Determining the meaning of arm gestures

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Abstract

Developing methods for determining the meaning of gestures in human-computer interaction, focusing especially on two-way interaction, is the object of a joint project of The Institute of Theoretical and Applied Informatics of the Polish Academy of Sciences in Gliwice and the Visual Research and Interaction Studio at the Academy of Fine Arts in Katowice. The aim of the project is to create a user interface for exploring virtual 3D spaces, based on natural human gestures.

This article presents the part of the project related to the development of methods for determining the meaning of gestures, carried out by the Visual Research and Interaction Studio of the AFA in Katowice . The foundation of this method is the concept of the gesture semantic field, understood as the sum of meanings attributed to a given gesture.

We have been searching for a natural gesture by applying three fundamental concepts: (1) Semantic Field, (2) Meaning Hierarchy, (3) frequency of occurrence of gesture meanings. These concepts were applied by using semantic tests, the results of which were statistically processed.

Keywords:

gesture, interface, semantic field, semantic analysis

Determining the meaning of arm gestures

Human communication involves transferring some information using a combination of available productive modalities , i.e. speech, hand, head or body gestures. It can be analyzed (Poggi, 2007, pp. 24-62) in terms of a *sending* person having a *goal* of causing some *addressee* to believe a preconceived *meaning*. In order to achieve this goal, the sender produces a *signal*, using a subset of organs in his or her body; the addressee receives it through a given sensory modality. Of many possible signal channels, gesture is probably both the oldest, in terms of usage history, and the most deeply rooted in human nature – as its key elements can be seen in primates' communication (King, 2004, pp. 178-219). There exists a variety of ways of how gestures can be used to depict concepts, reference objects and control transactions, for example by ordering or mediating signals. (Streeck, 2009, pp. 7-11).

But, while we are used to observing a successful human to human interaction where gestures play a major role, the task of breaking this interaction into distinct, repeatable elements is difficult. This poses a number of problems when one puts a computer, instead of a human, in place of the addressee. How should we embed the understanding of gestures in a machine? We have the technical means of capturing the data of human movement (i.e. either by using cameras or motion capture equipment). There are pattern classification methods for detection and recognition of gestures, given example templates and data input source . But what set of gestures ought we to use? The aim of the human computer interface (HCI) is to make a full use of the instinctiveness and naturality provided by the communication channel – but if we choose a gesture set that is too limited, or perceived as artificial, we risk degrading the performance to the

point where we almost lose any gains of using gestures. The ability to determine the meaning of a gesture is crucial for producing a system that has the properties of a good interface: perceived as intuitive, natural, fast to learn, allowing concentration on the task not on the interface, and having good overall performance.

Outline of the gesture meaning recognition method

The work on the method was divided into several stages and took two paths. One we called “from gesture to meaning” and it consisted in determining the meaning of presented gestures. The other was called “from meaning to gesture”, for which we selected a set of notions (selected commands characteristic of interface navigation) and one group of test subjects were performing gestures to convey them. A video recording of the gestures was then shown to the other group of people who were asked to give their interpretation. Subsequently the initial gesture meaning given to the first group was compared with the outcome from the second group. The article describes the results of the first research path and the methodology of the second.

The first research path “from gesture to meaning” began with designing and implementing a notation system for body position in space. The next step was to make a morphological table of arm positions, including all positions of the arm, forearm and hand. This material was the basis for taking photographic images of arm positions. Processed photographs were then used for constructing semantic tests. There were two modes of testing: personal interview and online survey. The principle of both test modes was the same: subjects were to give the meaning of the gesture in the photograph. The

result of the test is a hierarchic list of meanings for each gesture in the morphological table.

The method for determining gesture meaning was based on the concept of the gesture semantic field. This particular field is defined as the sum of meanings attributed to a particular gesture. The probability of the occurrence of a certain meaning determines its place in the hierarchy of all the meanings of a given gesture. The meaning that occupies the highest position in the hierarchy is considered to be the natural meaning of the gesture. Semantic fields are delineated for the sets of dynamic and static gestures.

