Modern SignWriting

MSW v1.0.0-alpha.8

compact and tractable
self-acting mathematical machines
for SignWriting

Stephen E Slevinski Jr
slevin@signpuddle.net

Abstract: Given that SignWriting is a 2-dimensional script, here are the specifications for an encoding model based on self-acting mathematical machines. This encoding model makes explicit those features which can be effectively and efficiently processed. Formal languages and regular expressions leverage these machines to solve fundamental problems.

Several generations of symbol sets, character encodings, and string representations have evolved with a natural writing script. Simple finite state machines explicitly illustrate several glass-box models of input, processing, and output.

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1. Stability

SignWriting is the universal script for writing any sign language. Sign languages are human languages based on visual gestures. Sign languages have proven to have many of the uses and benefits of other voiced and written languages, as well as other uses and benefits unique to sign language alone.

Modern SignWriting is a faithful encoding of SignWriting that is stable by design. It is based on the glass-box idea where all necessary information is available to understand input, processing, and output. We can faithfully predict the results of any processing without having to use a computer. The algorithms have been optimized for flexibility, accuracy, simplicity, and speed.

1.A. Semantic Versioning

Modern SignWriting follows the rules for Semantic Versioning v2 (semver.org) and uses a version string to communicate compatibility using three numbers: major, minor, patch. The version string for this document is v1.0.0. It is the first major version. Any string written according to this specification will always be understood by a v1 implementation. The minor version number is second in the version string. It represents an improvement that is compatible for all versions with the same major version and a lower minor version number. This document is the foundation for major version l and will be compatible with all improvements and fixes for major version 1.

1.B. Formal Words

A formal word requires a sequential string of characters. Each encoding in this document is based on the idea of a formal word as an abstract structure. For SignWriting plain text, there are 3 types of words: signbox, term, or punctuation.

The signbox is the 2-dimensional representation of a sign that uses symbols from the ISWA 2010. This 2-dimensional order is represented as a list of symbols with 2 numbers per symbol for coordinate positioning. The 1-dimensional order of the string for a signbox is sequential and will resolve issues of overlap. Beyond that, the sequential order of a signbox should be considered meaningful to the user and should not be modified.

A term is a signbox with an added prefix as a sequential list of symbols. The majority of signs do not use the term prefix. Collation is possible with terms using a binary string comparison. A list of plain signboxes can be sorted using approximate string matching for terms and prepending the term prefix from the exact or closest match found for the signbox.

A punctuation is an isolated symbol used to structure sentences.

1.C. Normal Strings

A normal string is predictable and common. For SignWriting, normal strings do not exist outside of a community of writers. Different editors will often produce different strings for the same sign. Normalization is only possible based on an agreement within a community. Normal strings are only possible when written against a dictionary, otherwise the inherent variability of the mathematical model will produce strings that are approximately equal or equivalent, but rarely the same.

1.D. Terminology

1.D.1. Grapheme, Symbol, and Glyph

For SignWriting, a grapheme is a written mark that corresponds to a part of a meaningful visual gesture. Graphemes are the smallest semantic units capable of causing a contrast in meaning. Many graphemes of SignWriting are visually iconic. When written by hand, the variety and style of graphemes is potentially unlimited. Graphemes are somewhat abstract and do not have a concrete visual form. There are 3 types of graphemes: writing, detailed location, and punctuation.

The writing graphemes of SignWriting represent a visual conception: either hands, movement, dynamics, timing, head, face, trunk, or limb. The body concept is a combination of trunk and limb. The writing graphemes are used in 2 dimensional clusters to create one or more morphemes: the smallest semantically meaningful units in a language. The graphemes do not change size or shape when combined in a visual pattern. The graphemes can overlap and obscure graphemes underneath.

Detailed location graphemes are used individually or sequentially. They represent isolated analysis that is written outside the 2 dimensional cluster.

Punctuation graphemes are used when writing sentences. They are used individually, between 2 dimensional clusters.

For SignWriting, a symbol is equivalent to a grapheme, part of a grapheme, or several graphemes combined. Each symbol has a normative name, a definitive visual representation, and an international agreed upon meaning. The symbols of SignWriting are restricted in size and general shape more so than for other scripts because of 2 dimensional placement and the relations between the symbols. The symbols of SignWriting do not morph or rotate, but can often be changed from one symbol to another through several possible transformations. The specific size and shape of each symbol is designed to balance and complement the other symbols.

The symbols of the ISWA 2010 are extensive and specifically organized for written sign language and sign gestures. The symbol set does not include the specific symbols of DanceWriting or the general symbols of MovementWriting.

Glyphs are concrete representations of the individual symbols. A glyph is a graphic image that provides the appearance or form for a symbol. Most often, the term glyph will corresponds to an image in a font. The glyphs of SignWriting are restricted in size and shape with their corresponding symbols.

The glyphs have two aspects: positive and negative space. All glyphs have positive space: the outline or line of the glyph. Some glyphs have negative space, referred to as the fill of the glyph. When one glyph overlaps another glyph, the negative space of the top glyph will neutralize the positive space of the glyph underneath so that the line of the glyph underneath is partially obscured by the overlap.

1.D.2. Cluster, Sign, and SignBox

For SignWriting, a cluster is a 2 dimensional arrangement of graphemes, glyphs, or symbols. A 2 dimensional cluster of graphemes can be called a graphogram, which should not be confused with a “grapheme cluster” - a technical Unicode term. Likewise, a 2 dimensional cluster of glyphs can be

called a glyphogram. A cluster can represents a sign of a sign language or a visual performance of a sign gesture. Many clusters are visually iconic.

