

A SYMBOLIC DESCRIPTIVE SYSTEM FOR FACIAL EXPRESSION CONVEYING LINGUISTIC INFORMATION IN SIGNING

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ABSTRACT

The kinds of change in facial expression which can be produced by a sender's neural control of facial muscles, and, at the same time, can be visually perceived by a listener are described in discrete symbols.

The linguistic information supplemented by the facial expressions in signing is categorized into syllabic, lexical and syntactic components. In order to control the facial expressions for this linguistic information, the timing and duration of the symbols are specified, and, by applying a set of concatenation rules, the control commands are generated.

The adequacy of the symbolic descriptive system and its control rules have been examined through a computer synthesis of artificial facial expression, taking the example of transmitting syntactic information in traditional Japanese sign language.

These facial expressions are combined with the symbolic descriptive system for hand shapes and arm actions and their control rules for the pictorial display of signing gestures.

1. SYMBOLIC DESCRIPTION

1.1. Elements of Facial Expression

The kinds of change in facial expression which can be produced by a sender's neural control of facial muscles [References 1 and 2], and, at the same time, can be perceived visually by a listener, are described in discrete symbols. Parameters used for the element of facial expression are as follows:

1. Opening and closing of the **eyelids**
 2. the **eye direction**
 3. raising, knitting and lowering of the **eyebrows**
 4. opening of the **nostrils**
 5. opening or closing of the **mouth**
 6. protrusion or corner pull of the **lips**
 7. popping up or drawing of the **chin**
- and
8. nod or shake of the **head**

The correspondence between the parameters of the elements and their symbols in a symbolic

ELEMENTS

PARAMETERS

EYELIDS: NEUTRAL
WIDELY OPENED
NARROWED, OR
CLOSED

EYE DIRECTION: NEUTRAL
DIRECTLY UP
DOWN
LEFT, OR
RIGHT
EACH IN TWO STEPS
DIRECT TO A PARTICULAR POINT

EYEBROWS: NEUTRAL
THE INSIDES RAISED, OR
KNITTED
THE LATERAL SIDES RAISED, OR
LOWERED
EACH IN TWO STEPS.

NOSTRILS: NEUTRAL
WIDELY OPENED

MOUTH: NEUTRAL
WIDELY OPENED
NARROWED, OR
CLOSED
THE LIPS PROTRUDED, OR
THE CORNERS PULLED Laterally
EACH IN TWO STEPS

CHIN: NEUTRAL
POPPING UP, OR
DRAWING IN THE CHIN
EACH IN TWO STEPS

HEAD: NEUTRAL
NOD, OR
SHAKE.
TILT FORWARD, OR
BACKWARD
EACH IN TWO STEPS

SYMBOLS

EL₀
EL+
EL-
EL--

EY₀
EYu+, u++
EYd+, d++
EYl+, l++
EYr+, r++
EYxy

EB₀
EBi+, i++
EBi-, i--
EBl+, l++
EBl-, l--

NR₀
NR+

MO₀
MO+
MO-
MO--
LP+, ++
LP-, --

CN₀
CN+, ++
CN-, --

HD₀
HDN
HDS
HD+, ++
HD-, --

Table 1: Correspondence between the parameters of elements and their symbols in a symbolic descriptive system of the facial expressions.