The aim of this project was to discover the possibilities of human communication with computers by means of gestures. A preliminary analysis of the perception of gestures in various areas of human activity was intended to estimate the overlap of constructed and natural gesture fields. We searched for the natural gesture by applying three fundamental criteria: (1) Semantic Field, (2) Meaning Hierarchy, (3) frequency of occurrence of gesture meanings.

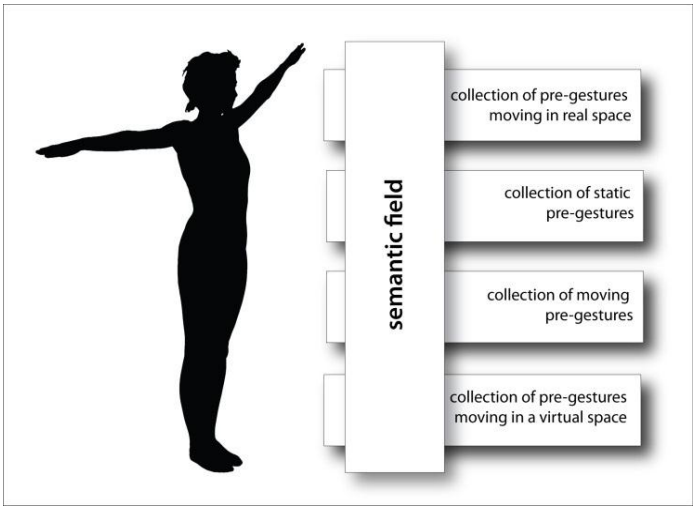


figure 1. Semantic field in groups of pre-gestures.

A gesture as movement endowed with meaning is an intermediary, a sign between communicating parties. It not only mediates, but also is an expression of a certain thought. Therefore, a gesture should be considered as a mediating and expressive element. These two sides of a gesture are its inseparable features. On seeing a gesture, one can ask how it mediates and how it expresses ideas. The mediating aspect of a gesture has a material nature connected with the perception of a moving object in space. The expressive aspect of a gesture has a mental character connected with the process of thought attribution.

Preliminary analysis

The analysis of gestures as communication elements began with collecting information on the function of gestures in the already existing communication systems. In that way we learned how and where gestures are used, decoded and interpreted. The analysis encompassed the following subjects:

Artificial machine languages and information code systems. Most gestures in such systems have the function of a system element connected with the other elements by means of some syntactic rule. The subject of the analysis were sets of signs and the syntactic rules among them. Most of these languages and systems are limited to a specific situation and constitute a closed set.

Languages and notation systems used for communicating with disabled people. Despite the great significance of such systems, their direct use in the project does not seem possible, since they involve very specific communication features that are not widespread.

Kinetography – the Laban-Knust notation system. The analysis of the notation system for three-dimensional movement of the human body in space and its transformation into a two-dimensional record was the source of inspiration for the system of recording the arm, forearm and hand position used in our project.

Silent cinema film footage analysis. Film footage analyzed from the perspective of gestures, focusing especially on silent cinema, reveals gesture as an intentionally constructed choreography composed of many parts. The complexity of a film gesture reflects the structure of conveyed meaning. The linear and sequential nature of film reveals new aspects of gesture. The crucial feature of our project is to show the same gesture from various points of view in order to change its basic meaning - hence the idea of five viewing angles for each gesture.

Semiology. We have drawn conclusions from theoretical works on the signification field of a gesture, in which the gesture connects with the language structure on one hand, and with culture in the broad meaning of the term on the other. The early draft of the project does not involve an extensive analysis of gestures in terms of their cultural context, but it is possible that the project will include such research at a later stage.

