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Brazilian Sign Language Lexicography and Technology: Dictionary, Digital Encyclopedia, Chereme-Based Sign Retrieval, and Quadriplegic Deaf Communication Systems

THIS ARTICLE DISCUSSES three encouraging new developments in Brazilian Sign Language (Língua de Sinais Brasileira, or Libras) lexicography and technology.[1] These are as follows:

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1. An illustrated trilingual encyclopedic dictionary with 1,620 pages and 9,500 entries in English, Portuguese, and Signwriting, with grammar classifications, definitions, and examples of the appropriate use of glosses and signs, as well as thousands of lifelike illustrations and descriptions of sign forms (i.e., cheremic structure) and meanings (i.e., sign referents).

2. A digital encyclopedia with a databank of fifty-six hundred signs glossed in Portuguese and English, each fully described and illustrated in its sign form and meaning. The digital encyclopedia is composed of two subsystems:

2.1. A sublexical indexing system that analyzes the structures of sign forms and displays them as alphanumeric code sequences in which letter strings correspond to cheremes and digits correspond to their respective allochers. By examining the signs and their sublexical components, users are able to retrieve the signs they are looking for.

2.2. A menu-based, sign-retrieval system that allows deaf users to search for and locate specific signs based on five parameters (i.e., hands, fingers, place, movement, and facial expression) along with their respective cheremes (e.g., articulation, orientation) and allochers (e.g., 1–9, A–Z). Because deaf users can search for signs on the basis of their sublexical components, this system enables them to dispense with traditional and less effective strategies, thus taking sign-language dictionaries beyond the alphabetical indexing of glosses and sign-language handbooks beyond the semantic grouping of signs.

3. A face-to-face communication and telecommunication system that deaf users with quadriplegia can operate with an eye-blink or air-puff. This enables them to easily select scanned, animated Libras signs and to compose Libras-based sign messages. Once the messages have been composed, the system enables these users to send the messages via computer networks. It also allows them to convert the messages into ASL-based sign messages. Finally, it enables users to have the messages printed and spoken with digitized speech in Portuguese and English. By allowing Brazilian deaf people with quadriplegia to compose messages in Libras and to convert them to spoken Portuguese, the system makes it possible for them to converse with both deaf and hearing blind people. And by converting those messages

from Libras to both ASL and English, it permits them to communicate with American and Canadian interlocutors and hearing blind people.

The Brazilian Sign Language Trilingual Encyclopedic Dictionary

The first dictionary of Brazilian Sign Language has recently been published (Capovilla and Raphael 2001c, 2001d). The dictionary has now become a reality after five years of intensive research cooperation between Libras deaf instructors from the National Federation of Deaf Education and Integration and hearing scientists from the Institute of Psychology at the University of São Paulo. Costello's (1994) dictionary of ASL was the inspiration for the new dictionary, and the Brazilian deaf authorities at the Federation's National Coordination of Libras Courses, as well as Brazilian scientific authorities and organizations, have approved its contents. It is a historic publication of paramount social importance and is already serving as a powerful instrument in the advancement of quality bilingual education in Brazil, as well as in the full exercise of the constitutional rights of Brazilian deaf people.

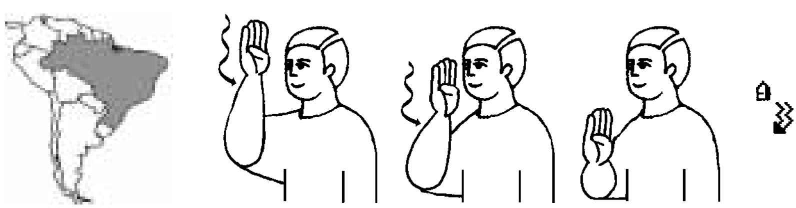
The first edition contains more than twenty thousand illustrations in two hardcover volumes. The main body contains a full description and illustration of each sign form and meaning. In addition, the dictionary includes three introductory chapters, an English-to-Portuguese dictionary, a semantic index and content section, three chapters on education and deafness, and three chapters on technology and deafness.

Introductory Chapters and the Main Body of the Libras Dictionary

The first introductory chapter (Capovilla, Raphael, and Luz 2001a) explains the structure of the dictionary and how to use it. The second (Capovilla and Raphael 2001a) illustrates the digital spelling of letters and numbers in Libras as well as other handshapes that can be systematically found in the dictionary. The third introductory chapter (Capovilla and Sutton 2001) teaches users how to read and write Libras signs in Signwriting, a cheremic system. In seventy-one pages it offers an extended, systematic description and explanation of the main principles and rules of Signwriting (Sutton 2000) for writing parameters, cheremes, and allochers. It also presents a systematic and fully illustrated account of how to apply those principles and rules to the precise writing of Libras signs.

The main body of the dictionary follows the three introductory chapters and is divided into two volumes (Capovilla, Raphael, and Luz 2001b, 2001c). Figure 1 illustrates one of the dictionary sign entries, the Libras sign BRAZIL. As the figure shows, each sign entry is composed of a number of items divided into a box above and text below the entry. The box contains three items:

1. a lifelike illustration of sign meaning (at left), which helps preliterate deaf children apprehend sign meaning without having to depend on Portuguese glosses



Brasil *(inglês: Brazil)*, **brasileiro(a)** *(inglês: Brazilian)*:
Brasil: *República Federativa, localizada na América do Sul. Sua capital é Brasília, a língua oficial é o Português e a maioria da população é católica, mas crescentemente protestante. É o maior país da América Latina e o quinto maior do mundo em extensão. A sua economia é a mais diversificada e a de maior potencialidade da América do Sul. Porém ainda há inúmeros locais de grande pobreza. Ex.: Tenho certeza que o Brasil tem um enorme potencial pata o futuro.* Brasileiro(a): *adj. m. (f.) Pertencente ou relativo(a) ao Brasil. Ex.: O povo brasileiro vota em eleições diretas. s. m. (f.) O(a) habitante ou natural do Brasil. Ex.: Como o sufixo "eiro" designa aquele que vive de uma atividade (padeiro, por exemplo), os primeiros extratores de pau brasil foram chamados de "brasileiros". Daí nosso nome. Caso contrário, seríamos hoje conhecidos como brasilienses, como seria esperado, uma vez que o sufixo "ense" designa "o que é natural de".*
Mão direita em **B**, palma para a esquerda, diante da face. Movê-la para baixo com um movimento ondulatório para os lados.

Figure 1. A typical sign entry (i.e., BRAZIL) from the Libras dictionary that exemplifies the components of each sign entry. The top box includes a lifelike illustration of sign meaning (at left), a lifelike illustration of sign form (in the center), and a Signwriting rendition of the sign (at right). The text at the bottom includes Portuguese and English glosses, grammar classification, gloss definition, examples of adequate use of glosses and signs, and a precise description of sign form.

2. a lifelike illustration (in the center) of sign form in stages of movement, which allows for greater resolution of overall movement. It also allows for the graphic animation of signs that the Libras-based communication system implements for deaf users with quadriplegia (described later in this article)

3. a Signwriting rendering (on the right) of the sign, which provides the first written record of Libras. Its purpose is to establish a consensual orthography of Libras in the hope that such sign writing may eventually evoke internal "signing" from the deaf mind as effectively as alphabetic writing evokes internal "speech" from the literate hearing mind, thus increasing children's formal analytic thinking resources in Libras.

The text at the bottom of each box is composed of five items:

1. Portuguese and English glosses, which provide an alphabetic indexing of signs and permit translating from Libras to Portuguese and English
2. grammar classification, which helps deaf children learn Portuguese grammar and understand how to use words in sentences and how the sentence context affects the morphemic structure of words
3. gloss definition, which helps deaf children increase their Portuguese vocabulary and world knowledge
4. examples of the appropriate use of glosses and signs, which leads to better skills in grammar and semantics, thus improving word use by deaf people and sign use by hearing people
5. sign form description, which allows for the precise articulation of signs by the Libras novice and complements the lifelike illustrations of sign forms

English-to-Portuguese Dictionary and Libras Semantic Index and Content

After the main body of the dictionary, the reader finds an English-to-Portuguese dictionary (Capovilla and Luz 2001) that provides an alphabetical index of all of the English glosses in the dictionary along with their corresponding Portuguese glosses, which serve as sign entries. The purpose of including such a dictionary is twofold: helping deaf Brazilians use Libras to read English and helping English readers locate Libras signs even if they are unable to read Portuguese. In so doing, the dictionary serves as an instrument that will help linguists worldwide to study Libras and also help Brazilian deaf people to read and comprehend English. It is important to note that Libras conditions the relationships between English and Portuguese glosses in the dictionary. That is, the Portuguese glosses listed as corresponding to English glosses are not literal translations but rather contextual translations accepted by the deaf community and mediated by Libras.