A sign is an over loaded term. It can refer to either the visual gesture produced by a real person or the written 2 dimensional representation of that sign.

A signbox is a 2 dimensional mathematical construct with a visual image of variable height and width. The size of a signbox is defined by the cluster of symbols used within the signbox. The border of each signbox is a tight bounding box as the smallest possible rectangle that encloses the set of symbols. The center of a signbox is explicitly defined, either by algorithm or user choice.

1.D.3. Viewpoints, Planes, and Perspectives

Writing based on vision uses two viewpoints: receptive and expressive. The receptive viewpoint is based on the idea of receiving an image. For the receptive viewpoint, the right hand of a signer will be written on the left side of the image. When SignWriting is used for transcription, the receptive view is most often used. The related writing systems of DanceWriting and MovementWriting normally use the receptive viewpoint.

The expressive viewpoint is based on the idea of expressing a concept. For the expressive viewpoint, the right hand of a signer will be written on the right side of the image. When SignWriting is used for authorship, the expressive view is most often used.

The are two main writing planes: the front wall (Frontal Plane) and the floor (Transverse Plane). The choice of writing plane determines the shape of the symbols, such as the fill pattern for the hands or the tail for the movement arrows.

There are two perspectives: front and top. The front perspective is a straight on view of the signer. The top perspective is a top-down view of the signer. Usually, a sign will be written from a single perspective.

2. Historical Foundation

2.A. Before SignWriting

Valerie Sutton invented the DanceWriting notation in 1966.

2.B. Handwritten SignWriting

Valerie Sutton invented the SignWriting script in 1974. The SignWriting script was written exclusively by hand for 10 years. The script has evolved, spread around the world, and continues to be written on paper and chalkboard.

When written by hand, lines are drawn to form each grapheme. Different styles draw different types of lines: either for personal taste, speed, or quality. The main types of handwriting are formal, cursive, and shorthand. Formal handwriting, equivalent to block printing, includes defined lines for all graphemes, specific palm facings for hand shapes, and detailed arrow heads and tails. Cursive handwriting is more fluid and less detailed. Handwriting for personal use can omit palm facings, generalize arrows, and

other liberties of personal consumption. Shorthand is a further reduction of detail, written for speed. Shorthand is a memory aid to a written record and should be rewritten soon after the notes were taken.

Understanding the ratios of size and shape for the graphemes improves hand writing.

2.C. Computerized SignWriting

When written with computers, the grapheme set must be limited and organized. A symbol is a reference to a grapheme rather than the grapheme itself. Each symbol has a unique identification.

In 1984, the first SignWriting prototype was created for the Apple IIe and Apple IIc. The application supported only a small subset of the SignWriting script.

In 1986, SignWriter was conceived by Richard Gleaves. Development started on the Apple IIe and Apple IIc. He pioneered the keyboard design for the SignWriting script. The resulting symbolset was limited due to the 128KB memory limit.

Richard Gleaves worked closely with Valerie Sutton and continued the development of SignWriter DOS to expanded the symbolset and improve the editor, resulting in the SSS-95 and a robust typing model.

The SSS-99 was created for SignWriter Java. The revamped symbolset was created without the limitations imposed upon the SSS-95.

The SSS-2002 reorganized the structure of the symbolset imposing a multi level hierarchy with the modern symbol ID. The SSS-2002 was the first symbolset used in the SignBank 2002 application by Todd Duell.

The SSS-2004 was created after reaching widespread international use. The SSS-2004 was the first symbolset used in the SignPuddle application by Steve Slevinski. This symbolset was expanded to include international MovementWriting concepts and became known as the International MovementWriting Alphabet.

The International SignWriting Alphabet 2008 was a major refactoring of the IMWA concept by eliminating the general MovementWriting symbols and focusing on the SignWriting script. The ISWA 2008 was the first symbolset released under the Open Font License.

The International SignWriting Alphabet 2010 was a further refinement of the symbolset to incorporate additional current best practices as deep in the standard as possible. The ISWA 2010 is the result of over 35 years of an inventor working with writers from around the world, and over 25 years of an inventor working with computers and programmers. The design balances complexity, efficiency, and usability. The ISWA 2010 defines 7 categories, 30 groups, and 652 bases. Understanding the basic concepts of the ISWA 2010 allows easy access to the graphemes without memorizing the minute details.

Since major standardization efforts started in 2008, there have been several disruptive but necessary changes in the data formats. With the formal specifications of Modern SignWriting, this type of disruption is no longer allowed. Signs for version 1 of Modern SignWriting will not change and will

always be compatible with applications that support MSW v1.

The formal specifications for Modern SignWriting are a continuation of the past; based on long standing historical usage.

2.D. Input Model

In 1986, Richard Gleaves pioneered the keyboard model for SignWriting. With SignWriter Dos, it was possible to type complete SignWriting sentences. New symbols required 2 key presses: first for the SymbolGroup and then for the BaseSymbol. Many selected symbol could be transformed by rotation, mirror, flop, or variation using additional keystrokes. Within a sign, the cursor is based on a selected symbol and 8 rotational directions. A new symbol is added to a sign based on the selected symbol position and the placement of the cursor around that symbol. This model is extremely powerful, but has a learning curve. The design is still valid for the modern symbol set, but it is not currently implemented in software.

In 2004, Stephen E Slevinski Jr created the first drag & drop editor for SignWriting. This model incorporated symbol hierarchy for symbol selection, but did not use the keyboard or the circular cursor. This model has proven to be effective and easy to learn.

