling the competing demands of ethnicity (embodied in an individual's mother tongue or vernacular), nationalism (manifested in having and propagating a national language) and modernization (seen to be synonymous with the using an international language)." (Bautista, 1999: 113)

MLE is not just a program to raise the people's functional literacy, but to address such problems about ethnicity, nationalism, and modernization. The approach to language variation is a delicate matter in making or breaking the national unity and identity of a linguistically and culturally heterogeneous nation. The scientific and empirical description of the languages is a neutral force between the regional and national language. This scientific perspective could be the bridge that connects speakers of more than 170 regional languages. A crucial component of the strong MLE program is to develop materials which reflect a modern and scientific view of the languages. This plays a role in the intellectualization a language.

Efficiency and effectiveness of teaching both the L1 and L2 would depend on understanding how both languages work and differ. In a multicultural and multi-linguistic setting of the Philippines, it would require the development of localized curriculum that empowers the student and preserves both national and cultural identity. Results from this study could provide objective and scientific insight that builds the student's value for a L1, while not raising animosity towards the second language. Pursuance of this study may be a viable contribution to the intellectualization of the Filipino language, and ultimately a contribution to the country's reinforcement of a national identity.

6.2 Digital Speech Systems

In digital speech processing as in normal human speech, prior knowledge on segmentation and unit selection is crucial. Filipino speech recognition and synthesis can be improved by the development of language models, which are based on computational analyses of the language.

6.2.1 Rhythm-Based Language Identification

A promising application of this study would be for Rhythm-based Language Identification (LID) systems. For a multilingual speech recognizers and machine translators, a rhythm-based LID system may be implemented in order for code-switching for digital systems to take place.

6.2.2 Computer Aided Learning

Speech recognition and synthesis can then be implemented on applications that can be used in the education system. Computer-aided learning applications can be developed to complement the traditional classroom setup, alternative learning systems, and the teacher training programs. The drop of computer prices has made computer-aided learning a viable option to address the growing needs of the education system.

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