In addition, the dictionary contains a semantic index (Capovilla and Raphael 2001b) and semantic content (Capovilla et al., Conteúdo semântico, 2001). They present all of the thematic categories the dictionary encompasses and enable users to quickly and easily locate semantically related signs. The semantic index lists thematic categories that encompass all of the signs in the dictionary. The semantic content lists every Libras sign in the dictionary and arranges them in the thematic categories. Although the main body of the dictionary is a reference tool for learning individual lexical signs, the semantic index and content help users to learn how to use semantically related signs. By facilitating sign learning, comprehension, and use, the dictionary can thus serve as a tool for teaching Libras in the context of conversation. It also provides information on specific academic areas in Libras and will help educational professionals to translate academic material into Libras in order to improve the quality of bilingual education in Brazil.

Chapters on Education and Deafness

After the English-to-Portuguese dictionary and the semantic index chapters, the reader finds three chapters on education and deafness. The first one (Capovilla 2001a) describes various educational philosophies and approaches to the deaf child and explains the evolution from oralism to Total Communication to bilingualism. It emphasizes the importance of language for the social, emotional, and intellectual development of the deaf child and revisits various psychosocial factors and historic concepts that help explain attitudes toward deaf people from the Greeks to contemporary times. It analyzes research findings that justify the shift in the education of deaf children from oralism to Total Communication to bilingualism and stresses the importance of bilingual education.

The second chapter (Capovilla et al., *Signwriting,* 2001) discusses how Signwriting may enhance bilingual education by helping people to attain biliteracy in the reading and writing of both orthographies (i.e., the alphabetic code of hearing people and the cheremic code of deaf people). It reminds us that writing systems provide languages and their communities with the stability of social contracts, as well as with geographic and historic coalition and continuity. The chapter explains that writing brings together members of language communities scattered over vast territories and allows the evolution of their culture and the continuity of their heritage over generations. Without the benefit of a stable and reliable writing system, a language remains limited and ends up dissipating in geographic and historic variations.

The chapter concludes that the advent of an effective visual system (such as Signwriting) for writing signs may become as important to the building of deaf history as the advent of the alphabet has been for the history of Western hearing civilization. Because it does not represent meaning directly, Signwriting is not ideographic writing. Instead it maps the units (i.e., cheremes) of the sublexical structure of signs, just as the alphabet maps the units (i.e., phonemes) of the sublexical structure of spoken words. Because the alphabetic code maps speech, its decoding by hearing readers produces internal speech, and that is why it is so powerful in the cognitive development of hearing children. By the same token, since Signwriting maps signs, its decoding by deaf readers produces internal signing, and that is why it may be powerful in the cognitive development of deaf children. The chapter concludes that, both as an instrument to help deaf people to systematically reflect and improve on their own language and as a vehicle of metalanguage, Signwriting is expected to produce sign language formalization and contribute to the cognitive and language development of deaf children.

The third chapter (Capovilla and Capovilla 2001) explains the alphabetic code processing and reading acquisition difficulties that deaf children exhibit, especially semantic paragraphias and paralexias. Given that the alphabetic writing system maps speech sounds but not sign forms, there is a functional continuity between alphabet and speech on one hand but a discontinuity between alphabet and sign on the other. For the hearing child, the alphabetic decoding of print via grapheme-to-phoneme conversion (i.e., phonemic decoding) produces the very same lexical items (i.e., the phonological image of spoken words) that the child uses for thinking and communicating. However, for the deaf child, the alphabetic decoding of print via digital spelling does not produce the same lexical items (i.e., the cheremic image of lexical signs) that the child uses for thinking and communicating in daily life. That is why it is so hard to learn and so poor a vehicle for the natural fostering of thinking by deaf children.

In attempting to solve the discontinuity problem, the oralist approach proscribed sign language and prescribed speech articulation training, lipreading, and cochlear implants. However, because deaf people have no access to phonology, the alphabetic code is opaque, and only about 30 percent of speech sounds are visible. Moreover, a cochlear implant is not always indicated, and even when it is, there is no guarantee of its effectiveness, availability, affordability, and service reliability in peripheral countries exposed to political or economic crises that frequently disrupt public and private health services and discontinue treatment and technical assistance. In order to solve the discontinuity problem, a bilingual approach informed by cognitive neuropsychology proposes to maintain sign and to replace the alphabetic code with the cheremic writing of sign language. In so doing, deaf children may benefit from visual print in precisely the same way as hearing children benefit from alphabetic print in order to reach higher levels of cognitive development and sign language formalization. The chapter concludes that eventually, with a system such as Signwriting, the decoding of print may directly produce the same lexical items (i.e., the cheremic sign images) that the deaf child uses for thinking and communicating.

Chapters on Technology and Deafness

The last three chapters present technological developments for deaf education and communication and discuss the issue of technology and deafness. The first chapter (Capovilla 2001c) provides a full explanation of the benefits and problems of cochlear implants (i.e., computerized prostheses that perform the function of the lost hair cells by directly stimulating the auditory nerve of the cochlea). The chapter provides technical information about hearing and hearing loss, as well as about cochlear implants and their technical indications and contraindications. For instance, it discusses the indications for adults who have sustained profound bilateral loss postlingually but for less than ten years and who derive no benefit from amplification devices. It also discusses the indications for children from two to seventeen years of age who present profound bilateral loss either prelingually (i.e., before two to four years of age) or postlingually. That indication can be made only if those children have sustained the loss for less than six years and only if they have systematically failed closed-set auditory discrimination tests and, even so, only after they have concluded an auditory rehabilitation program for more than six months with the use of adequate amplification devices.

The chapter also provides information on the procedures involved in the assessment, surgery, speech-processor programming, and auditory rehabilitation. It presents some of the limitations and benefits of implants, especially with respect to multichannel implants that improve lipreading skills and may produce auditory recognition independent of lipreading. It discusses some of the effects the technology has created in the deaf community as well as that community's negative reaction to implants. Finally the chapter provides information on how to obtain the implant in Brazil and offers practical recommendations and cautionary notes. Thus it offers information relevant to educators and practitioners who counsel both deaf people and the parents of deaf children who are wrestling with the question of whether to accept or reject implantation.

The second chapter (Capovilla et al., *SignoFone,* 2001) describes a multimedia system named SignoFone (Sign-Phone), which is based on Libras, for face-to-face telecommunication by deaf people with physical impairments. The chapter uses graphically animated Libras signs and their corresponding printed and digitized spoken words in Portuguese and English. The system allows users to select signs either directly (i.e., via a mouse or touch-sensitive screen) or indirectly (i.e., via automatic scanning and devices sensitive to air-puff, eye-blink, or discrete movements). Thus, users can easily arrange signs in messages, which can then be sent via computer networks, as well as printed and spoken in Portuguese and English. The purpose is to allow for sign-based telecommunication between deaf interlocutors and for face-to-face, sign-to-speech communication between deaf and hearing interlocutors.

The system's main purpose, however, is to allow sign-based and sign-to-speech communication by Brazilian deaf people who have quadriplegia or have undergone amputations. Thus, deaf people with serious impairments such as cerebral palsy can become active members of their sign language community and pursue academic and professional achievements. Also, deaf people who have suffered spinal cord injury may remain active members of their sign language community and resume their work and social life. Finally, deaf people who have a terminal illness and who have developed a fatal motor neuron degenerative disease such as amyotrophic lateral sclerosis may retain their personal identity, obtain adequate medical care, and take an active part in the much-needed psychological and spiritual counseling in sign language that can be provided in such situations (Capovilla et al., *Esclerose lateral amiotrófica,* 2000). The chapter describes the multimedia communication system and explains how to configure it to particular users and conference groups.

The third chapter (Capovilla et al., *BuscaSigno,* 2001) describes the prototype of Sign-Tracking, the sublexical sign-retrieval system of Libras signs that allows deaf people to retrieve these signs from the *Digital Encyclopedia* without depending on Portuguese glosses. It also allows users to select signs for communication in the Sign-Phone communication system without depending on semantic indexing. This article describes a new, upgraded, and more powerful version of the sublexical sign-retrieval system of Libras signs. It also discusses a brand-new version of the communication system that uses the sublexical sign-retrieval system as a gateway for sign selection for communication.

The Digital Encyclopedia of Brazilian Sign Language: Its Sublexical Indexing System and Menu-Based Sublexical Sign-Retrieval System

The *Digital Encyclopedia of Brazilian Sign Language* (Capovilla et al., *Enciclopédia Digital,* 2003) provides a precise description and real-life illustration of each sign form (i.e., sublexical structure) and each sign meaning (i.e., lexical referent) it contains. Each sign is glossed in

Portuguese and English and is described and illustrated in its cheremic structure and meaning. The encyclopedia indexes all of the signs based on their sublexical structure (explained later). Such a highly advanced sublexical indexing strategy permits dispensing with other less sophisticated indexing strategies, such as the alphabetic ordering of glosses and the semantic grouping of thematically related signs.

Sign language books that are printed on paper have relied on traditional indexing strategies such as the alphabetic ordering of glosses in dictionaries (Capovilla, Raphael, and Luz 2001b, 2001c) and the semantic grouping of related signs in handbooks of functional use (Capovilla 2003). The problem with the semantic grouping strategy is that, by not taking advantage of a language system, it fails to provide a reliable and systematic means for effective sign retrieval. In fact, when trying to group signs semantically, if one distributes the signs among a few basic classes, the large groupings that result prevent effective sign perusal and retrieval. In turn, if one increases the number of classes in an attempt to reduce class size, then one is faced with classification ambiguities that make the signs difficult to retrieve. Even more serious retrieval problems may occur if one uses levels of classification (i.e., if one divides the classes into subclasses). It is therefore clear that, even though the semantic grouping of signs is a good strategy for fostering contextual sign learning, it works poorly as an effective sign-retrieval mechanism, which works well only if it is based on a language system.