3. International Corpus

From education to research, from entertainment to religion, SignWriting is useful because people are writing.

3.A. Historical

Since it's beginnings in 1974, SignWriting has always been a practical script that has been used by real people writing real text. What started in one country has spread around the world.

Dating from 1986 till today, there is an extensive set of documents for SignWriter Dos (and other editors) from multiple countries around the world.

3.B. Modern

Since 2004, an international corpus has been building. It was undergone several symbol set updates. It has grown from comma delimited data, to XML, and finally to formal words. Each conversion has enabled the international corpus to grow and evolve. Along the way, data from previous historical formats has been reentered into the corpus.

In 2012, the international corpus has hundreds of thousands of signs from dozens of different languages.

The quality of the corpus is inconsistent. There are many spelling mistakes and older forms of writing. The body of work isn't the end, but the start of something more. As more people learn to write and develop their own style, the quality of the corpus will naturally improve.

4. Mathematical Model

If you use information correctly, the model will behave correctly. Mathematics is not subjective, but deterministic. Access to the subsystem internals make it easier to understand. This provides knowledge independent of experience.

Through trial and evaluation, the model has been successively refactored to reduce the complexity and the computation cost of the implementations. Several generations of empirical data has been created by applying the model to real world situations. The consequences of the model has been observable by the senses. Problem areas and shortcomings have been resolved to create a robust solution.

4.A. Abstract Structure

The abstract structure of the formal strings is governed by a set of laws. The grammar of the formal strings are based on syntactic rules that define their internal structure.

4.B. Proto Encoding

$C \subset L\ (G)$
* C = the corpus of international text
* $\subset$ = the subset of
* L = the modern SignWriting language
* G = the formal grammar of modern SignWriting

$G = (N,\Sigma,P,S)$
* N = the set of non-terminal tokens
* Σ = the set of terminal tokens
* P = the set of production rules
* S = the start token

$N = \{S,T,A,B\}$
* S = start token
* T = term
* A = ordered prefix
* B = signbox

$\Sigma = \{a,b,l,m,r,w,s,p,n\}$
* a = prefix marker
* b = signbox marker
* l = left lane marker
* m = middle lane marker
* r = right lane marker
* w = writing symbol
* s = sequential symbol
* p = punctuation symbol
* n = number token

Word production rules
* P1: $S \rightarrow T$
* P2: $S \rightarrow B$
* P3: $S \rightarrow p$
* P4: $T \rightarrow AB$
* P5: $A \rightarrow Aw$
* P6: $A \rightarrow As$
* P7: $A \rightarrow aw$
* P8: $A \rightarrow as$
* P9: $B \rightarrow Bwnn$
* P10: $B \rightarrow b$
* P11: $B \rightarrow l$
* P12: $B \rightarrow m$
* P13: $B \rightarrow r$

Sentence production rules
* P14: $S \rightarrow ST$
* P15: $S \rightarrow SB$
* P16: $S \rightarrow Sp$

4.C. Regular Expressions

A regular expression is used to examine text and identify strings that match a stated pattern. A regular expression is written in a concise and flexible formal language. It contains literals and metacharacters. A literal is any character that we literally want to find in the string. A metacharacter is a special character with a unique meaning that is not literally in the string, but represents a type of search pattern.

4.C.1. Regular Expression Basics

Characters	Description	Example
*	Match a literal 0 or more times	ABC* matches AB, ABC, ABCC, ...
+	Match a literal 1 or more times	ABC+ matches ABC, ABCC, ABCCC, ...
?	Match a literal 0 or 1 times	ABC? matches AB or ABC
{#}	Match a literal "#" times	AB{2} matches ABB
[ ]	Match any single literal from a list	[ABC] matches A, B, or C
[-]	Match any single literal in a range	[A-C] matches A, B, or C
( )	Creates a group for matching	A(BC)+ matches ABC, ABCBC, ABCBCBC, ...
(|)	Matches one of several alternatives	(AB|BC|CD) will match AB, BC, or CD

4.C.2. Proto Encoding Patterns

Pattern	Description
wnn	A single writing symbol positioned with 2 numbers
(wnn)*	Zero or more writing symbols, each positioned with 2 numbers
b(wnn)*	A signbox used for horizontal writing
[lmr](wnn)*	A signbox in a lane used for vertical writing
a[ws]+	A prefix with one or more writing or sequential symbols
(a[ws]+)?	An optional prefix with one or more writing or sequential symbols
p	A punctuation
(((a[ws]+)?b(wnn)*)|p)+	A sign text for horizontal writing as a string of signboxes (with optional prefixes) and punctuation
(((a[ws]+)?[lmr](wnn)*)|p)+	A sign text for vertical writing as a string of signboxes in lanes (with optional prefixes) and punctuation

4.D. Variability

The symbols and their meaning are based on an international agreement that does not allow for variability. Everyone should understand the individual symbols to mean the same thing regardless of language or writing style.

Beyond the individual symbols, there are two primary spelling rules for writing a sign as a 2 dimension cluster of symbols: 1) write the position of contact and 2) every sign has a center.

Beyond the individual symbols, there exists a vast amount of variability in how people write: horizontal or vertical, minimalist or exacting detail, few heads or lots of heads, stick figures or detached hands.

Even within the same style, there exists five types of variability for Modern SignWriting.