David McNeill topology of gestures. Gestures and their synchronization with speech are elements of a dialectic that together form units called growth points. Growth points combine two opposing modes of thinking – namely image and language. McNeill focuses on a real-time correspondence of thought and language, treating language as multi-channel and as a part of the context which he calls the dynamic dimension.

Gesture research in the field of linguistics, particularly by McNeill, leads to the conclusion that language and gestures together create the message. McNeill claims that gestures are an integral part of language, in the same way as words, phrases and sentences are. Gestures and language form one system; gestures are just as good at representing human thinking processes. This also means that gestures similarly to linear language can convey varied and complex mental structures.

A detailed analysis can be found at http://my.opera.com/gestyzbwii/blog/2009/05/31/15-gesture-acquisition-of-movement-or-meaning

The conclusions of this analysis allowed for the evaluation of the relevance degree of the relation between the meaning and the gesture for further work on the project.

Position notation system

Our body position notation system draws on the experience of the gesture meaning system used in teaching rhetoric (Bacon,1872, pp. 40-52) and elements of the Laban-Knust's kinetography system (Lange, 1975, pp. 21-29), used for recording the positions of a dancer's body in space.

While moving in space the body uses three basic dimensions:

Dimension 1 – back – front

Dimension 2 – right – left

Dimension 3 – top – down

Combining the three dimensions marks three planes:

DIMENSION PLANE	1	2	3
Table	front - back	right - left	
Door		right - left	top - down
crosswise	front - back		top - down

Table plane – combination of dimensions 1 and 2

front back – right left.

Door plane – combination of dimensions 2 and 3

right left – top down.

Crosswise plane – combination of dimensions 1 and 3

front back – top down.

Each plane contains eight directions: four basic and four intermediary, resulting from the former ones.

Each plane contains eight directions: four basic ones and four intermediary being their resultant. The whole model contains twenty-four directions in three planes and eight directions being a resultant of movements in diagonal planes across a cube. After subtracting the six overlapping directions from the total sum of thirty-two, twenty-six directions remain.

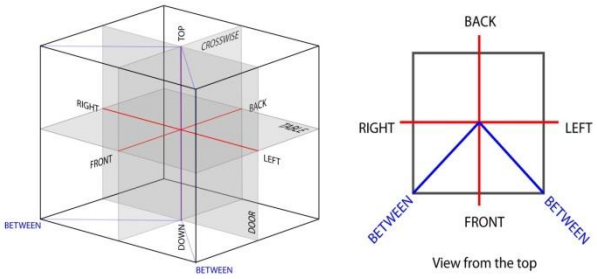


figure 2. Planes of the arm and forearm movement.

In the system used, cubic models were placed at three joints of each arm: shoulder, elbow and wrist.

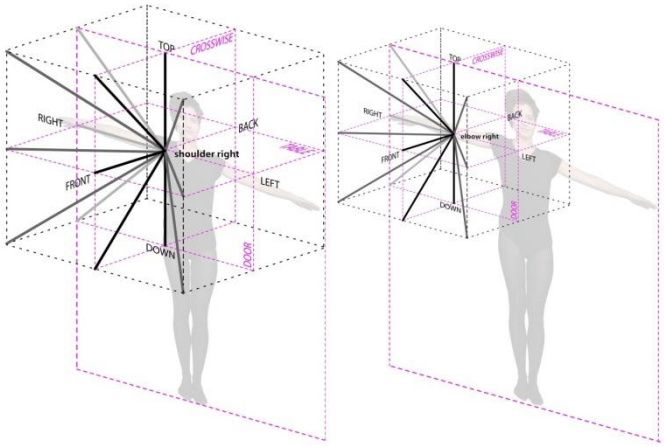


figure 3. Arm and forearm positions.

Notation used for the arm, forearm and hand includes both arms. It has the form of a contingency table. Horizontally the planes are placed in the following order: Table (T), Door (D), Crosswise (C) and directions top (t), down (d), left (l), right (r), front (f), back (b). Vertically, for the left and right arm: arm (A), forearm (FA), hand (P).