The problem with the alphabetic ordering strategy is that, despite being based on an established language system (i.e., the alphabet), it pertains to the spoken language of hearing people and not to the signed language of deaf people. In other words, the usual strategy of indexing signs according to the alphabetic indexing of their glosses ironically requires deaf people to relinquish their own language as a tool for acquiring knowledge. Although it means well, the alphabetic strategy remains essentially chauvinistic, ethnocentric, and hearing centered. Perhaps it is time for technology to concentrate on sign language as not only an object of knowledge but also a tool that deaf people can use to acquire knowledge of both the world and language itself. Powerful microcomputers now make this a good idea whose time has come. Nowadays sign language e-books (i.e., electronic books) may rely on more sophisticated linguistic indexing strategies, such as cheremic encoding, that can map the sublexical structure of signs to allow for effective sign retrieval. Yet, despite the obvious technical advantages of cheremic indexing and retrieval systems, the question of efficiency is but one of many relevant aspects. For instance, a sign-retrieval system based on sign properties will be not only more pragmatically effective but also more anthropologically respectful.

Sublexical Indexing System

The sublexical indexing system (Capovilla, Duduchi, and Rozados 2003) used in the *Digital Encyclopedia* enables the menu-based, sign-retrieval system to locate any of the signs in the Libras databank. Figure 2 illustrates the screen layout of the sublexical indexing software, which contains seven windows. From top to bottom, windows 1–7 and their respective contents are as follows: window 1: sign gloss in Portuguese; window 2: alphanumeric sequence that encodes the sublexical structure of the sign form; window 3: sign gloss definition, grammar classification, functional use description, and description of the sign form; window 4: the sign-meaning illustration filename and the directory in which it is located; window 5: the sign-meaning illustration; window 6: the sign-form illustration filename and the directory in which it is located; and window 7: the sign-form illustration. Thus, the figure shows an illustration of the Libras sign AMAZON in its form (window 7) and meaning (window 5), a description of its meaning and form (window 3), and finally its sublexical structure (window 2).

In figure 2, window 1 displays the Portuguese gloss (i.e., "Amazonas") that corresponds to the Libras sign on the screen. Window 2 displays the cheremic components of that Libras sign in the form of an alphanumeric code sequence in which strings of letters stand for cheremes and numbers stand for allochers. According to the alphanumeric code sequence, the cheremic components of AMAZON are AMD36 (right-hand articulation: open), OP3 (right-palm orientation: forward), OMD5 (right-hand orientation: pointing up), LA32 (articulation place: touching forehead), MMD4 (right-hand movement: toward the right), and MDD11 (right-hand finger movement:

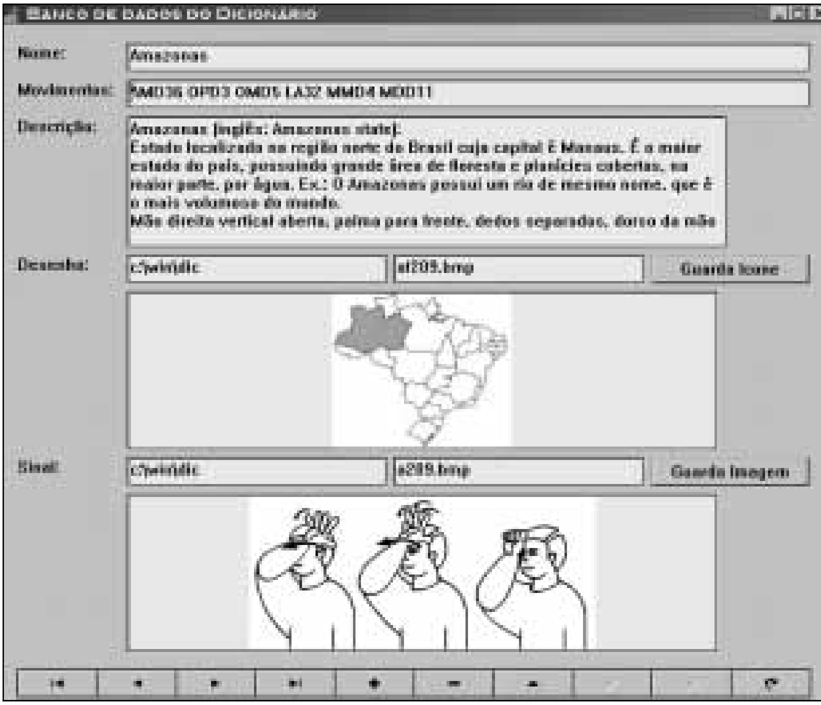


FIGURE 2. Screen layout (with its seven windows) of software for sublexical indexing of Libras signs. The sign form AMAZON is encoded as an alphanumeric sequence of cheremes and allochers (window 2). It is also thoroughly described in Portuguese (last section of window 3) and fully illustrated in stages of movement (window 7). The sign meaning is pictorially illustrated (window 5), glossed in Portuguese (window 1) and English (first section of window 3), and thoroughly defined in Portuguese (center of window 3).

closing one by one). Window 3 displays both Portuguese and English glosses that correspond to the Libras sign and gives a definition in Portuguese and an example of the sign's functional use. It also displays a written description of the sublexical sign structure that is alphanumerically encoded in window 2. That is, the easy-to-follow Portuguese description in window 3 maps—point by point and in order—every chereme and its respective allocher of the alphanumeric sequence in window 2, thus precisely reflecting the sign form in window 7. Window 5 displays the picture of what the Libras sign stands for (i.e., the Amazon state), and window 4 displays the filename corresponding to that picture, as well as the directory where that graphic file is stored. Window 7 displays the Libras sign form (i.e., AMAZON), and window 6 displays the filename corresponding to that sign form, as well as the directory in which that graphic file is stored.

The sublexical analysis and indexing make use of five parameters: hands, fingers, place, movement, and facial expression.

Each parameter has a number of cheremes:

I. Hands
   A. Hand articulation (AM)
   B. Palm orientation (OP)
   C. Hand orientation (OM)
   D. Relationship between hands (RM)

II. Fingers
   A. Finger type (QD)
   B. Finger articulation (AD)

III. Place
   A. Articulation place in signing space (LA)

IV. Movement
   A. Hand movement (MM)
   B. Finger movement (MD)
   C. Body movement (MC)
   D. Movement type (TM)
   E. Movement frequency-intensity (FI)

V. Facial expression
   A. Type of facial expression (TEF)

Each chereme has a number of allochers. For instance, palm orientation has the following allochers:

Up
Down
Forward
Backward
Left
Right

The alphanumeric sequence that encodes this sublexical indexing rigorously follows the order given in this description. Because the coding abbreviations are from Portuguese, one last detail a user needs for decoding the cheremic string is that the letter *D* stands for "right," and *E* stands for "left." Thus, for instance, *AMD* means right-hand articulation and *OPE* means left-palm orientation.

Figure 3 illustrates the screen layout of the sublexical indexing software showing the Libras sign INDIAN, which is illustrated in its form (window 7) and meaning (window 5), described in its meaning and form (window 3), and coded in its sublexical structure (window 2). A comparison between figures 2 and 3 in window 7 reveals that the sublexical structure of INDIAN contains the sublexical structure of AMAZON as one of its components (i.e., AMAZON is the first part of INDIAN). If the sign form similarities are apparent, they must also be

FIGURE 3. Screen layout of software for cheremic indexing of signs. The Libras sign INDIAN is illustrated in its form (window 7) and meaning (window 5). Its meaning (window 3) and sublexical structure (window 2) are also described. The first component of the sign INDIAN is AMAZON, as both a visual inspection (window 7) and a computerized analysis (window 2) reveal.

readily identified by the sublexical component analysis encoded in the alphanumeric sequence (window 2).

When an elementary sign (e.g., AMAZON) is part of a more complex sign (e.g., INDIAN), then the alphanumeric code sequence of the elementary sign (i.e., AMD36, OPD3, OMD5, LA32, MMD4, MDD11) must reoccur in the alphanumeric code string of the complex sign. And that is precisely the case with these two signs. A comparison of window 2 in figures 2 and 3 confirms that the sublexical structure of INDIAN contains the sublexical structure of AMAZON as one of its major components. In window 2, the alphanumeric code sequence of the elementary sign AMAZON (AMD36, OPD3, OMD5, LA32, MMD4, MDD11) reoccurs in the first part of the alphanumeric code sequence of the complex sign INDIAN. The complete sublexical structure of INDIAN is (AMD36, OPD3, OMD5, LA32, MMD4, MDD11) AMD36, OPD4, OMD5, LA17, MMD6, LA15, MMD7, FI3. The first component unit of INDIAN is AMAZON, whose cheremic components appear in parentheses. The second component unit is the second part of the alphanumeric code string that appears outside the parentheses. Its key elements are OPD4 (right-palm orientation: backward), LA15, 17 (articulation place: mouth, touching mouth), MMD6, 7 (right-hand movement: forward, backward), and FI3 (movement frequency: twice).