4.D.1. Viewpoint Variability

Some signs can be written from the front perspective (straight-on view of the signer) or from the top perspective (top-down view of the signer). Although these written signs represent the same sign, they will not use the same string.

4.D.2. Symbol Variability

Symbol choice is sometimes subjective. A sign can be written with more, less, or different details. The choice of detail will affect the choice of symbol and hence the string.

4.D.3. Center Variability

Every 2 dimensional cluster of symbols has a center by definition. This center is defined as the origin of the signbox space (0,0). The center of a signbox is important for layout.

All signs that do not contain a head or trunk symbol will center the same regardless of writing direction. Horizontal writing will center on the head symbols only. Vertical writing will center on both the head and the trunk symbols.

A hybrid centering technique can solve both writing directions at the same time. The vertical center of a signbox should be based on the heads alone. The horizontal center of a signbox should be based on heads and trunks.

A custom center allows the user to specifically set the center of a sign and override any predetermined value.

4.D.4. Order Variability

The order of symbols in a signbox string is only meaningful for issues of overlap when one symbol is positioned on top of another and the negative space of the top symbol obscures part of the positive space of a lower symbol. Otherwise, the order of the symbols is irrelevant to the visual representation of a string. The relationship is surjective with several strings mapping to a single visual image. Order variability can be exploited to resolve issues of ambiguity. Two different signs with the same visual appearance but different meanings can have different spellings based on order variability.

4.D.5. Position Variability

Within the formal strings, the precise position of each symbol is user defined. Unless written against an accepted dictionary, a user has the ability to fine tune the position of each symbol. For a single symbol, there is no positional variability. Two symbols will have dozens of approximate relations.

More than two, and the number of approximate relations increases exponentially.

5. Symbol Set

The ISWA 2010 is a mathematical alphabet. It is the end result of 8 years of standardization efforts with writers from around the world. Serious standardization efforts were started in 2004 with the International MovementWriting Alphabet. These efforts refocused with the ISWA 2008. These efforts were realized for the symbol set with the ISWA 2010.

Valerie Sutton created and named each symbol of the ISWA 2010 with a definitive image and a normative ID. Steve Slevinski reflected Valerie's design though visual and mathematical models.

The normative IDs structure the symbols as a hierarchy with 6-degree of features. A symbol ID is a sequence of six formatted numbers of increasing detail. The first dashed number defines the Category (11). The first two dashed numbers define the SymbolGroup (11-22). The first four dashed numbers define a BaseSymbol (11-22-333-44). The fifth number represents the fill (55). The sixth number represents the rotation (66). A symbol ID is a combination of BaseSymbol ID with a fill value and a rotation value. A symbol ID has the format "nn-nn-nnn-nn-nn-nn", where each "n" is a digit from 0 to 9.

The ISWA 2010 is fully documented and available under the Open Font License with a file based font, either PNG or SVG, either individual files or XML.

5.A. Symbol Types (3)

5.A.1. Writing Symbols

The writing symbols of SignWriting represent a visual conception: either hands, movement, dynamics, timing, head, face, trunk, or limb. The body concept is a combination of trunk and limb.
The writing symbols are used in 2 dimensional clusters to create one or more morphemes: the smallest semantically meaningful units in a language. The symbols do not change size or shape when combined in a visual pattern. The symbols can overlap and obscure symbols underneath.

5.A.2. Detailed Location Symbols

Detailed location symbols are used individually or sequentially. They represent isolated analysis that is written outside the 2 dimensional cluster.

5.A.3. Punctuation Symbols

Punctuation symbols are used when writing sentences. They are used individually, between clusters.

5.B. Categories (7)

Category 1: Hands

Handshapes from over 40 Sign Languages are placed in 10 groups based on the numbers 1-10 in American Sign Language.

Category 2: Movement

Contact symbols, small finger movements, straight arrows, curved arrows and circles are placed into 10 groups based on planes: The Front Wall Plane includes movement that is “parallel to the front wall” and the Floor Plane includes movement that is “parallel to the floor”.

Category 3: Dynamics

Dynamics Symbols are used mostly with Movement Symbols and Punctuation Symbols, to give the "feeling" or "tempo" to movement. They also provide emphasis on a movement or expression, and combined with Puncuation Symbols become the equivalent to Exclamation Points. The Tension Symbol, combined with Contact Symbols, provides the feeling of 'pressure", and combined with facial expressions can place emphasis or added feeling to an expression. Timing symbols are used to show alternating or simultaneous movement.

Category 4: Head & Faces

Starting with the head and then from the top of the face and moving down. Group 22 includes head movement and views of the head. Groups 23-26 include detailed facial expressions and movement of parts of the face and neck.

Category 5: Body

Torso movement, shoulders, hips, and the limbs are used in Sign Languages as a part of grammar, especially when describing conversations between people, called Role Shifting, or making spatial comparisons between items on the left and items on the right. This category is important when writing sign language storytelling and poetry. All sign languages have some signs that point below the hips, or touch the torso, or hunch the shoulders, or touch the arms and wrists.

Category 6: Detailed Location

Detailed Location symbols are used in the SignSpelling Sequence and not in the Spatial SignSpelling. May be useful for sorting large dictionaries, refining animation, simplifying translation between scripts and notation systems, and for detailed analysis of location sometimes needed in linguistic research.

Category 7: Punctuation

Punctuation Symbols are used when writing complete sentences or documents in SignWriting. The Punctuation Symbols do not look like the symbols for punctuation in English, but they do have similar meanings. SignWriting punctuation symbols include a period, comma, colon, semicolon, exclamation point and so forth.