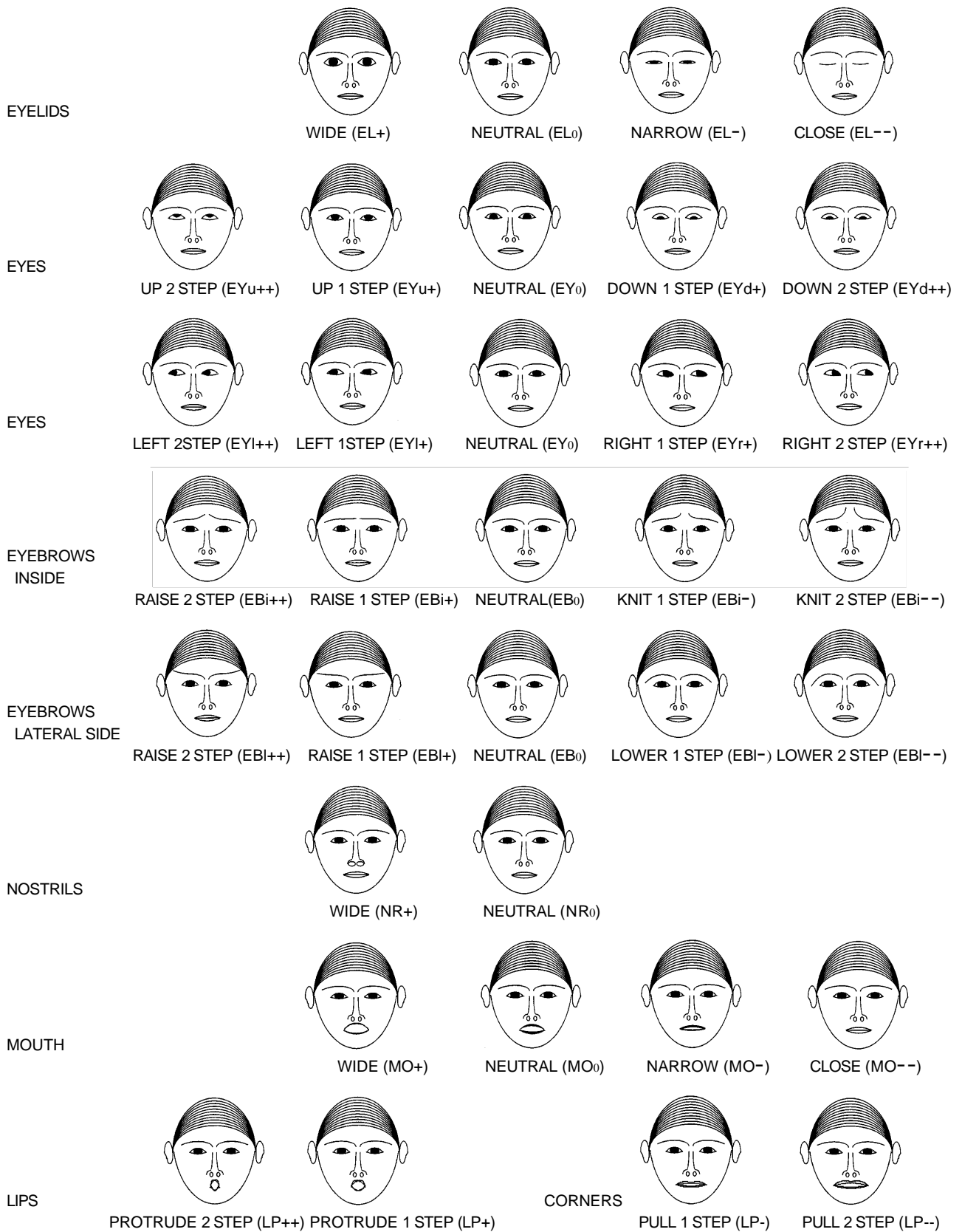


Figure 1: Computer synthesized facial expression for each of the symbols.

descriptive system of facial expression is shown in Table 1, and the computer synthesized facial expression for each of the symbols is shown in Figure 1.

1.2. Computer Synthesis

With these parameters, all the changes in facial expression can be described symbolically. There are forty-four symbols in all. Those parameters are assembled by referring to the previous studies on the facial expressions [References 3, 4 and 5], so that all the changes in facial expression conveying linguistic information both in speaking and signing, as well as emotional information, can be described symbolically.

Each of those parameters of the elements of facial expressions are specified by a set of pictorial parameters such as center, radius and portion of an ellipsoid. They are derived by looking up the table of typical values for each of the parameters, and controled in the computer program in order to synthesize the actions in the elements.

For the actions of chin and head, the projection on the two-dimensional display screen of their three dimensional movements is simulated in the computer program.

2. CONTROL RULES

2.1. Linguistic Information

The facial expressions convey emotional information, but, the correspondence between them is not strictly one to one, if the emotional information is analyzed precisely. The facial expressions also convey linguistic information in speaking, but the correspondence between them is not clearly established in any language.