The sublexical indexing software is a powerful instrument for computerized component analysis of the sublexical structure of signs. In cross-linguistic studies, it allows for intensive morphemic analysis that may reveal unsuspected similarities in morphemically related signs. It can also shed light on the linguistic encoding of visual information during working-memory tasks (Klima and Bellugi 1979).

The Menu-Based Sublexical Sign-Retrieval System

Figure 4 illustrates the screen layout of the digital encyclopedia and sign-retrieval system (Capovilla, Duduchi, and Rozados n.d.) showing the Libras sign WORLD. The screen is divided into two halves, with four windows on the left and one on the right. Window 1 shows a list of alphabetically ordered Portuguese glosses, with a scroll bar on its right side, and the gloss mundo ("world") highlighted (i.e., selected). The gloss that the user selects in window 1 determines the

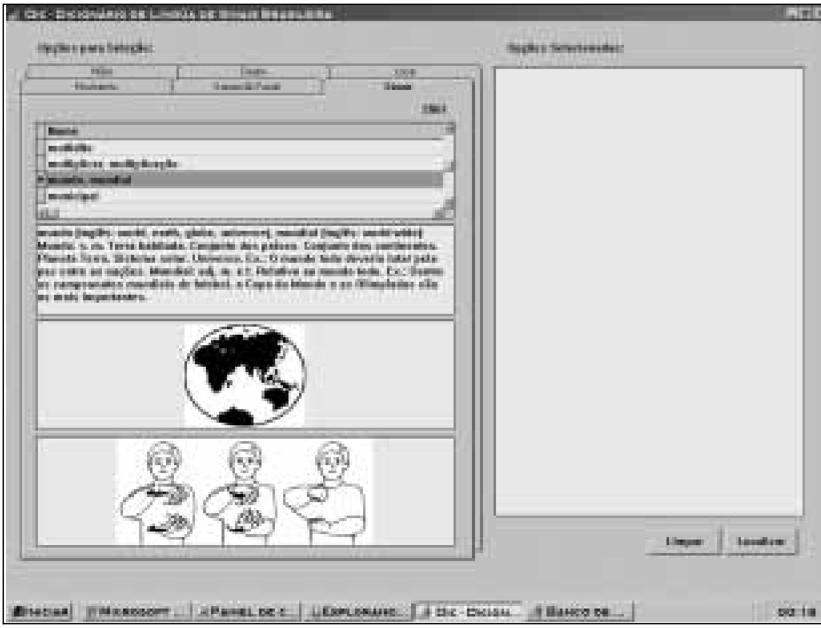


FIGURE 4. Screen layout of the digital encyclopedia and menu-based, sign-retrieval system. At the top left there is a pop-up retrieval menu with six options: the default option ("Signs") and five parameter options ("Hands," "Fingers," "Place," "Movement," and "Facial expression") that permit selecting cheremes and allochers as criteria for sign retrieval. The default option "Signs" contains four windows and displays the number of signs (2,861) available for search in the first encyclopedia volume. WORLD is glossed in Portuguese (window 1), and its meaning and form are defined and described, respectively, in window 2. It is also illustrated in its meaning (window 3) and form (window 4). By clicking the mouse in the scroll bar at right, the user can peruse the whole content of the first volume.

contents of the other three windows at the bottom. Window 2 shows the English gloss ("world") that corresponds to the Portuguese gloss selected in window 1. It also shows the Portuguese gloss, grammar classification, a definition, and an example of the appropriate use of each meaning. Finally, it shows a full description of the sign form, thus allowing for its precise articulation by readers. Window 3 shows an illustration of the sign meaning, and window 4 shows an illustration of the sign form. Thus, as one uses the mouse or keyboard to scroll up and down the list of glosses (in window 1), one can peruse all of the other items. These include sign-form illustrations (window 4) and descriptions (at the bottom of window 2), along with their respective meaning illustrations (window 3) and definitions (in the middle of window 2).

A pop-up cheremic menu with six options appears at the top left, above the four windows. The sixth option, "signs" ("sinais"), is the default, and the four windows described earlier pertain to it. Thus, upon entering the system, the "signs" menu is open, and the total number of signs the volume contains appears below the word "signs." For the purpose of demonstration, the first version of the digital encyclopedia has been divided into two volumes. Volume 1 contains 2,861 signs from *A* to *M,* and Volume 2 contains 2,740 signs from *N* to *Z.* The screens illustrated in this article are from Volume 1, which is why the default number below "signs" is 2,861 rather than 5,601.

On the pop-up cheremic menus at the top left, the remaining five options are those that readers use to retrieve signs. Each option corresponds to a specific parameter: hands ("maos"), fingers ("dedos"), place ("local"), movement ("movimento"), and facial expression ("expressao facial"). By clicking on a parameter, one obtains a list of cheremes pertaining to that parameter. Then, by clicking on any chereme, one obtains a list of allochers. Finally, by clicking on any of the allochers, one can select it as a criterion for sublexical sign retrieval. Thus, for instance, by clicking on the parameter "hands," one obtains four cheremes: hand articulation, palm orientation, hand orientation, and relationship between hands. By clicking on the second chereme (palm orientation), one obtains allochers such as "up," "down," "forward," "backward," "left," and "right." By clicking on the first allocher, "up," one selects the sign feature "palm up" as the criterion for sign retrieval.

A permanent record of all of the individual sign features selected as criteria for sign retrieval is kept in the window at right. Below that window are two buttons: "Clear window" ("Limpar") and "Sign search" ("Localizar"). By clicking on the right button, one performs the sign search based on the criteria shown in the window above the button. Once the search is finished, a click on the left button erases the contents of the window, and a new search may begin.

The same sublexical encoding system is used for both sign indexing and sign retrieval. Although the present version displays the options in Portuguese, a more recent version (in progress) uses a graphic interface, with each menu option given in both Portuguese and Libras.

A Practical Example: Retrieving the Sign INDIAN

To illustrate how to use the sign-retrieval system to locate specific Libras signs, suppose that one wants to retrieve the Libras sign INDIAN (figure 3). By visualizing the sign form, one distinguishes a number of relevant sign features. An informal and common-sense description of that sign might be the following: The open right hand points up and touches the forehead. The right palm faces forward. The hand moves toward the right as the fingers close one by one. Then the right hand (facing backward) moves back and forth at the mouth, touching it twice. The pop-up menus enable readers to use any of these feature components as criteria for sign retrieval. By clicking on the menus, one selects the appropriate parameters, primes (cheremes), and subprimes (allochers) to match the visualized sign-form features. One can perform a sign search based on any number of selected allochers. As one selects more and more allochers, the number of sign candidates that simultaneously satisfies all of them decreases. Normally it will not be necessary to specify more than six sign features in order to obtain a fairly small and manageable sample that one can easily peruse by scrolling through the sign gloss window.

Suppose that one wants to begin a search by retrieving all of the signs in which the right hand is open. To do that, one could begin by clicking on the parameter "hand" on the pop-up menu. A number of chereme options appear. By clicking on the first chereme option—"hand configuration"—a number of allochers appear. By clicking on the allocher "open," one has automatically selected the first criterion for sign search. The selected allocher then appears in the window at right. Once the user clicks the "Locate" ("Localizar") button below the right window, the system searches all of the signs that satisfy the criterion "right hand open." Figure 5 illustrates the search result. It shows that the system retrieved 851 signs that match the chosen criterion. In addition, it displays in the first left-hand window all 851 glosses that correspond to those signs. Now, by clicking the mouse on the scroll bar to the right, one can peruse all of the 851 signs

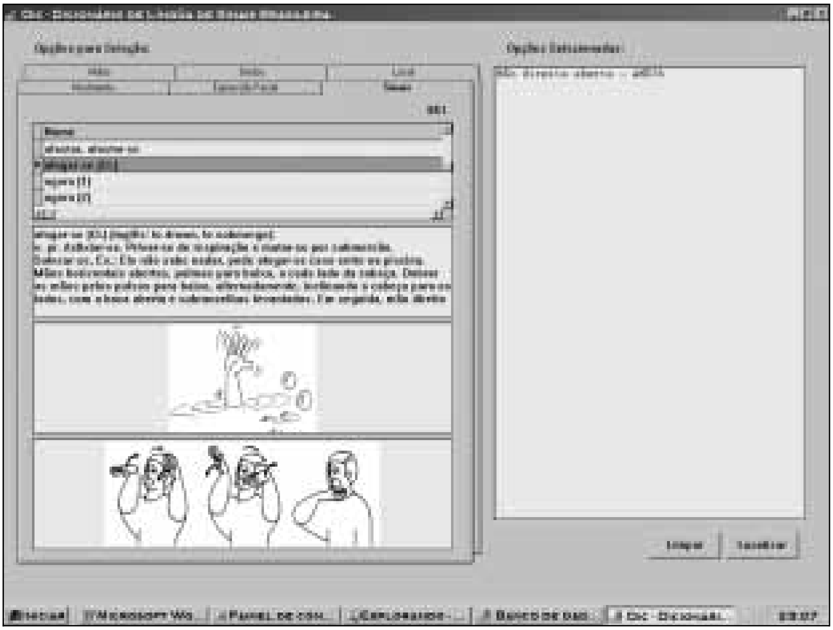


Figure 5. Screen layout of the digital encyclopedia and menu-based, sign-retrieval system after the completion of the first search using the criterion specified in the window at right (i.e., right hand open). At left, the default option "Signs" is open and shows that the first volume contains 851 Libras signs (one of which, to drown, is shown) that satisfy the sign-feature search criterion specified at right.