Each gesture is recorded in this table – example below.

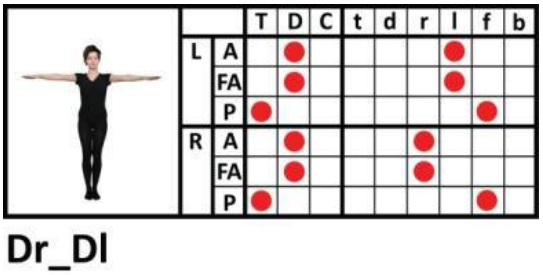


figure 4. Notation of the Dr-Dl position

Morphological table

Based on a morphological table photographs of arm positions were taken, including all possible positions of the arm, forearm and hand. The basic set of gestures are all combinations of the outstretched right and left arm. For one arm the number of possible positions in all planes is 14. There are 196 combinations in total. Each of the 196 gestures from the table is photographed from five different angles, producing the sum of 980 outstretched arm images.

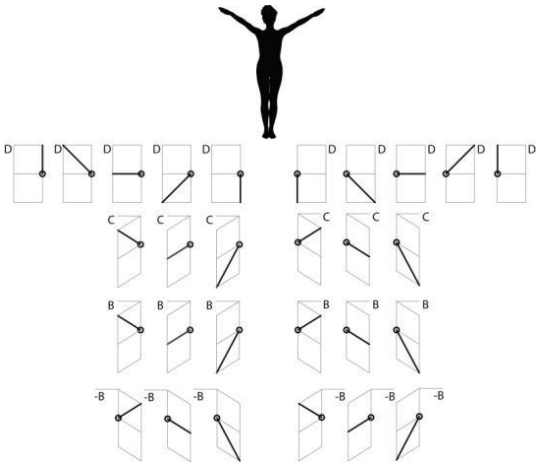


figure 5. Combinations of the right and left arm – notation schematics.

The set of all positions can be divided into three groups.

Group 1 – Positions with arms outstretched.

Group 2 – Positions with arms bent at the elbow.

Group 3 – Positions with various hand positions.

Notation system is the same for all groups.

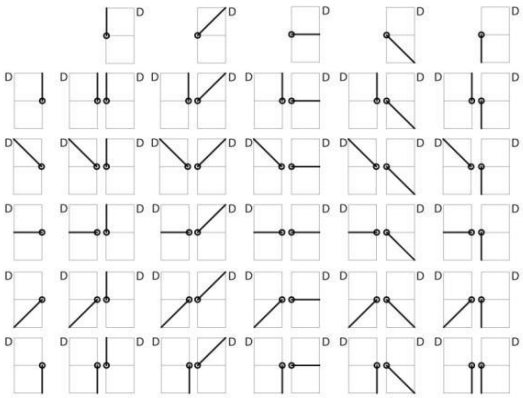


figure 6. Morphological table. Group 1 – door plane – outstretched arm positions

Group 1 is independent from the others and it can be called the basic set of outstretched arm positions. The next groups are built on the foundation of the basic set. Each arm position is ascribed a set of all forearm and palm positions. Group 3 depends on groups 2 and 1. Group 2 depends on group 1 and does not depend on group 3.

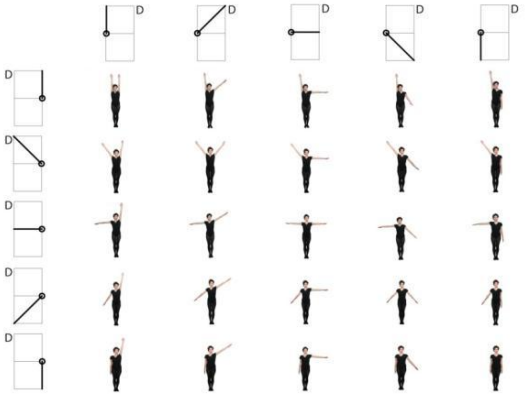


figure 7. Morphological table. Group 1 – door plane – outstretched arm positions

For group 2 the contingency table for outstretched arm positions is supplemented by all possible forearm positions. In this table, all possible positions of the forearm with relation to each arm position are presented. The number of all possible forearm positions for all arm positions, for both arms is 27556.

