COMPUTERIZED SPELLING RECOGNITION OF WORDS EXPRESSED IN THE SOUND APPROACH© PHONETIC ALPHABET

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This article deals with the possible computer applications of the Sound Approach© English phonetic alphabet. The author reviews his preliminary research into some of the more promising approaches to the application of this phonetic alphabet to the processes of machine learning, computer spell-checking, etc. Applying the mathematical approach of rough sets to the development of a data-based spelling recognizer, the author delineates the parameters of the international cooperative research project with which he has been engaged since 1997, and points the direction of both the continuation of the current project and of future studies, as well.

Key Words: *machine learning, rough sets, voice recognition OS, spelling recognition, ESL pronunciation training, data mining, artificial intelligence, phonetic alphabet*

1. Background and Motivation

In 1993-1994, Dr. Michael Higgins of Yamaguchi University developed and did initial testing on a new system of phonetic spelling of the sounds in English as an aid to learning better English pronunciation and improving listening and spelling skills in English for Japanese students of English. The method, subsequently entitled "A Sound Approach", was tested initially on Japanese high school and university students. The results of the testing indicated that the creation of a "sound map" of English was very helpful in overcoming several common pronunciation difficulties faced by Japanese learners of English as well as improving their English listening, sight reading, and spelling skills. [1] It was further tested on Japanese Kindergarten children (ages 3-6), primary school pupils (ages 6-11), and Russian primary school pupils (ages 9-10) and secondary school students (ages 11-13) with similar results. [2-3] It was further tested on a wide range of international ESL students at the University of Regina. These latest results, while still preliminary, indicate that it is an effective and useful tool for helping any non-native speaker of English to overcome pronunciation and orthographic barriers to the effective use of English. The current stage of development for ESL/EFL (English as a Second Language/ English as a Foreign Language) includes lesson plans for teachers, flip-cards and a workbook for students, and laminated wall charts. The next stage of development includes interactive CD-ROMs and various computer applications.

One of the objectives of the Sound Approach to teaching English language is the development of a spelling recognition system for words expressed in a phonetic alphabet of forty-two symbols known as the Sound Approach Phonetic Alphabet (SA). The SA alphabet represents without ambiguity all sounds appearing in the pronunciation of English language words, and does so without using any special or unusual symbols or diacritical marks; SA only uses normal English letters that can be found on any keyboard but arranges them so that consistent combinations of letters always represent the same sound. (See Appendix A) Consequently, any spoken word can be uniquely expressed as a sequence of SA alphabet symbols, and pronounced properly when being read by a reader knowing the SA alphabet. Due to representational ambiguity and the insufficiency of English language characters to adequately and efficiently portray their sounds phonetically (i.e., there are between 15 and 20 English vowel sounds depending on regional dialect, but only five letters to represent them in traditional

English orthography), the relationship between a word expressed in SA alphabet and its possible spellings is one to many. That is, each SA sequence of characters can be associated with a number of possible, homophonic sequences of English language characters (e.g. "tuu" is equivalent to "to", "too", and "two"). However, within a sentence usually only one spelling for a spoken word is possible. The major challenge in this context is the recognition of the proper spelling of a homophone/homonym given in SA language. Automated recognition of the spelling has the potential for development of SA-based phonetic text editors which would not require the user to know the spelling rules for the language but only being able to pronounce a word within a relatively generous margin of error and to express it in the simple phonetic SA-based form. Computerized text editors with this ability would tremendously simplify the English language training process, for example, by focusing the learner on the sound contents of the language and its representation in an unambiguous form using SA symbols, and in a wider sense, allow for more equal power in the use of English by any native or non-native speaker of English.

2. **Approach**

The approach adapted in this project would involve the application of the mathematical theory of rough sets in the development of a data-based word spelling recognizer. The theory of rough sets is a collection of mathematical tools mainly used in the processes of decision table analysis, reduction and decision rules derivation from data (see, for instance references [4-9]).