(window 4) and their corresponding descriptions (window 2) and illustrations (window 3). The figure clearly shows that the Libras sign to drown is one of those 851 signs in which the right hand is open.

Because 851 signs are too many to peruse in order to retrieve a specific sign (in this case, indian), one may specify a second sign-form feature as an additional criterion for sign search. For example, to narrow the search by specifying that the right palm faces forward, one simply clicks on the parameter option "hand," then on the chereme option "palm orientation," and finally on the allocher option "forward." This second criterion for sign search is then displayed in the window at right. When the user clicks the "Locate" button, the system performs a second search among the 851 signs in order to find those signs that satisfy both criteria: right hand open and right palm facing forward. Figure 6 illustrates the search results. The system has retrieved 128 signs that simultaneously match the two criteria and has displayed their corresponding glosses in the first window at left. By clicking the mouse in the scroll bar to the right of that window, one can peruse all of the 128 signs, along with their descriptions and illustrations. Figure 6 shows that AMERICA is one of the 128 signs that satisfy both criteria.

Again, however, 128 signs are still too many to peruse. Therefore, one may specify a third sign-form feature as an additional criterion for sign search. Comparing the obtained sign (i.e., AMERICA) to the visualized desired sign (i.e., INDIAN), one can narrow the search and eliminate competing signs by specifying a conspicuous feature of the desired sign that is missing in the obtained sign. Comparing both

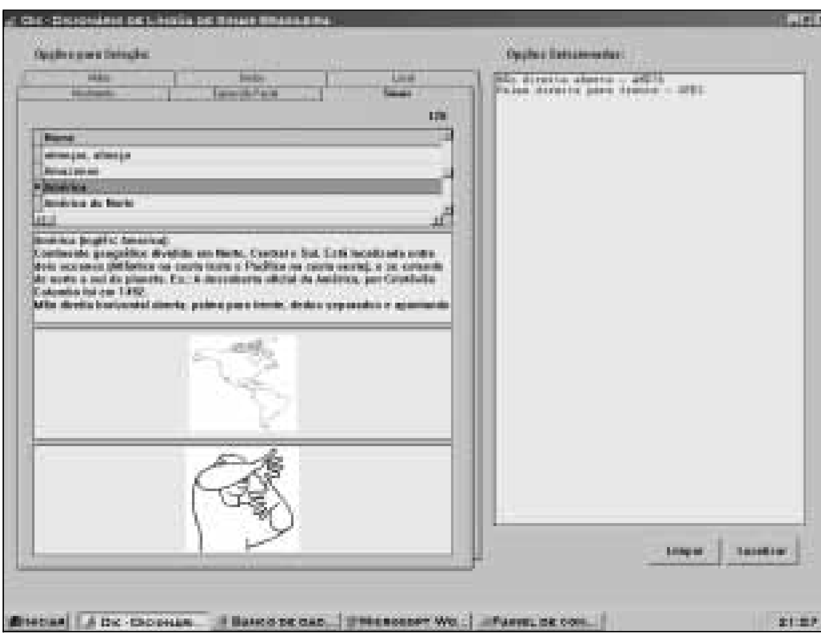


FIGURE 6. Screen layout of the digital encyclopedia and menu-based, sign-retrieval system after the completion of the second consecutive search using the two criteria specified in the window at right (i.e., right hand open and right palm facing forward). At left, the default cheremic menu "Signs" shows that there are 128 Libras signs (one of which, AMERICA, is shown) that satisfy the two criteria specified at right.

signs, one realizes that there is a difference between them (e.g., the hand that points left in AMERICA points upward in INDIAN). That difference can be the additional criterion to further limit the search and come closer to the desired sign. Thus, one may want to specify that the right hand must point up. Again one simply clicks on the parameter "hand," then on the chereme "Hand orientation," and finally on the allocher "pointing up." The system then displays the third criterion in the window at right. Once one clicks the "Locate" button, the system performs a third search among the 128 signs in order to find those that satisfy the three criteria: right hand open, right palm facing forward, and right hand pointing up. Figure 7 shows that the third criterion eliminated 51 competing signs. The system has located 77 signs that simultaneously match all three criteria and displayed

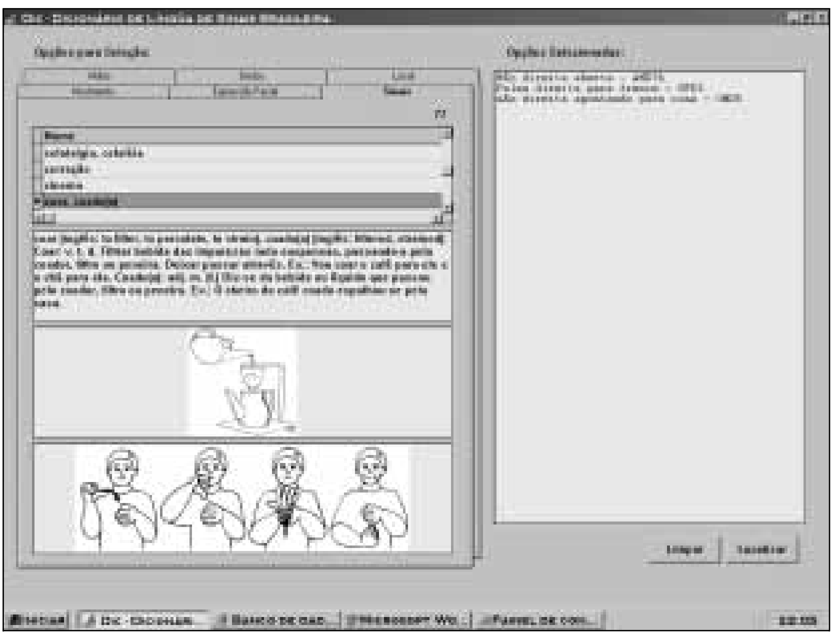


FIGURE 7. Screen layout of the digital encyclopedia and menu-based, sign-retrieval system after the completion of the third consecutive search round using the criteria specified in the window at right (i.e., right hand open, right palm facing forward, and right hand pointing up). At left, the default cheremic menu "Signs" shows that there are seventy-seven Libras signs (one of which, TO PERCOLATE, TO FILTER, FILTERED, is shown) that satisfy all three search criteria.

their corresponding glosses in the first window at left. Now, by clicking the mouse in the scroll bar and perusing the results, one sees that the Libras sign for TO PERCOLATE, TO FILTER and FILTERED is one of the 77 signs that contain all three sublexical elements at some point. That is, in each of those signs, the right hand is open at some point. Additionally, at some other time or at the same time, it points up. And again, at some other time or at the same time, it also faces forward.

Once more, however, a sample of 77 signs is still too large. Therefore, one may wish to specify a fourth sign-form feature. By comparing the obtained sign (i.e., TO PERCOLATE) to the visualized sign (i.e., INDIAN), one can limit the search even more. A distinctive feature of INDIAN is that the right hand touches the forehead. Thus, one can add this to the selection criteria by clicking on the parameter "place," then on the chereme "articulation place," and finally on the allocher "touching forehead." This fourth criterion is displayed in the window at right. Once the "Locate" button is clicked, the system performs the fourth consecutive search round, now among only these 77 signs, in order to find the ones that satisfy all four criteria simultaneously. Figure 8 shows the results. The fourth criterion eliminated 68 competing signs, so only 9 remain that simultaneously match all four criteria. Figure 8 also shows that HEADACHE is one of those 9 signs.