For the series of signed words in a phrase or sentence, basically expressed by hand shapes and arm movements, part of the linguistic information is supplemented by the facial expressions [References 6 and 7]. The facial expressions for linguistic information in traditional sign language (not simultaneous with speech) contain a greater variety of elements used under more strict conditions, compared with spoken language. This is because the signing with hand shapes and arm actions needs to be supplemented by the facial expressions, in order to enable the linguistic information to be transmitted more effectively.

For this reason, linguistic information conveyed by the facial expressions in traditional sign language is taken as the most useful material, in order to construct a basic framework of the control rules for the facial expression in this study. (Those facial expressions are not same as the ones used in body languages for non-verbal communication.)

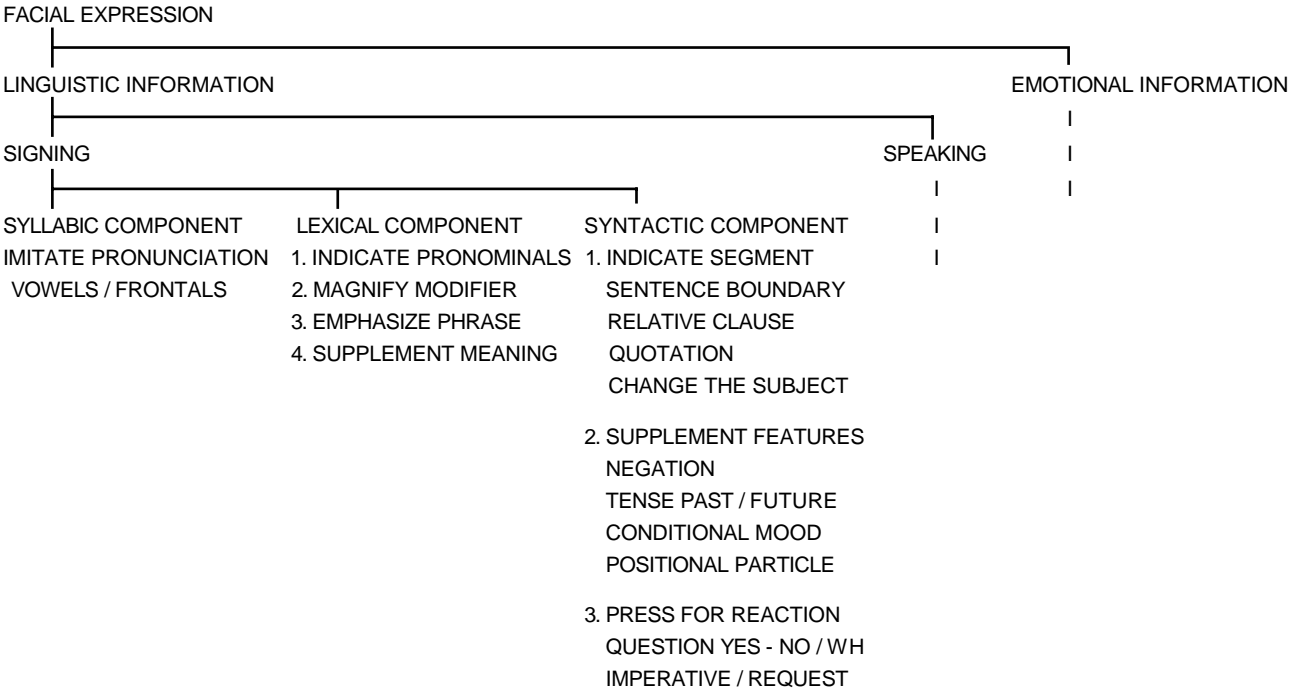


Figure 2 : Linguistic information conveyed by facial expressions in signing.

Linguistic information conveyed by the facial expression in signing is schematized in Figure 2.

The linguistic information to be supplemented to the sign gestures by hands and arms is categorized into syllabic, lexical and syntactic components. In the **syllabic component**, the pronunciation of vowels and frontal consonants is imitated through the actions of mouth and lips.