In the word spelling recognition problem, one of the difficulties is the fact that many spoken words given in SA form correspond to a number of English language words given in a standard alphabet. To resolve, or to reduce this ambiguity, the context information must be taken into account. That is, the recognition procedure should involve words possibly appearing before, and almost certainly after the word to be translated into standard English orthography. In the rough-set approach this will require the construction of a decision table for each spoken word. In the decision table, the possible information inputs would include context words surrounding the given word and other information such as the position of the word in the sentence, and so on. Identifying and minimizing the required number of information inputs in such decision tables would be one of the more labor-intensive parts of the project. In this part, the techniques of rough sets, supported by rough-set based analytical software such as KDD-R [10-11], would be used in the analysis of the classificatory adequacy of the decision tables, and their minimization and extraction of classification (decision) rules to be used in the spelling recognition. It should be emphasized at this point that the process of minimization and rule extraction would be automated to a large degree and adaptive in the sense that inclusion of new spoken word-context combinations would result in regeneration of the classification rules without human intervention. In this sense the system would have some automated learning ability allowing for continuous expansion as more and more experience is accumulated while being used. The adaptive pattern classification part of the system development will be directed by Dr. Wojciech Ziarko, Computer Science Professor at the University of Regina, one of the pioneers and key members of the community of researchers in the area of rough sets and its applications to pattern classification and data mining, developer of several systems for data analysis and data pattern identification such as DATAQUEST [12], DATALOGIC [13] and most recently of the system KDD-R [10-11] .

3. **Rough Sets**

The theory of rough sets and their application methodology has been under continuous development for over 15 years now. The theory was originated by Zdzislaw Pawlak [4] in the 1970's as a result of long term fundamental research on logical properties of information systems, carried out by himself and a group of logicians from the Polish Academy of Sciences and the University of Warsaw, Poland. The methodology is concerned with the classificatory analysis of imprecise, uncertain or incomplete information or knowledge expressed in terms of data acquired from experience.

The primary notions of the theory of rough sets are the approximation space and lower and upper approximations of a set. The approximation space is a classification of the domain of interest into disjointed categories. The classification formally represents our knowledge about the domain, i.e., knowledge is understood here as an ability to characterize all classes of the classification, for example, in terms of features of objects belonging to the domain. Objects belonging to the same category are not distinguishable which means that their membership status with respect to an arbitrary subset of the domain may not always be clearly definable. This fact leads to the definition of a set in terms of lower and upper approximations. The lower approximation characterizes domain objects about which it is known with certainty, or with a controlled degree of uncertainty [7-8] that they do belong to the subset of interest, whereas the upper approximation is a description of objects which possibly belong to the subset. Any subset defined through its lower and upper approximations is called a rough set.

The main specific problems addressed by the theory of rough sets are:

1. representation of uncertain, vague or imprecise information;
2. empirical learning and knowledge acquisition from experience;
3. decision table analysis;
4. evaluation of the quality of the available information with respect to its consistency and presence or absence of repetitive data patterns;
5. identification and evaluation of data dependencies;
6. approximate pattern classification;
7. reasoning with uncertainty;
8. information — preserving data reduction.

A number of practical applications of this approach have been developed in recent years in areas such as medicine, drug research, process control and others [5,9]. The recent publication of a monograph on the theory and a handbook on applications facilitate the development of new applications [4-5]. One of the primary applications of rough sets in artificial intelligence (AI) is for the purpose of knowledge analysis and discovery in data [6]. Several extensions of the original rough sets theory have been proposed recently to better handle probabilistic information occurring in empirical data, and in particular the Variable Precision Rough Sets (VPRS) model [7-8] which serves as a basis of the software system KDD-R to be used in this project. The VPRS model extends the original approach by using frequency information occurring in the data to derive classification rules.

In practical applications of rough sets methodology, the object of the analysis is a flat table whose rows represent some objects or observations expressed in terms of values of some features (columns) referred to as attributes. Example decision tables are shown in Appendix B. Usually, one column is selected as a decision or recognition target, called a decision attribute. The objective is to provide enough information in the table, in terms of attributes of a sufficient number and quality, and a sufficient number of observations, so that each value of the decision attribute could be precisely characterized in terms of some combinations of various features of observations. The methodology of rough sets provides a number of analytical techniques, such as dependency analysis, to asses the quality of the information accumulated in such table (referred to as a decision table). The decision table should be complete enough to enable the computer to correctly classify new observations or objects into one of the categories existing in the table (that is, matching the new observation vector by having identical values of conditional attributes). Also, it should be complete in terms of having enough attributes to make sure that no ambiguity would arise with respect to the predicted value of the target attribute (which is the spelling category in the case of this application). One of the advantages of the rough sets approach is its ability to optimize the representation of the classification information contained in the table by computing so-called reduct, that is, a minimal subset of conditional attributes preserving the prediction accuracy. Another useful aspect is the possibility of the extraction of the minimal length, or generalized decision rules from the decision table. Rules of this kind can subsequently be used for decision making, in particular for predicting the spelling category of an unknown sound.