Even though most people would certainly consider nine signs to be a fairly small sample, one might still want to perform a fifth consecutive search round for the sake of exercise or research. Comparing the obtained sign (i.e., HEADACHE) to the visualized sign (i.e., INDIAN), one can narrow down the search by specifying yet another conspicuous feature of the desired sign that is missing in the obtained sign. In this example, the distinctive feature of INDIAN is that the right hand moves toward the right. Thus, one can eliminate competing signs. As before, one simply clicks on the parameter "movement," then on the chereme "hand movement," and finally on the allocher "toward the right." When the "Locate" button is clicked, the system searches among the nine signs for the ones that satisfy all five criteria simultaneously. Figure 9 illustrates the results of this fifth round. Only

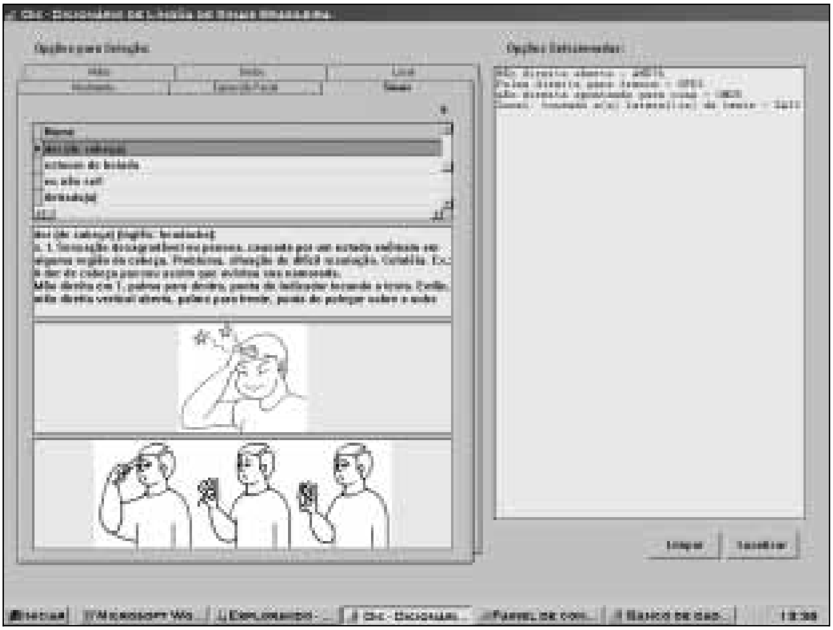


Figure 8. Screen layout of the digital encyclopedia and menu-based, sign-retrieval system after the completion of the fourth consecutive search round using the criteria specified in the window at right (i.e., right hand open, right palm facing forward, right hand pointing up, and right hand touching forehead). At left, the default cheremic menu "Signs" shows that there are only nine Libras signs (one of which, HEADACHE, is shown) that satisfy all four cheremic search criteria.

five signs remain that meet all five criteria. Figure 9 shows that AMAZON is one of those five.

So far the search has been very successful. By specifying five sign-form features as criteria for sign retrieval, one has reduced the sample from the original 2,861 signs in volume one to only five signs. Of these, one is the target and the other four are competitors. One of the four competitors is AMAZON, which forms the first part of INDIAN and is composed of six sign-form features: right hand open, palm facing forward, pointing up, touches forehead, moves toward the right, and fingers close one by one. Of these six features, only one has not been selected as a search criterion (i.e., right-hand fingers close one by one). Since that is a comparatively rare feature, if it had been chosen in the first place, the five-step search might well have been reduced to only one or two steps. The question now is how to

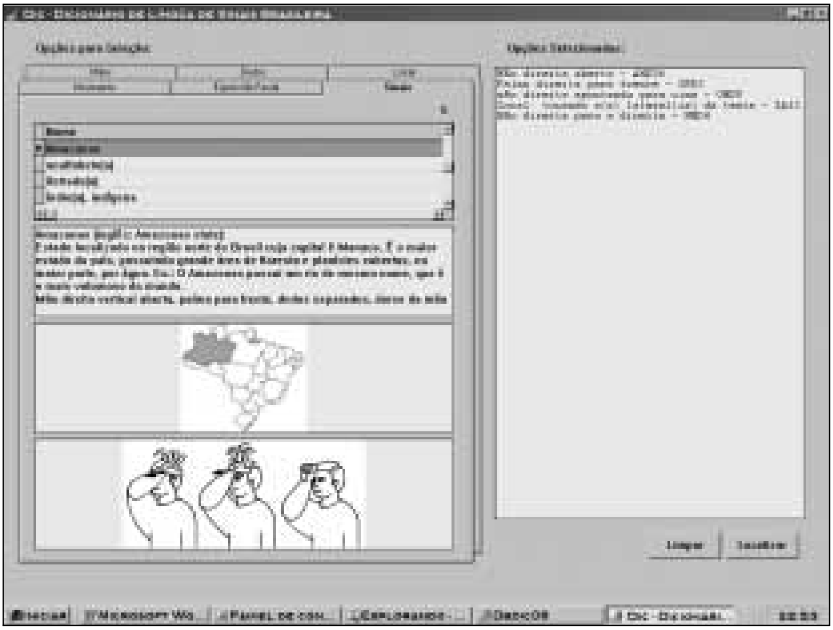


FIGURE 9. Digital encyclopedia and menu-based, sign-retrieval system. Screen layout after the completion of the fifth consecutive search round using the criteria specified in the window at right (i.e., right hand open, right palm facing forward, right hand pointing up, right hand touching forehead, and right hand moving toward the right). At left, the default cheremic menu "Signs" shows that there are only five Libras signs (one of which, AMAZON, is shown) that satisfy all five cheremic search criteria.

eliminate AMAZON and obtain INDIAN. Since the first part of INDIAN is AMAZON, in order to eliminate AMAZON along with the other competitors, one could simply specify one of the sign-form features that belong exclusively to the second part of INDIAN. There are six sign-form features in the second part of INDIAN that do not occur in AMAZON: right palm facing backward, right hand articulating next to mouth, right hand touching mouth, right hand moving forward, right hand moving backward, and right hand moving twice. Thus, one could simply specify that the right palm faces backward. To do this, one clicks on the parameter "hand," then on the chereme "palm orientation," and finally on the allocher "backward." Of course, one can also eliminate competing signs by specifying that the right hand moves forward. However, of the six sign-form features in INDIAN that are absent in AMAZON, suppose one specifies one of the most conspicuous ones: right palm touching mouth. To do this, one clicks on the parameter "place," then on the chereme "articulation place," and finally on the allocher "touching mouth." This sixth criterion is then displayed in the window at right. Once the "Locate" button is clicked, the system searches again to find the one sign that satisfies all six criteria simultaneously. Figure 10 illustrates the result of the sixth and last search. Only one sign remains.

The *Digital Encyclopedia of Brazilian Sign Language* presents detailed information on fifty-six hundred Libras signs whose cheremic components are fully indexed by the sublexical indexing system as alphanumeric code sequences. That enables the menu-based, sign-retrieval system to search through the Libras sign bank in a very effective way. The cross-indexing of sublexical features (i.e., parameters,

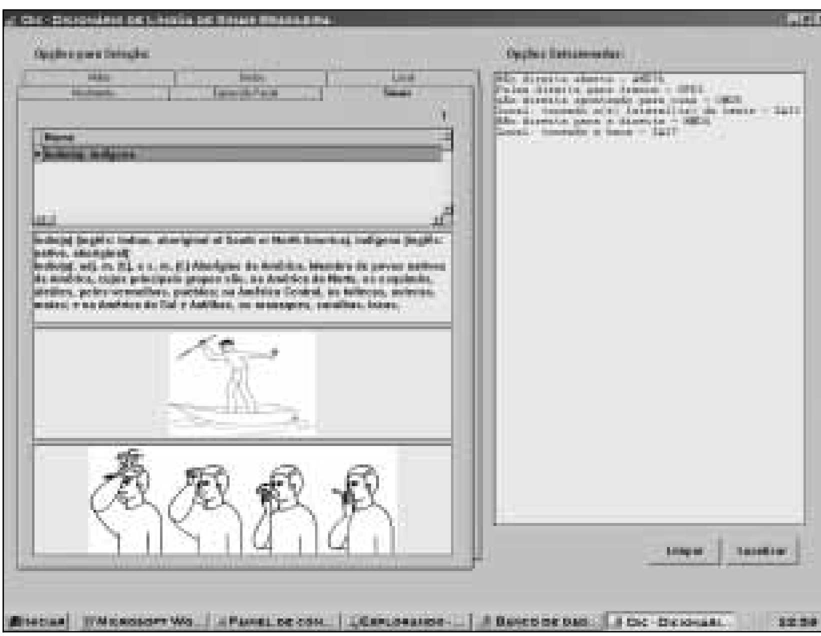


FIGURE 10. Digital encyclopedia and menu-based, sign-retrieval system. Screen layout after the completion of the sixth consecutive search round using the criteria specified in the window at right (i.e., right hand open, right palm facing forward, right hand pointing up, right hand touching forehead, right hand moving toward the right, and right hand touching mouth). At left, the default cheremic menu "Signs" shows that there is only one Libras sign (i.e., INDIAN) that satisfies all six cheremic search criteria.

cheremes, and allochers) is a practical tool for rapidly accessing any desired sign independently of glosses. It also facilitates the analysis of sublexical structures of sign corpora in cross-linguistic studies of the constitution of sublexical structures and in psycholinguistic studies of the effects of sublexical structure on information encoding and processing.

Communication Systems for Deaf People with Quadriplegia

As explained earlier, there are two traditional sign-indexing strategies: the alphabetic ordering of glosses, which dictionaries typically use, and the semantic grouping of related signs, which is typically used in manuals. The Sign-Phone communication system preceded the sublexical-feature, sign-retrieval system this article describes. Thus, the communication system that Brazilian deaf people with quadriplegia use still employs the traditional indexing strategy of semantic grouping. A new version of the communication system in which the sublexical-feature, sign-retrieval system acts as a gateway to the communication system is currently in preparation.