5.C. SymbolGroups (30)

There are 30 SymbolGroups. The first 2 dashed numbers in the symbol ID identify the group. The 30 groups can be divided into 3 sets of 10. The first ten are hands, category 1. The second ten are movements, category 2. The third ten are categories 3 thru 7. In order, 1 group for the Dynamics & Timing category, 1 for Head, 4 for Face, 1 for Trunk, 1 for Limb, 1 for Detailed Location, and 1 for Punctuation.

First Set	Second Set	Third Set
01-01 Index	02-01 Contact	03-01 Dynamics & Timing
01-02 Index Middle	02-02 Finger Movement	04-01 Head
01-03 Index Middle Thumb	02-03 Straight Wall Plane	04-02 Brow Eyes Eyegaze
01-04 Four Fingers	02-04 Straight Diagonal Plane	04-03 Cheeks Ears Nose Breath
01-05 Five Fingers	02-05 Straight Floor Plane	04-04 Mouth Lips
01-06 Baby Finger	02-06 Curves Parallel Wall Plane	04-05 Tongue Teeth Chin Neck
01-07 Ring Finger	02-07 Curves Hit Wall Plane	05-01 Trunk
01-08 Middle Finger	02-08 Curves Hit Floor Plane	05-02 Limbs
01-09 Index Thumb	02-09 Curves Parallel Floor Plane	06-01 Detailed Location
01-10 Thumb	02-10 Circles	07-01 Punctuation

5.D. BaseSymbols (652)

There are 652 BaseSymbols. The first 4 dashed numbers of a symbol ID identify the base. The 652 bases are divided between the 30 groups. For each group, there are less than 60 bases. The bases are often displayed in columns of 10.The details of the individual BaseSymbols is beyond the scope of this document. Please refer to the ISWA 2010 HTML Reference or any of Valerie Sutton's ISWA 2010 documents.

5.E. Symbols (37,811)

The symbols are variably sized; they do not share a common height or width. The symbols are static; they do not rotate or morph. Each symbol has a unique name as the symbol ID.

The symbol ID is a six part number formatted for zero padding with a mask of "xx-xx-xxx-xx-xx-xx-xx". The six individual numbers of the symbol ID listed by order are: category, group, base, variation, fill, rotation.

The first number by itself identifies the Category, together with the second number identifies the SymbolGroup ID.

The third number identifies the BaseSymbol place, usually with an "01" for the fourth number: variation. When more than one BaseSymbols share the first three numbers, the fourth number will order these BaseSymbols with variation numbers starting from 1.

The fifth and six numbers uniquely define an individual symbol. They are used to place symbols on a 6 by 16 palette. Each BaseSymbol has a unique symbol palette that lists the symbols on a 6 by 16 grid with valid columns and valid rows. Any cell on a valid column and a valid row is valid and must identify a symbol. Any cell on an invalid column or an invalid row does not represent a symbol and is invalid.

The fill modifier can best be understood through the palm facing of the hand graphemes. The palm facing is based on planes. The SignWriting script uses two planes: the Front Wall (Frontal Plane) and the Floor (Transverse Plane). There are 6 palm facings. The first three palm facings are parallel with the Front Wall. The second three palm facings are parallel with the Floor. The reader can view the signer from different viewpoints (expressive or receptive) and can view the hands from different perspectives (front or top), but no matter what the viewpoint or perspective, the first three Fills represent the palm facing parallel to the Front Wall and the second three Fills represent the palm facing parallel to the Floor.

Fill	Indicator	Meaning
01	grapheme with white palm	reader sees palm of hand parallel Front Wall
02	grapheme with half black palm	reader sees side of hand parallel Front Wall
03	grapheme with black palm	reader sees back of hand parallel Front Wall
04	grapheme with white palm and broken line	reader sees palm of hand parallel Floor
05	grapheme with half black palm and broken line	reader sees side of hand parallel Floor
06	grapheme with black palm and broken line	reader sees palm of hand parallel Floor

The fill modifier is redefined for the movement arrows of category 2.

Fill	Indicator	Meaning
01	a grapheme with a black arrow head	movement of the right hand
02	a grapheme with a white arrow head	movement of the left hand
03	a grapheme with a thin, unconnected arrow head	spatial overlapping of movement arrows for the left and right hands when they move as a unit
04	Irregular arrow stems	building blocks for complex movement

The rest of the other bases use a fill modifier for grouping and visual organization that is meaningful only for a particular base symbol or small set.

The rotation modifier can best be understood through the hand symbols. The first 8 rotations progress 45 degrees counter clockwise. The last 8 rotations are a mirror of the first 8 and progress 45 degrees clockwise. Zero (0) degrees is understood to point to the top of the grapheme.

Rotation	Direction	Degrees from top
01	Counter Clockwise	0
02	Counter Clockwise	45
03	Counter Clockwise	90
04	Counter Clockwise	135
05	Counter Clockwise	180
06	Counter Clockwise	225
07	Counter Clockwise	270
08	Counter Clockwise	315
09	Clockwise	0
10	Clockwise	45
11	Clockwise	90
12	Clockwise	135
13	Clockwise	180
14	Clockwise	225
15	Clockwise	270
16	Clockwise	315

6. Symbol Encoding

Every symbol of the ISWA 2010 has a normative name as the symbol ID, which is 18 characters long. These names is overly verbose and are not used directly for encoding.

6.A. 16-bit Symbol Code

A 16-bit code is an integer between 0 and 65,535. This type of value is perfect for a primary key for database lookup or other integer index. Through a simple formula, each symbol has a unique 16-bit codepoint in the x-ISWA-2010 coded character set.