In the current preliminary testing of SA, a selection of homonyms were put into representative sentences. The words in the sentences were assigned numbers (features) according to a simple, and relatively unrefined, grammatical protocol. These numbers were then inserted into decision tables and using KDD-R it was found that the computer could accurately choose the correct spelling of non-dependent homonyms (i.e., those homonyms for which the simple grammatical protocol was unable to determine the correct spelling from the context) 83.3% of the time, as in the sentence, "The ayes/eyes have it." With dependent homonyms, as in the sentence, "We ate eight meals," the computer could accurately choose the correct spelling more than 98% of the time. Example decision tables for different homonyms used in these experiments are shown in Appendix B.

4. Major Stages of the Initial Project

The initial project can be divided into the following major stages which, depending on funding, could have significantly shortened time-frames:

Stage 1

Construction of decision tables for the selected number of English language homonyms or homophones. This part would involve research into possible contexts surrounding the selected words in typical sentences and their representation in decision table format. This would also involve rough set analysis, optimization and testing (with respect to completeness and prediction accuracy) of the constructed tables using existing software systems Dataquest or KDD-R. The related activity would be the extraction of classification rules from such tables. This is a very labor-intensive part of the project since the number of possible homonyms or homophones is in the range of approximately 3000. The time-frame for this part of the project is approximately two years. Dr. Michael Higgins, Professor at Yamaguchi University Faculty of Technology, is in charge of the linguistic aspects of representing the rule contexts of the English homonyms in basic decision tables. The actual decision table construction for the advanced adaptive pattern classification is under the supervision of Dr. Wojciech Ziarko, Computer Science Professor at the University of Regina.

Stage 2

Editor development using the tables constructed in Stage 1 as a main component of the spelling recognition system. The editor would have some learning capabilities in the sense of being able to automatically acquire new feedback word combinations in cases of unsuccessful recognitions. The editor will be constructed in a similar pattern to Japanese Romaji-Hiragana-Kanji word processing selection tables. (See Appendix C) The estimated time for this stage of the project is approximately one year to construct a working prototype system assuming two full-time programmers would be involved in the system development. The system will be developed for different computational environments including PC and UNIX platforms.

Stage 3

This stage would involve both system testing and refinement, going through multiple feedback loops until satisfactory system performance and user satisfaction is achieved. The system would be tested with English language students at Yamaguchi University and other international locations. The accumulated feedback would be used to retrain and enhance the system's spelling recognition capabilities and to refine the user's interface to make it as friendly as possible. It is also felt that using SA, it can be adapted to any regional pronunciation style (e.g., Australian, British Received, Indian, Irish, etc.) by offering the user their choice of "keyboard" for their particular area. For example, in standard International Broadcast English the word "table" would be represented in SA by spelling it "teibul", whereas in Australian English it could be represented in SA by spelling it "taibul" and the computer would still offer the standard orthographic representation of "table" in the spell-checking process in either "keyboard" format. At this stage, not only could it be used as an ordinary spell checker, but could be programmed for speech as well so that the user could have the word or passage read and spoken by the computer in either sound spelling or in regular spelling. As a normal spell checker, for example, it would be difficult to distinguish between the words "bother" and "brother." However, with speech capacity, the user could potentially hear the difference and catch the mistake. This could also become an excellent teaching/learning device for practicing and learning correct pronunciation whether for native or for non-native English speakers. (See Appendix D for a more complete listing of possible future developments stemming from this initial project.)