Although the new version of the communication system permits sign retrieval by sublexical component features (i.e., cheremes), in the traditional communication system described here signs must be retrieved on the basis of semantic classes. In the present version, the signs are grouped in semantic categories (e.g., people, professions, countries, body, hygiene, food, clothing, and animals) and grammatical categories (e.g., pronouns, verbs, adjectives, and adverbs). When a user selects a category, it "unfolds" into its corresponding signs. When a user selects a sign it migrates to a communication area, thus allowing one to compose messages that one can speak and print.

Figures 11 to 14 illustrate four screen layouts of Sign-Phone. The typical screen presents forty cells in a matrix of five rows and eight columns. Each cell contains a graphically animated Libras sign on top and its corresponding gloss at the bottom. (In this article we have translated the glosses from Portuguese to English.) As a communication system, Sign-Phone works in both a message-composition mode and a message-storing-retrieval mode. The message-composition mode consists of two types of screen: a sign-category screen (figure 11) and a sign-item screen (figure 12). The message-storing-retrieval mode also contains two types of screen: a message-recording screen

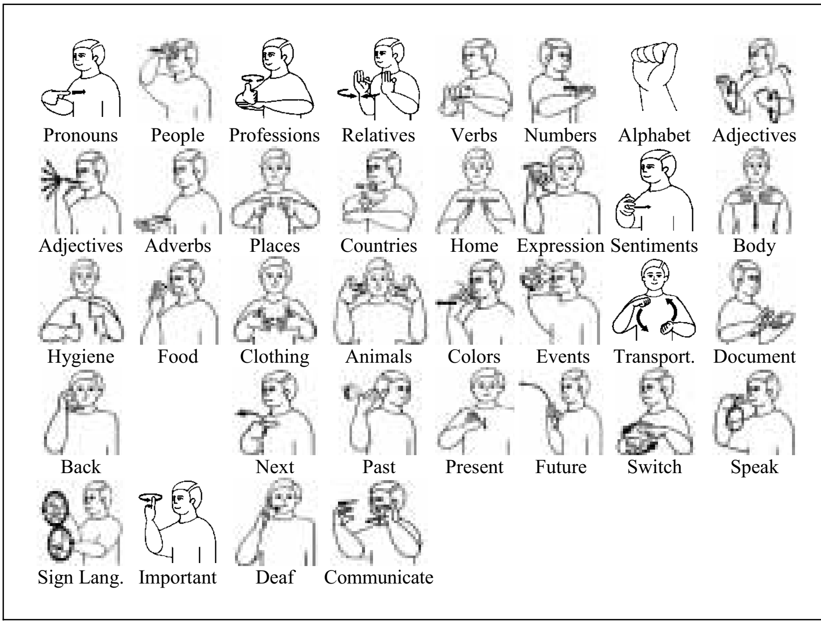


Figure 11. Layout of the first sign-category screen of the Libras communication system for deaf people with quadriplegia. The choice area (rows 1–3) contains twenty-four sign categories available for display. The system-command area (row 4) contains seven commands that allow navigating back and forth, producing spoken output, indexing verbs in appropriate tense, and switching between sign languages and among screen modes. The message-composition area (row 5) contains the Libras message SIGN LANGUAGE (IS) IMPORTANT (TO) DEAF COMMUNICATION.

(figure 13) and a message-retrieval screen (figure 14). In all four types of screen, the twenty-four cells in rows 1 to 3 compose the choice area, the eight cells in row 4 compose the system-command area, and the eight cells in row 5 compose the message-composition area.

The contents of the choice area vary according to the mode and screen type in effect. The message-composition mode consists of two types of screen. In sign-category screens, the choice area displays twenty-four sign categories at once, whose selection displays the category as a number of semantically related sign-item screens. For instance, selecting the category FRUIT displays the components of that category—all fruit signs—such as APPLE, BANANA, CHERRY, LEMON, ORANGE, and WATERMELON. In sign-item screens, the choice area displays twenty-four signs at once, which result from the display of a given category and

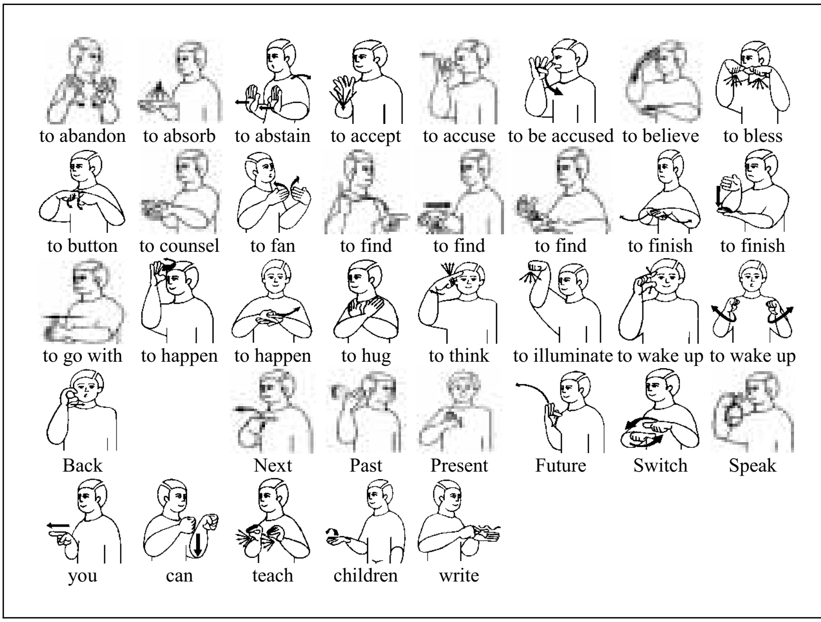


FIGURE 12. Layout of the first verb screen that results from displaying the verb category. The sign-item screen shows the choice area containing twenty-four verb signs available for selection; the system-command area with the seven commands; and the message-composition area containing the Libras message YOU CAN TEACH CHILDREN (TO) WRITE.

whose selection moves them to the message-composition area. For instance, when ORANGE is selected, it migrates to the message-composition area and can be used in messages such as I LIKE ORANGE.

The message-composition mode is used for composing new messages in a sign-by-sign fashion in real time. In order to select individual signs, one advances through a number of sign-category screens to find the category that contains the target sign. Then one displays that category, peruses the resulting sign screens for the desired sign, and then selects it. Then one repeats the process to select the next message sign. Therefore, in the message-composition mode the user has to perform extensive navigation through the system in order to select each sign. And that takes considerable time. To save time and increase the message output rate, the user may choose prestored messages; in the message-storing-retrieval mode, users can store messages for later use as well as retrieve previously stored messages.

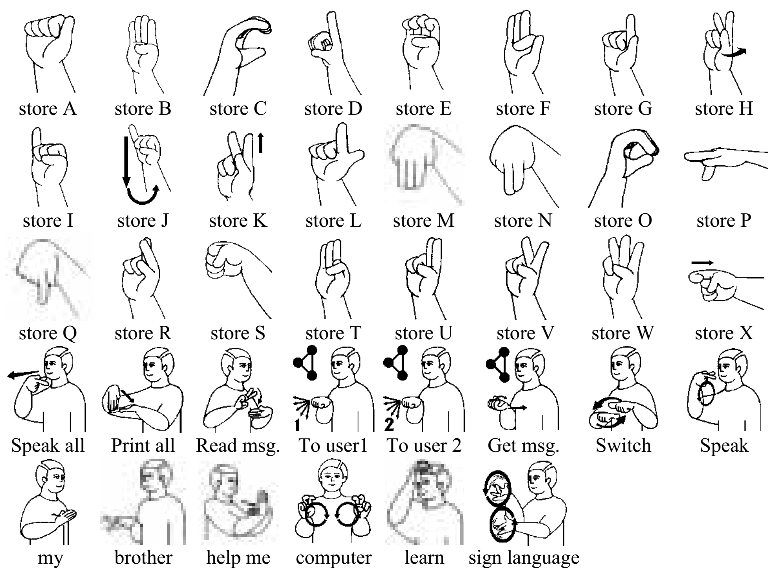


Figure 13. Layout of the message-storing screen showing the choice area that contains twenty-four bins available for recording and prestoring messages for later use. The message-composition area contains a Libras message: MY BROTHER HELPED ME COMPUTER LEARN SIGN LANGUAGE. The system-command area shows eight commands. SPEAK ALL retrieves all twenty-four messages previously stored in the bins. It exhibits them in row 5 and produces their spoken output. PRINT ALL produces a printed output instead of a spoken one. READ MESSAGE retrieves particular messages that are stored in the bins. GET MESSAGE, SEND MESSAGE TO USER 1, and SEND MESSAGE TO USER 2 permit users to exchange messages in the network.