There are 652 BaseSymbols, numbered from 1 to 652. Each BaseSymbol can be visualized on a grid of 6 columns and 16 rows: for the 6 fills and 16 rotations. Each symbol can be identified by 3 values of BaseSymbol, column and row.

If we start on the first BaseSymbol grid, give the first symbol a code value of 1, incremented down the first column, continue to the next column, and continue through the remaining BaseSymbols; we end up with numbers from 1 to 62952.

Given any symbol with:

BaseSymbol number = n
Fill = f
Rotation = r

code = (n-1)*96 + (f-1)*16 + r

6.B. ASCII Symbol Key

The symbol key is a formatted string, 6 ASCII characters long, that identifies a symbol. The symbol key makes explicit features of the symbol otherwise only implicit in the symbol ID.

The first character of the symbol key is always "S". This aids in parsing and human readability. The last 5 characters represent the symbol encoding in hexadecimal: base 16.

Base 10 is called decimal and is the most widely used numbering system. This uses 10 digits from 0 through 9. Hexadecimal numbers use base 16. This uses 16 digits, from 0 through 9 and from “a” through “f”.

Given any symbol with:

BaseSymbol number = n
Fill = f
Rotation = r
dechex = function that converts a decimal number to a hexadecimal number.

key = S . dechex(n+255) . dechex(f-1) . dechex(r-1)

6.C. Encoding Data

Most operations of layout and searching can be completed without requiring additional information outside of the sign text strings. There are 4 special cases that require access to outside information.

6.C.1. ID to Key

The symbol ID does not have an automatic conversion to symbol key without additional information. Every one of the 652 BaseSymbols has a unique mapping from BaseSymbol ID to BaseSymbol

number. The data file includes 652 entries of the format “xx-xx-xxx-xx equals BS #”

6.C.2. Valid Fills and Rotations

Each BaseSymbol has 2 integer values that define validity for fills and rotations. The Binary Fills value is a 6-bit number from 1 to 63. This value defines which fills are valid for the BaseSymbol. The Binary Rotations value is a 16-bit number from 1 to 65,535. This value defines which rotations are valid for the BaseSymbol. The data file includes 652 entries that map each BaseSymbol to 2 different values: one for the Binary Fills value and one for the Binary Rotations value.

Given any symbol defined as a Symbol Key:

Symbol Key = “S” . H1 . H2 . H3 . H4 . H5
Fill Power = 2 ^ hexdec(H4)
Rotation Power = 2 ^ hexdec(H5)
Binary Fills = look up value for BaseSymbol
Binary Rotations = look up value for BaseSymbol

The symbol key represents a valid symbol if both:

(Fill Power BITWISE AND Binary Fills) > 0
(Rotation Power BITWISE AND Binary Rotations) > 0

6.C.3. BaseSymbol Variations

Most symbol IDs use a variation number of 1. This is the fourth number of the symbol ID. A few symbols utilize the variation number to create a relationship between different BaseSymbols: such as arrows of different length. When BaseSymbols are related through the variation number, the first 3 numbers of the symbol ID will be the same, and the variation number will start at 1 for the first BaseSymbol and increase by 1 for each subsequent related BaseSymbol. The data file includes 652 entries that list the number of variations for each BaseSymbol. BaseSymbols that are related by variation will have the same number of variations. The symbol ID must be referenced to determine the variation number for any symbol.

6.C.4. Symbol Sizes

Every symbol of the ISWA 2010 has a specific width and height. These values are needed for string preprocessing that includes centering or sizing. These values can be determined several different ways.

Image Analysis

The PNG or SVG image can be analyzed for each symbol to determine the width and height.

ID or Key Lookup

Using the 16-bit symbol code or symbol key, the width and height can be accessed from a database or other data storage.

6.D. Transformations

Many selected symbol could be transformed by rotation, mirror, flop, or variation.

Given any symbol defined as a Symbol Key:

Symbol Key = "S" . H1 . H2 . H3 . H4 . H5
Fill = hexdec(H4) + 1
Rotation = hexdec(H5) + 1;

New symbol keys should always be checked for validity. If the symbol key is not valid, repeat the transformation.

6.D.1. Reflection Transformation

If Binary Rotations > 255 there are more than 8 rotations:
If Rotation > 8
Rotation = Rotation - 8
Else if Rotation <= 8
Rotation = Rotation + 8

If Binary Rotations < 256 there are 8 or less rotations
Rotation 1 mirrors 1
Rotation 2 mirrors 8
Rotation 3 mirrors 7
Rotation 4 mirrors 6
Rotation 5 mirrors 5

Symbol Key = "S" . H1 . H2 . H3 . dechex(Rotation - 1) . H5

6.D.2. Rotation Transformation

Rotations 1 thru 8 loop
Rotations 9 thru 16 loop

If Rotation < 9
Clockwise
Rotation = Rotation - 1
Counter Clockwise
Rotation = Rotation + 1

If Rotation > 8
Clockwise
Rotation = Rotation + 1
Counter Clockwise
Rotation = Rotation - 1

Symbol Key = "S" . H1 . H2 . H3 . dechex(Rotation - 1) . H5

6.D.3. Flop Transformation

Fills 1 thru 6 loop
Fill = Fill + 1

Symbol Key = "S" . H1 . H2 . H3 . H4 . dechex(Fill - 1)

6.D.4. Variation Transformation

Each BaseSymbol has 2 numbers that deal with variations: the first is the specific variation number in the Symbol ID and the second is the general number of variations found in a data file.