Stage 4

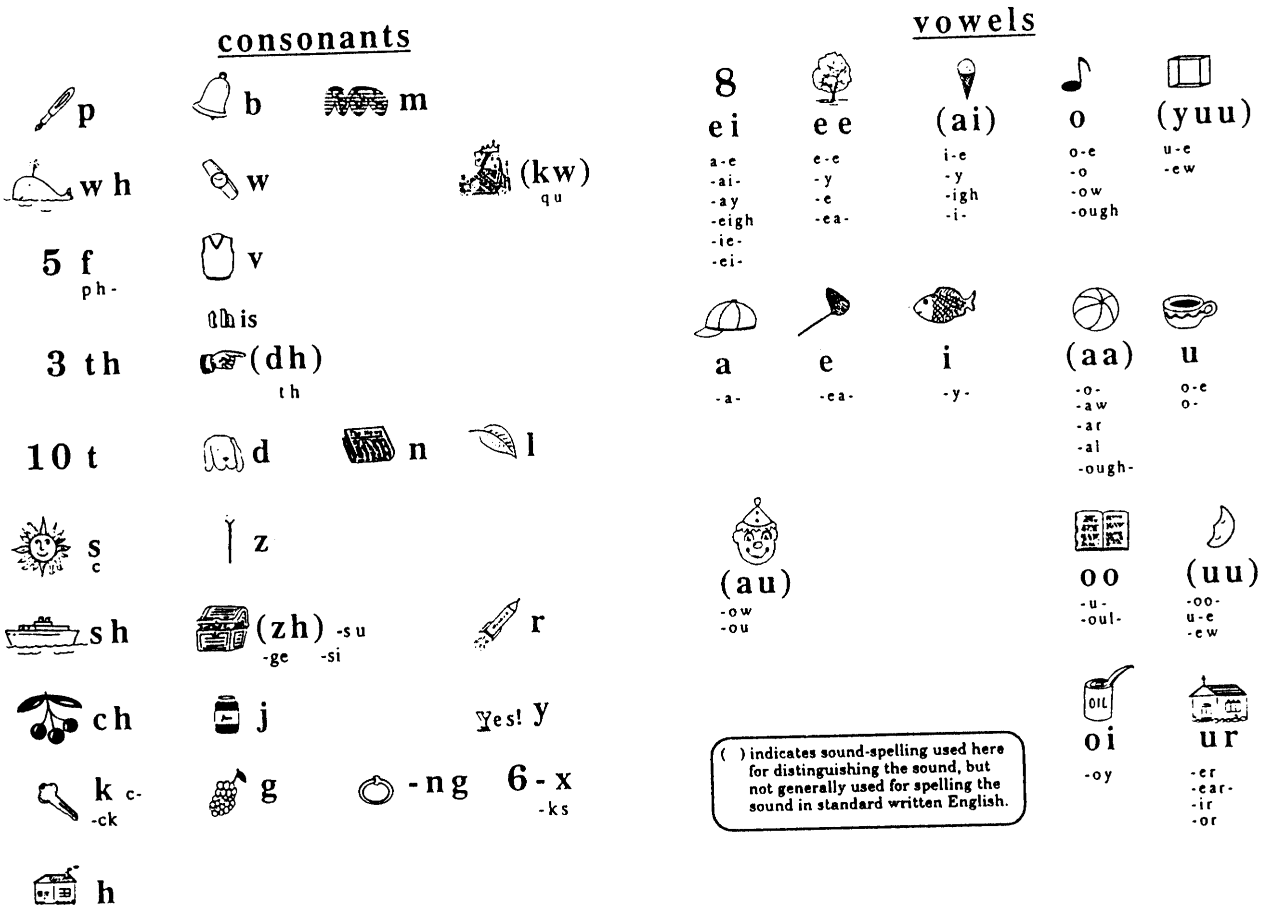
System commercialization.

Conclusion

In the initial study on the efficacy of the Sound Approach© phonetic alphabet in meeting the requirements for the development of easily accessible and accurate computer word recognition capability conducted at the Universityof Regina in 1997, the VPRS (Variable Precision Rough Sets) model was used to construct decision tables on a list of various English homonyms. It was found that the Sound Approach© phonetic alphabet and the VPRS model were quite compatible with each other in determining generalized decision rules used in decision making for predicting the correct spelling of a word written either phonetically or in standard English orthography. It was found that even using a relatively unrefined grammatical protocol, the software KDD-R, which is based on the VPRS model, was able to correctly identify the correct spelling of non-dependent homonyms 83.3% of the time. This accuracy rate rivals already extant forms of standard spelling recognition systems. When confronted with dependent homonyms, the computer could accurately choose the correct spelling more than 98% of the time.

It is felt that with further refining of the grammatical protocol and expansion of the sample sentences using the approximately 3000 English homonyms, a spelling recognition system could be constructed that would allow even non-native speakers of English to gain equal access and power in the language. Further, this would be but one of the necessary building blocks for the construction of a total voice recognition operating system, and a major step forward in computer speech technology. It is also considered that these advancements have considerable commercial possibilities that should be developed.