The message-storing-retrieval mode consists of two types of screen. In message-recording screens, the choice area displays twenty-four bins from *A* to *X* for recording messages. When the message-recording screen is active, one selects any letter-hand sign bin, and the message appears in the message-composition area and is stored in that same bin. For instance, after composing a message such as PLEASE HELP ME GO TO BATHROOM, one can store it in the first bin simply by touching the letter-hand *A*. In turn, in message-retrieval screens, the choice area displays twenty-four bins from *A* to *X* for retrieving the messages previously stored there. When the message-retrieval screen is active, one can touch any letter-hand sign bin,

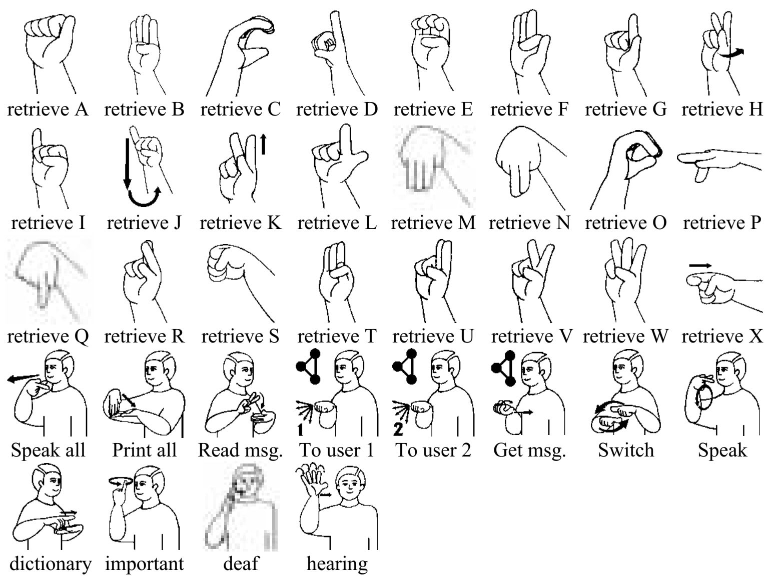


FIGURE 14. Layout of the message-retrieval screen. The choice area shows twenty-four letter-hand sign bins, each one containing a prestored message that is available for immediate retrieval simply by touching on the letter-hand sign where it has been prestored. The message-composition area shows a Libras message, DICTIONARY (IS) IMPORTANT (TO) DEAF AND HEARING, which has been retrieved just by touching the letter-hand C (third bin), where it was prestored.

causing the message stored there to appear in the message-composition area. For instance, when one needs to go to the bathroom, a poor alternative would be to go through the long process of navigating through the screens, displaying a number of sign categories, and selecting a number of items in order to compose the message. Instead, one can activate the message-retrieval screen and retrieve the bathroom message by simply touching the bin where one had stored it. Then the message PLEASE HELP ME GO TO BATHROOM appears at once in row 5.

When the system is in the message-composition mode, its choice area displays all of the Libras signs with graphic animation distributed in thousands of sign screens, under hundreds of semantic sign-category screens distributed in dozens of other screens. In order to navigate through all of the system screens in search of target signs, one may use the commands in the system-command area. There the navigation command "Next" brings up the following screen, while "Back" returns to the previous one. The command "Speak" produces the spoken output of the message (shown in row 5). The commands "Past," "Present," and "Future," when selected right after a verb, specify the appropriate verb tense, so that the verb can be properly indexed when uttered or printed in sign-to-speech communication. The command "Switch" changes both between sign languages (i.e., back and forth between Libras and ASL) and among screen modes (i.e., back and forth from message composition to message storing to message retrieval). By selecting "Switch," the user switches from any message-composition mode screen (figures 11 and 12) to the message-storing mode screen (figure 13), in which up to twenty-four different messages of up to eight elements each can be stored for later retrieval. By selecting "Switch" a second time, the user switches from the message-storing mode screen (figure 13) to the message-retrieval mode screen (figure 14), where the user can retrieve any of the twenty-four different messages previously stored there just by touching its corresponding letter-hand bin. Finally, by selecting "Switch" one more time, the user switches from Libras- to ASL-based communication in order to compose messages in ASL.

When the system is in the message-storing-retrieval mode, the commands are "Speak all," "Print all," "Read message," "Send message to user 1," "Send message to user 2," "Get message," "Switch" (i.e., changing languages or modes), and "Speak." The commands "Speak all" and "Print all" retrieve all of the messages stored in the 24 bins, display them in the message-composition area, and produce their spoken and printed output in Portuguese. The command "Read message" retrieves a specific message that has been stored in one of the 24 bins. The commands "Get message," "Send message to user 1," and "Send message to user 2" permit a user to exchange messages with other deaf interlocutors with paralysis when Sign-Phone is implemented in computer networks. The command "Get message" downloads the messages that other deaf users have sent. The commands "Send message to user 1" and "Send message to user 2" permit private conversation with each deaf interlocutor with paralysis.

Figure 11 illustrates the first sign-category screen layout. The choice area displays twenty-four sign categories. Once a user selects a category, the area displays a number of sign-item screens containing all of the semantically related signs in that category. Once the user selects a sign, it becomes part of a new message and migrates to the message-composition area, which, in this case, shows the message SIGN LANGUAGE (IS) IMPORTANT TO DEAF COMMUNICATION. The commands in the system-command area permit navigating through the system. Additionally, they allow users to index verbs in appropriate tenses, to produce message output in digitized speech, and to switch between sign languages and among screen modes.

Figure 12 shows the layout of the first verb sign-item screen that results from the display of the verb category shown in figure 11. This screen shows the choice area containing 24 verb signs available for selection; the system-command area with its seven commands; and the message-composition area. When a user selects a verb sign (e.g., TO TEACH), it migrates to the message-composition area and becomes part of a Libras message such as the one shown in row 5 (i.e., YOU CAN TEACH CHILDREN (TO) WRITE). However, because the Portuguese glosses of the Libras signs shown in the choice area have been translated to English, the screen gives the false impression of containing practically all of the signs from *A* to *W* (i.e., from TO ABANDON to TO WAKE UP). But in Portuguese, the equivalent of TO WAKE UP is ACORDAR. In reality the communication system contains 1,700 verbs distributed in more than seventy screens. Thus, only the first 24 of the 1,700 verb signs are shown on the screen (figure 12).

Figure 13 illustrates the message-storing screen showing the choice area, which contains twenty-four bins from *A* to *X* available for recording and prestoring messages for later use. It also shows the message-composition area, which contains the Libras message MY BROTHER HELPED ME COMPUTER LEARN SIGN LANGUAGE. By selecting any letter-hand sign bin, the message appearing in row 5 becomes stored in that same bin. Thus, after writing the message, one can store it in the first bin simply by touching the letter-hand *A*. The screen also shows the system-command area with eight commands.

Figure 14 illustrates the layout of the message-retrieval screen showing the choice area that displays twenty-four letter-hand sign bins available for retrieving the messages previously stored there.

When the user selects any letter-hand sign bin from *A* to *Z,* the Libras message previously stored there appears in the message-composition area. For example, DICTIONARY (IS) IMPORTANT (TO) DEAF AND HEARING. In the message-retrieval screen, the eight commands of the system-command area are the same as those of the message-storing screen.

The system permits the use of all of the Libras signs in the digital encyclopedia for message composition and daily communication. Users with different types and degrees of impairments can fully customize the system by configuring a number of parameters. Figure 15 illustrates one of the configuration screens that permit a user to choose from different scanning strategies (serial or row-column) and from different input devices (keyboard, mouse, or touch screen). It also permits a user to adjust the scanning speed and the graphic animation speed (both in milliseconds) to the particular hardware available. Finally, it permits one to record in detail and in real time the

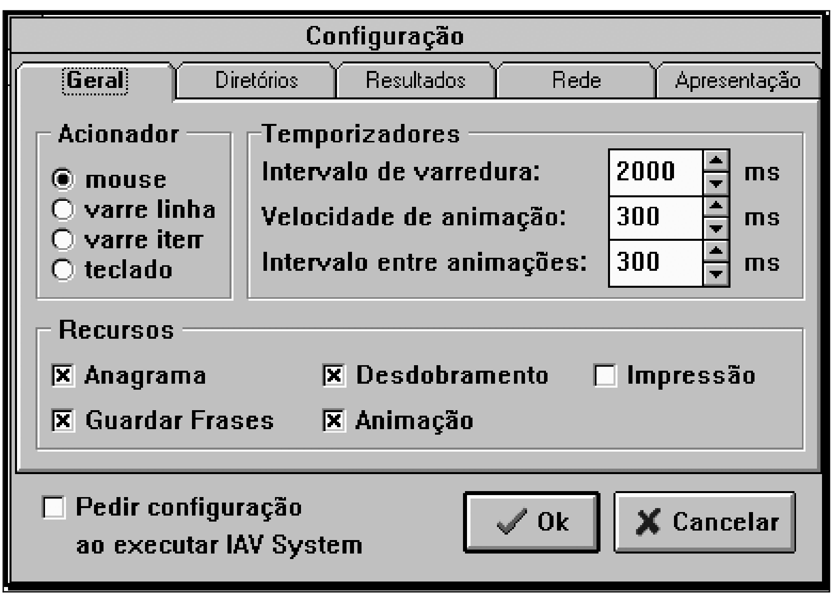


Figure 15. Layout of one of the system-configuration screens that permits specifying which parameters (e.g., input devices, scanning strategies and speed) are to be used in order to customize the system to the particular needs of deaf users with serious impairments.

precise navigation patterns a user exhibits in order to determine how to perfect the system design and engineering in order to meet the communication needs of deaf users with quadriplegia.

Note

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