Given any symbol:
Variation number = symbol specific value from the symbol ID
Number of variations = BaseSymbol value from a data file

The variation transformation is available if the number of variations is greater than 1:
If (variation number < number of variations)
Variation number = variation number + 1
Else if (variation number = number of variations)
Variation number = 1

7. Script Layout

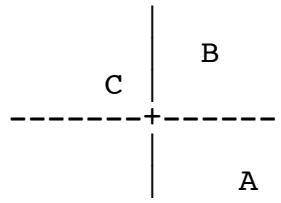
Sign languages are fundamentally different than spoken language, just as vision is fundamentally different that sound. SignWriting is an unusual script because the writer chooses a symbol from a vast symbol set and the writer chooses the 2-dimensional position for each symbol. A 2-dimensional cluster does not have a normative string representation.

The layout of the SignWriting script is based on clusters and punctuation. Each cluster represents a sign of a sign language or a visual performance of a sign gesture.

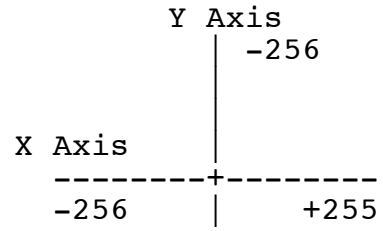
Punctuation divides the clusters into sentences. Most commonly, the clusters are arranged vertically, from top to bottom aligned on their centers. Other times, the signs are arranged horizontally from left to right.

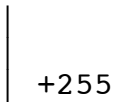
7.A. SignBox

Each sign is a 2 dimensional arrangement of writing symbols. A sign is considered centered if the center is at coordinates (0,0).



SignBox space is 2 dimensional.





7.B. Vertical Layout

When written vertically, SignWriting can use 3 different lanes in a column of text to represent body weight shifts. Body weight shifts are important to the grammar of sign languages, used for two different aspects of sign language grammar: 1) role shifting during sign language storytelling, and 2) spatial comparisons of two items under discussion. One "role" or "item" is placed on the right side of the body (right lane), and the other on the left side of the body (left lane), and the weight shifts back and forth between the two, with the narrator in the middle (middle lane).

For body weight shifts to one side or the other, the center of the cluster is aligned with a fixed horizontal offset from the middle lane in either the left or right lane. Punctuation is always used in the middle lane.

There are 3 lanes for layout: left, middle, and right. Only one lane is used at a time going down the page.

L	M	R
	X	
	X	
X		
	X	
		X
	X	

7.C. Horizontal Layout

8. Encoding Forms

Machine readable.
Make explicit features of the text otherwise only implicit and can not be automatically analyzed.
Text encoding exists solely to support the various processes that act upon text.
Efficient internal text representation.
Resolve hard problems in a principles way.
Essential properties to establish identity.

Symbol Encoding – composition letters, unambiguous, computer processable way.
Script Encoding – larger structural units of words and sentences. Dynamic composition of symbol

choice and position.

8.A. FSW – Formal and Regular SignWriting for Storage

Formal and regular ASCII words

8.B. KSW – Key-base SignWriting for Display

Variant forms of Kartesian Display

8.C. CSW – Character SignWriting

Pure character model without markup language. This is an unformatted string of special purpose characters with codepoints from the 12-bit coded character set of x-BSW-12 or codepoints in the Unicode PUA.

Name	BSW Codepoint(s)	Unicode PUA
Sequence Marker	B+100	U+FD800
SignBox Marker	B+101	U+FD801
Left Lane Marker	B+102	U+FD802
Middle Lane Marker	B+103	U+FD803
Right Lane Marker	B+104	U+FD804
Columns 1 thru 6	B+110 – B+115	U+FD810 – U+FD815
Rows 1 thru 16	B+120 – B+12F	U+FD820 – U+FD82F
SignWriting Grid Pages	B+130 – B+3BB	U+FD830 – U+FDABB
Negative Numbers: -256 thru -1	B+700 – B+7FF	U+FDE00 – U+FDEFF
Positive Numbers: 0 thru 255	B+800 – B+8FF	U+FDF00 – U+FDFFF

Type	Section	Symbol Key	x-BSW-12	Unicode PUA
Writing		100 - 37e		U+FD830 - U+FDAAE
Writing	Hands	100 - 204		U+FD830 - U+F934
Writing	Movement	205 - 2f6		U+FD935 - U+FDA26
Writing	Dynamics	2f7 - 2fa		U+FDA27 - U+FDA2A
Writing	Timing	2fb - 2fe		U+FDA2B - U+FDA2E
Writing	Head	2ff - 309		U+FDA2F - U+FDA39
Writing	Face	30a - 36c		U+FDA3A - U+FDA9C
Writing	Trunk	36d - 375		U+FDA9D - U+FDAA5

Writing	Limb	376 - 37e		U+FDAA6 - U+FDAAE
Detailed Location		37f - 386		U+FDAAF - U+FDAB6
Punctuation		387 - 38b		U+FDAB7 - U+FDABB

The BSW string has been designed for an easy conversion to Unicode. Each x-BSW-12 codepoint can be shifted by the value of U+FD730. For example, codepoint B+39A becomes U+FDA9A.