Appendix A — Sound Approach Phonetic Alphabet System



Appendix B — Example Decision Tables

Values of the observations:

0: none
1: verb
2: noun/pronoun
3: adjective
4: adverb
5: article
6: connective
8: number
9: possessive
a: let, please, etc.
b: will, shall, can, etc.
c: prepositions

Sample Table 1: "ai" (IPA symbol: aɪ); (Sound Spelling: ai)

Head Word	Sentence Number	-5	-4	-3	-2	-1	Spelling
1	15	2	b	1	2	c	aye
2	16	8	2	c	2	1	aye
3	17	0	0	0	0	0	aye
4	18	0	0	0	0	5	ayes
5	19	0	0	2	1	9	eye
6	20	0	2	1	2	5	eye
7	21	0	0	0	0	9	eyes
8	22	0	0	0	0	5	eyes
9	23	0	0	2	1	1	eyes
10	24	1	1	c	1	5	eye
11	25	0	0	0	0	2	eyed
12	26	0	0	0	5	2	i
13	27	0	0	0	0	0	I

Sample Sentences:

15. "I'll love you for aye."
16. "All those in favor say, 'aye'."
17. "Aye, Captain."
18. "The 'ayes' have it."
19. "He injured his eye at work."
20. "He gave me the eye."
21. "Her eyes are blue."
22. "The eyes have it."
23. "She's making eyes at me."
24. "I'm going to keep an eye on you."
25. "He eyed the situation carefully before he went in."
26. "The letter i comes after the letter h and before j."
27. "I want to go out tonight."

Sample Table 1a — Reduct: "ai" (IPA symbol: aɪ)

Head	-2	-1	Spelling
1	2	c	aye
2	2	1	aye
3	0	0	aye
4	0	5	ayes
5	1	9	eye
6	2	5	eye
7	0	9	eye
8	0	5	eyes
9	1	1	eye
10	1	5	eye
11	0	2	eye
12	5	2	i
13	0	0	I

Non-determinable

Sample Table 2: "a" (IPA symbol: æ); (SA Spelling: ant)

Head Word	Sentence Number	-5	-4	-3	-2	-1	Spelling
1	1	0	0	c	1	5	ant
2	2	0	2	1	c	5	ant
3	3	5	3	0	5	3	ant
4	4	0	0	0	0	9	aunt
5	5	0	0	2	1	9	aunt

Sample sentences:

1. "There is an ant crawling on the window."
2. "He kicked over an ant hill."
3. "The red ant attacked the black ant."
4. "My aunt Patti came for a visit."
5. "Hello. I'm your aunt."

Sample Table 2a — Reduct: "a" (IPA symbol: æ);

Head	-1	Spelling
1	c	ant
2	3	ant
3	9	aunt

Appendix C — Model of Users Word Processing Selection Tables

(Word in SA)

eid ——— (Menu Choices with minimal meaning)

aid (noun)		A person or thing that offers help
aid (verb)	→	To give support or help
aide (noun)	→	An assistant or a nurse's aide
ade (noun)	→	A drink made from fruit juice and water

Note: The selection order will change based upon the number of times any particular word is chosen with the most common going to the top of the list. In the above example, the word "ade" is the least commonly used in ordinary context and so appears at the bottom.

Appendix D: Future Possibilities and Ramifications

In addition to the grammar-based spelling recognition system outlined in the foregoing pages, there are several other applications, some of which have been also mentioned briefly above, that should be more specifically mentioned.

* A phonetic keyboard specifically for non-native English users who need to write in English but do not have a full command of English spelling rules. This keyboard could also be programmed to reflect regional/language-grouping pronunciations of English in much the same way that the sound recognition system could be programmed (i.e., Australian, British, Japanese, Dutch, German, Russian, Filipino, Vietnamese, Indian, etc.). This would put specific vowel sounds, for example, on the same key: ei ee ai yuu aa oo uu oi ur. The same would hold true for the consonant sounds that are expressed in SA using more than one letter, as in dh.

* Full text-reading capability. If the computer can "learn" how to pronounce words using SA as the programming base, then truly natural sounding text reading capacities are possible.

* Single word pronunciation text reading in either SA or standard spelling.

* SA training AVI's and interactive CD-ROMs.

* Fully integrated voice recognition OS which can be adjusted according to regional/language-grouping "keyboards" as previously described.

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「サウンドアプローチ」による
音声アルファベットで表記された単語の綴り認識のコンピューター化

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この論文は、「サウンド・アプローチ」による英語の音声アルファベットのコンピューター化の可能性について論じている。この音声アルファベットは、コンピューター自身の学習、そして、それによる綴りのチェックなど、多方面へ応用がなされるのではないか、その将来性に著者は期待して自己の初期研究を顧みた。データに基づく綴り認識装置の開発に数学の「ラフセット」を適用して、1997年から関わってきた国際共同研究プロジェクトのパラメーターを定義する。これは、現在の共同プロジェクトの継続および将来の研究方向を定めるものであると言える。