The **Lexical component** includes;

1. indicating pronominals
 2. magnifying modifiers
 3. emphasizing phrases
- and
4. supplementing meaning

The **Syntactic component** includes;

1. indicating segments such as sentence boundaries, relative clauses, quotations, and changing the subject
 2. supplementing features such as negation, past or future tense, conditional mood, positional particle
- and
3. pressing for a reaction such as yes-no or wh-questions and imperative or request mood

Elements of facial expressions used for lexical and syntactic components are eyes, eyelids, eyebrows, nostrils, mouth and lips (different from those for the syllabic component [References 8 and 9]), chin and head.

2.2. Generation of Control Commands

In order to control the facial expression, the timing and duration of the action of parameters of the elements are specified for a series of words in phrases, clauses or sentences. They are accompanied with a note concerning whether they are mandatory or voluntary. The voluntary symbols are realized only if the elements are not occupied by the mandatory ones. Those data are stored temporarily in a form of matrix of words vs. symbols.

Next, concatenation rules are applied to provide distinction among the priority symbols, reduction of the adjacent symbols, or diffusion of the symbols, if the elements are not occupied by other symbols. The results are stored in modified matrix of words vs. symbols.

Rules of generation of the control commands for facial expressions are schematized in Figure 3.

By combining the specification and the concatenation rules, control commands for each of the parameters is currently being computer-programmed, and the facial expression is synthesized on a computer screen especially designed for graphic display.

In a future version of the control of facial expressions, it is planned to use neuro-muscular parameters instead of current pictorial parameters,

SERIES OF SIGNED WORDS IN PHRASE / CLAUSE / SENTENCE WITH HAND SHAPES / ARM ACTIONS

LINGUISTIC INFORMATION CONVEYED BY FACIAL EXPRESSIONS

| SYLLABIC COMPONENT ELEMENTS | LEXICAL COMPONENT | SYNTACTIC COMPONENT |
|-----------------------------|--|---------------------|
| MOUTH / LIPS | EYES, EYELIDS, EYEBROWS, NOSTRILS, MOUTH, LIPS, CHIN, HEAD | |

SPECIFICATION OF SYMBOLIC DESCRIPTION WITH TIMING / DURATION

ASSIGNMENT OF MANDATORY SYMBOLS / VOLUNTARY SYMBOLS (IF NOT OCCUPIED BY MANDATORY SYMBOLS)

↓ MATRIX OF WORDS VS. SYMBOLS

APPLICATION OF CONCATENATION RULES

DISTINCTION OF PRIORITY SYMBOLS REDUCTION OF ADJACENT SYMBOLS DIFFUSION OF SYMBOLS (IF NOT OCCUPIED)

↓ MODIFIED MATRIX OF WORDS VS. SYMBOLS

GENERATION OF CONTROL COMMANDS

NEUROMUSCULAR CONVERSION

SMOOTHING BY THE NATURE OF THE ELEMENTS

Figure 3 : Rules of generation of the control commands for facial expressions.

so that the concatenation rules work more smoothly by reflecting the nature of the elements of the facial organs [References 10 and 11].

2.3. Japanese Sign Language

In the case of transmitting syntactic information in traditional Japanese sign language, for example, the following items are installed in the database [Reference 12].

1. **Yes-no question:** Raise the eyebrows, open the eyes wide, and lean the upper body forward
 2. **Wh-question:** The same as the yes-no question, plus shaking of the head
 3. **Imperative form:** Raise the chin
 4. **Postpositional particle** [no] and [to] (mean "of" and "and" in Japanese, respectively): Raise the eyes and eyebrows
 5. **Conditional sentence:** Raise the eyebrows
 6. **Change the subject:** Raise the eyebrows
 7. **Negation:** Shake the head
 8. **Emphasis:** Knit the eyebrows
 9. **Past tense:** Quick mouth opening as in [ta] (a past particle in Japanese)
- and
10. **Sentence boundary:** Nod and blink

The adequacy of the symbolic descriptive system for the facial expression (SYDFEX) and its control rules (CORFEX) have been examined through a computer synthesis of artificial facial expressions.