There are 10 tokens used with Cartesian SignWriting revision 3. They can be grouped in 4 layers: the 4 structural makers, the 3 ranges of base symbols, the 2 modifiers, and the numbers.

```
Q L B R
 w s P
  i o
   n
```

A string of x-BSW-12 characters can be visualized as tokens rather than characters. A tokenized view replaces each character with 1 of the 10 token values. The use of tokens clarifies structures and simplifies regular expressions.

wio
- a writing symbol as 3 characters of writing base, fill modifier and rotation modifier.

nn
- coordinates with X and Y values as 2 numbers.

wionn
- a spatial symbol as 5 characters with 3 characters of a writing symbol and 2 characters for coordinates for top left placement.

(wionn)*
- zero or more spatial symbols.

[ws]
- a writing base symbol or a detailed location base symbol.

[ws]io
- a writing symbol or a detailed location symbol.

([ws]io)+
- one or more writing symbols and/or detailed location symbols.

Pio
- a punctuation symbol as a punctuation base symbol with a fill modifier and a rotation modifier.

9. Regular Searching

Searching is either exact or approximate. An approximate search uses a coordinate range for each symbol. This type of searching is reflexive and symmetrical, but it is not transitive. The approximate search is not based on visual equivalence.

9.A. Regular

9.B. Formal

9.C. Filter

9.D. Displacement

10. Display Variant Forms

10.A. Raw

A minimal sign text string contains the minimal amount of data required to represent text. It defines signs and punctuations. A sign is defined with a lane and zero or more spatial writing symbol. A sign can be preceded by an optional sequence. Punctuation is always used alone. A sign canvas can use any section of the coordinate space.

[LBR](wionn)*
- a cluster of writing symbols in a lane

(Q([ws]io)+)?
- an optional sequence of writing and/or detailed location symbols

Pio
- a punctuation symbol

((Q([ws]io)+)?[LBR](wionn)*)|(Pio)
- a sign text

10.B. Expanded

10.C. Layout

A layout sign text string defines maximum coordinates for signs and top-left coordinates for punctuation. Defining sizes in the data stream makes layout possible without needing to access symbol size. Sign text for layout requires that each sign uses the coordinates 0,0 as the absolute center (Section 2.2).

[LBR]nn(wionn)*
- a cluster of writing symbols in a lane with defined maximum coordinates

(Q([ws]io)+)?
- an optional sequence of writing and/or detailed location symbols

Pionn
- a punctuation symbol with top-left coordinates
((Q([ws]io)+)?[LBR]nn(wionn)*)|(Pionn)
- a sign text for layout

10.D. Display

A display sign text string combines multiple signs and punctuations onto a series of defined height canvases using transformation parameters to determine the placement of the various signs and punctuation. When written vertically in columns, the height represents the vertical length that all canvases share in common. For rows, the height represents the horizontal length in common with all canvases. Sign text for display defines the top left of every canvas as 0,0 and does not use negative numbers.

Bnn([wsP]ionn)*
- a cluster of symbols with defined maximum coordinates

Transformational Parameters

Name	Value	Description
length	number of pixels	The chunk size of columns or rows
width	number of pixels	The width of the column or row
breadth	number of pixels	The breadth of all columns or rows
padding	number of pixels	Distance from closest symbol to width edge.
form	col,cols,row, or rows	Form of display. The form can be a single strip as a column or a row. The form can be a panel of multiple columns or rows.
style	fix or flex	The style of the width is either fixed by the width or flexible. For a flexible style, the margin is used as the distance from the edge of the column or row and the edge of the closest symbol. If a width is given, a flexible style will use the width as the minimum column or row width.
signTop	number of pixels	Padding before a sign.
signBottom	number of pixels	Padding after a sign.
puncBottom	number of pixels	Padding after a punctuation.
offset	number of pixels	The horizontal offset from the center of the middle lane to either the left or the right.
top	number of pixels.	The distance from the start of the column or row and the edge of the first symbol.
justify	option number: 1, 2, 3	Justify 1 pulls punctuation to the end of a column or row by moving signs closer together. Justify 2 pushes sign apart to evenly cover a column or row. Justify 3 will both pull punctuation and push signs.

11. Sorting Terminology

A sequence is a list of writing symbols and/or detailed location symbols. A valid sequence must contain at least one symbol and can not contain punctuation. A sequence is an optional sign prefix used to define a temporal order.

The temporal order of a sign distinct from the visual cluster. Neither structure can be derived from the other.

With the use of the sequence, sorting is natural when using the ISWA 2010 order. The sequence prefix will naturally enable comparison and sorting of signs without any special functions or configuration.

Symbol orders other than the ISWA 2010 order are not directly supported. This may be an issue if a language group chooses an alternative order for their specific hand shape subset. It is advised to maintain the same hand shape order as the ISWA 2010 for all subsets. Otherwise, sorting will require construction of a custom Unicode sorting table.

There are several theories on the best way to structure a sequence. The most productive is based on the SignSpelling Sequence theory of Valerie Sutton. A sequence is structured as a series of starting handshapes followed by optional movements, transitional handshapes, movement, and end handshapes. Only symbols from category 1 (hands) and category 2 (movement) should be used in this first section. The last section of the sequence should contain symbols of dynamics & timing, head & face, or body: categories 3, 4, and 5.

Detailed location symbols from category 6 can be used in a sequence, but are rarely (if ever) needed for a sequence in general writing.

11.A. Different and Exact

11.B. Direct Sort

11.C. Sorting Unordered SignBoxes

12. Spelling Normalization

12.A. Unordered and Inexact

12.B. Reflected Statistics

Strength, association, displacement

12.C. Exact Spelling

12.D. Normal within a Community

12.E. Symbol Subsets

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