Recording

Gesture images are grouped according to five shooting angles:

A. angle a (left side);

B. angle b (45 degrees, left side);

C. angle c (en face);

D. angle d (45 degrees, right side);

E. angle e (right side)

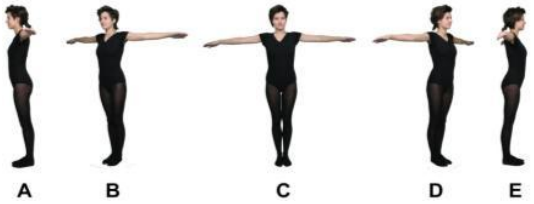


figure 8. Shooting angles A-E

The set of processed photographs of a gesture is constructed on the basis of shape similarity. First, photographs are grouped according to similarity of the gesture in the en face position. Then, in each of these groups, comparisons of the gesture in all the shooting angles are made. From each group, one photograph is selected as a representative for subsequent research.

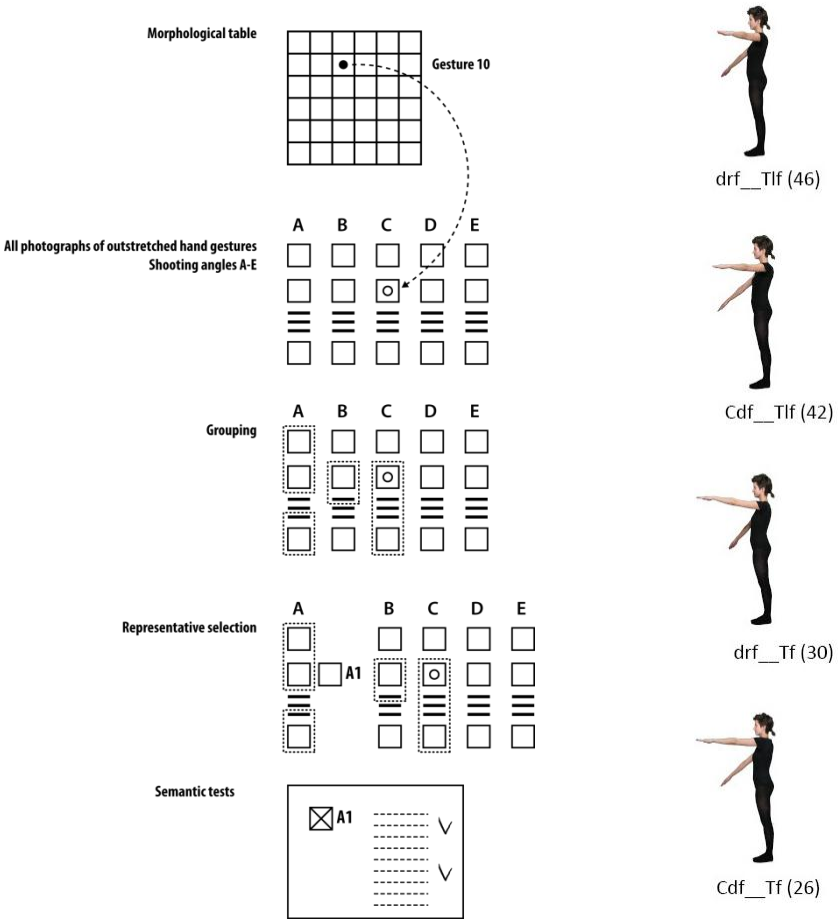


figure 9. Schematics of the procedure for selecting a representative for semantic tests and an example of grouping according to shape (different gestures, similar viewing angles).