3. APPLICATIONS

3.1. Hand and Arm Sign Gestures

Those facial expressions are combined with the symbolic descriptive system for the hand shapes (SYDHASH) and arm actions (SYDARMA) and

their control rules (CORHASH, CORARMA) for the pictorial display of signing gesture.

Constitution of computer synthesis scheme of the sign gestures is schematized in Figure 4.

Hand shapes:

In order to model the finger actions, firstly, hand shapes were described combining both the combination of finger actions for changing the shapes, and the mutual relationships among the fingers, for each of the combinations of the fingers in the primary action. Hand shapes used in signing are described using the new descriptive symbol system composed by combining the finger actions described above. The system consists of symbols for the five fingers, marks denoting actions, and several marking conventions [Reference 13].

Arm actions:

The position of the wrist is described by a combination of the rotation of the upper arm in the horizontal / vertical plane, the external / internal rotation of the shoulder joint, and extension / flexion of the elbow joint. States of rotation of the upper arm and the shoulder joint are classified based on the direction of rotation from the neutral position. The direction of the hand and the facing of the palmar or dorsal surface of the hand is derived by combining the pronation / supination of the forearm joint and extension / flexion of the wrist joint for each of the hand positions [Reference 14].

The action of the hand can be described by the transition from a state classified by the position and direction of the hand and the facing of the palmar or dorsal surface to another state, or repeated transition. In addition to the above described actions, actions in which the hand touches the body are used in signing.

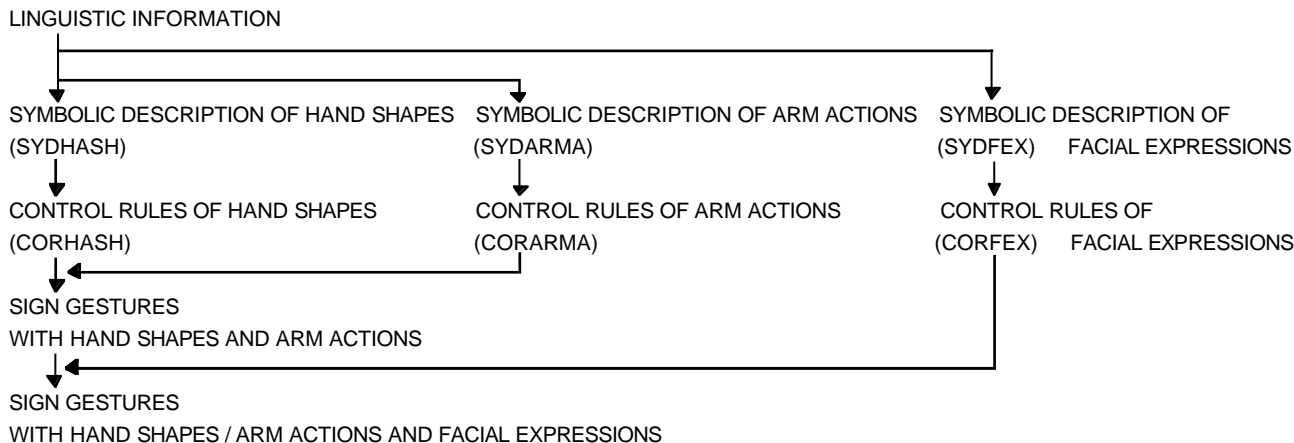


Figure 4: Constitution of computer synthesis scheme of the sign gestures.

The principle which underlays the design of control rules of the facial expressions are applicable to the control of the hands and arms, as it explains a basic characteristic of the organization of the media common to any communication channel.

The neuro-muscular control parameters have already been taken into account in the biomechanical modeling of the hand shapes and arm actions.

3.2. Electronic Sign Language Dictionary

The symbolic descriptive system and control rules of the facial expression developed in this study, by combining with those for hands and arm actions, can be utilized to furnish **data base** to electronic sign language dictionary with moving pictures of hand, arms and faces of the signer [Reference 15].

The dictionary can be applied to the **self-learning system** of sign language for beginners [Reference 16], as well as a **laboratory facility** for detailed analysis of nature of the sign gestures. It is also expected to be applied to **multi-media display** of language information for the deaf persons.

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