Gesture photographs are divided into groups according to similarities among them. Similarities are identified by comparing the inner and outer contour outline. The outer contour is the line that delineates the silhouette. Similarity is established by comparing the outer contour of the gestures. In that way, a set of similar gestures is created on the basis of the outer contour . The next step is to divide the set into smaller sets. The division is made by comparing the inner contour of gestures, that is the outline of the arms – arm, forearm and hand. For two gestures to be included in the same group, the area delineated by the inner contour must overlap in about 75 per cent. One photograph is selected from each group as a representative for subsequent research.

Semantic tests

Semantic tests were conducted in two modes: personal interview and Internet survey. For both modes separate test cards were prepared, one for a personal interview and one for the Internet survey.

In the personal interview, the test subject is shown a photograph and name (code) of a gesture on a screen and the task is to infer the meaning of the gesture, and then to enter the meaning (or meanings) in the chart, next to the gesture code. The results are then transmitted to a collective data spreadsheet.

In the Internet survey, two variations were used: email and online access. The email survey was prepared as an active PDF file. The file comprises 14 pages of gesture photographs. On each page there is a photograph of a gesture and five fields in which the subject enters the inferred meaning of the gesture. The photographs for each survey are selected at random – two gestures from each group. The test subject receives the survey by email. The task is to give the meanings (up to five) inferred from the gesture in the photograph. The results are sent back as an XML file. In effect we receive a list of meanings for each of the five viewing angles of a gesture.

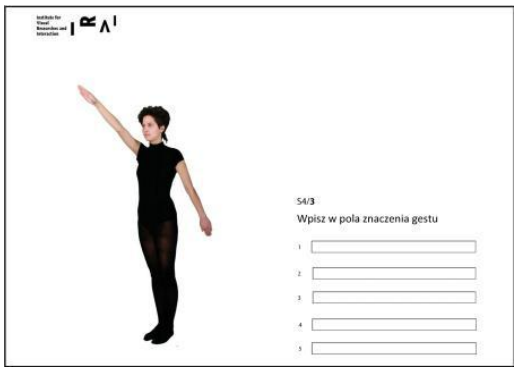


figure 10. Internet survey card

The online survey was conducted by means of the www.moje-ankiety.pl portal. This website allows to construct surveys which include open-ended questions and photographs. Each survey is identified by its name, description, key words and category, and includes 11 photographs. The results are exported in an Excel file.

Survey of static position – direct and online.

Number of participants – 80, Number of completed surveys – 581

All meanings were grouped according to semantic similarities.

Thus the following groups were created:

1. Pointing direction.

Includes the meanings: kierowanie ruchem [directing traffic], policjant na skrzyżowaniu [policeman at an intersection], rozwidlenie [bifurcation], rozgałęzienie [branching], skrzyżowanie [junction], w prawo [to the right], w lewo [to the left], prosto [straight ahead], do przodu/przed siebie [ahead/headlong], do tyłu [back], w bok [to a side], w górę [up], do góry [up], w dół [down], ukos [slant], na ukos, po skosie [diagonally].

2. Combined directions.

Includes the meanings: góra-dół [up-down], wyżej-niżej (naprzemiennie) [above-below (alternating)], w lewo w prawo [to the left to the right], w górę i w bok [up and to a side], przód [front], w lewo [left], przód w bok [front to the side], do tyłu [back], w bok [to a side], w górę i w prawo [up and to the right], w górę [up], przód tył [front back], do przodu na dół [ahead down], do przodu do góry [ahead up], przed i u góry [in front of and above], w lewo w dół [to the left down], w górę w lewo [up and to the left], na boki [from side to side], prawo-lewo [right-left], na dół [down], przed siebie [straight ahead], na wprost i dół [ahead and down], przód tył dół [front back down], wskazywanie miejsca/obiektu [pointing to a place/object], pokazanie punktu przed sobą

[pointing to a spot in front of oneself], wskazywanie [pointing], wskazywanie punktu na górze [pointing to a spot overhead], na dole [below], dół [downside], wskazywanie czegoś w dole [pointing to something below], na wprost [ahead], przed [in front], przede mną [in front of oneself], u góry [above], góra [upside], wysoko [high up], z tyłu [behind], tył [back], z boku [aside], bok [side], obok [aside], nisko [low], coraz wyżej [getting higher], wzbijać się [taking off], przede mną i z boku [in front of me and aside], przede mną [in front of me], nisko-w dole [down below], chcę sięgać gdzieś wysoko [I want to reach high], podawanie ręki [shaking hands].

3. Terms for measurements and height.

Includes the meanings: wskazywanie wysokości [indicating height], wskazanie (porównanie) dwóch wysokości - mały duży [indicating (comparison) two heights – small and big], pokazywanie małego rozmiaru [indicating a small size]
niski [short], mały [small], wskazywanie szerokości (szeroko) [indicating the width (wide)], coś jest duże [something is big].

4. Terms for actions.

Includes the follwing meanings: baczność [at attention], chwytanie [catch], chwytanie czegoś z tyłu [grab something from behind], ćwiczenia [exercise], gimnastyka [workout], przysiady [squats], rozciąganie się [stretching], pływanie [swimming], latanie [flying], zataczanie koła [circling], obrót [pivot], przygotowanie do skoku [preparing to jump], skok [jump], skoczek narciarski [ski jumper], otwieranie

[opening], obejmowanie [embracing], poddanie się [giving up], pozdrowienie [greeting], powitanie [welcome], nazistowskie pozdrowienie [Nazi salute], salutowanie [salute], machanie komuś [waving at someone], oddawanie czci [hailing], pokłony [bows], błogosławienie [blessing], opuszczanie [leaving], opadanie [falling], unieś [raise it], podnoszenie [raising up], wzrastanie [growing], kierowanie ruchem [directing traffic], zgłaszanie się [volunteering], zatrzymywać [to stop something], wymachy [throwing one's arms about], chodzenie [walking], maszerowanie [marching], podaj/podaj rękę [shake hands], ciągnie ją coś [something is pulling her], ciągnie się za mną [something is trailing me], pajacyki [jumping jacks], chodź za mną [follow me], do mnie [to me], przytul mnie [hug me], podaj mi rękę dziecko i chodź tam [give me your hand child and follow me there], stać i patrzeć na [to be standing and looking at], wytnij [cut it out], cięcie [a cut].

5. Terms for states.

Includes the following meanings: radość [joy], hurra [hurrah], szczęście [happiness], stan spoczynku [rest], bezczynność [idleness], zastój [standstill], spokój [tranquility], gotowość [readiness], oczekiwanie [waiting], otwartość [openness], otwarty [open], zachwianie [unsettling], chwieje się [it is shaking], swoboda [liberty], wolność [freedom], dążenie do równowagi [pursuing balance].

6. Terms for "command".

Includes the following meanings: cisza/uciszać [quiet], stop [stop], stój [stop moving], stać [stop], zatrzymywanie [stopping] siadać [sit down], droga wolna [open road], odejdź [leave], wynoś się [go away].

7. The rest, termed "other"

Includes the following meanings: samolot/szybowiec [airplane/glider], pion [vertical line], linia prosta [straight line], horyzont [horizon], poziom [level], kąt [angle], kąt prosty [straight angle], kąt rozwarty [wide angle], kąt ostry [sharp angle], rozwarta paszcza [open mouth], otwarcie [opening], wskazówki zegara [hands of a clock], nożyce [scissors], dziób ptaka [bird's beak], klapanie [clapping], bocian [stork], brak przejścia [dead end], znak mniejszości/większości [smaller than/bigger than], równia pochyła [inclined plane], przekątna [diagonal], prosta postawa [straight back], taniec [dance], tancerka [dancer], szybkość [speed], prędkość [speed], krzyż [cross], Titanic [the Titanic], ponad wszystkim [above all].

"From meaning to gesture" – making gestures on the basis of meanings

The second research track, mentioned before. This method is divided into three stages:

Meaning – image. In this method test subjects are given a meaning (command) and asked to make the corresponding gesture. The meanings-commands were prepared on the basis of analyzing the usefulness of interface in widely known computer operating systems, and are listed as 67 commands. For the benefit of the survey, 67 sentences were constructed, using the commands in question. On hearing the sentence

with the command the subject was supposed to make the gesture corresponding to the command. Subjects performed all 67 gestures in one session recorded on video. The response gestures are grouped according to frequency of use and similarity.

Image – meaning. A moving image of the gesture is shown and the subject is asked to give its meaning. A video file with all recorded gestures is edited into separate 67 parts. For the benefit of the second part of the survey, 670 gesture clips were made on the basis of meanings given by the group of ten subjects taking part in the first part of the survey. In the second part of the survey, subjects are shown the video clip with the gesture and are asked to give its meaning. The meanings are grouped according to their frequency.

Comparison. At this stage, a comparison is made between the list of meanings from stage 1, 67 commands, with the list of meanings from stage 2.

Example: The meaning “cofnij” [back] from the list of 67 commands was presented as a gesture with a semantic field made up of the meanings: 1. podejdź do mnie [come to me]; 2. przesunąć [to push aside]; 3. przestawić [to set aside]. Such a distribution of the semantic field of a dynamic gesture suggests that the command “back” falls outside of this field and cannot be associated with the gesture. In other words, the command “back”, transformed into a dynamic gesture, lost its meaning.

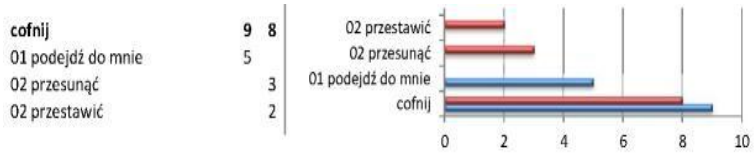


figure 11. semantic field of the word “back”

Semantic test data

As a result of conducting the test we obtained a list of meanings for each representative (a representative being a photograph of one gesture from the set of related gestures, selected for testing). Each list was constructed hierarchically according to similarity of occurring meanings. In effect we obtained a hierarchy of meanings for each representative, that is the semantic field of a given gesture.

2c-1 		2c-2		2c-3		2c-4		2c-5	
0		0		0		0		0	
0		0		0		0		0	
1	nie idź prosto, skręć w prawo	0		0		0		0	
1	nie podchodź	0		0		0		0	
1	wysokość	1	mały	1	równy	0		0	
1	prosto	0		0		0		0	
1	salutowanie	0		0		0		0	
1	zakaz wjazdu	0		0		0		0	
1	droga	1	skrzyżowanie	0		0		0	
1	południowy-zachód	0		0		0		0	
1	brak przejścia	1	stać - teraz idą ci z prawej	0		0		0	
0		0		0		0		0	
1	stop	1	wskazuje kierunki	0		0		0	
0		0		0		0		0	
1	pozwolenie na skręt w prawo	1	jakaś litera	0		0		0	
1	stop, nie ma przejścia na prawo								
1	w prawo		blisko						
1	skręć w prawo								
1	w prawo		kierunek						
1	zaraz zrobie pirueta!								
1	stój idź w lewo		do przodu, do boku						
1	wskazanie wysokości								
1	kierunek - w lewo								
1	gimnastyka		aerobik						
1	lewa wolna		ruch do przodu w prawo		zakres przestrzeni prawo z przodu				
1	zatrzymaj sie i skręć w prawo		popatrz w prawo		po mojej lewej stronie				
1	pokazuje wysokość		stoi na baczność						
1	w prawo		prawa strona		prawy kierunek				
1	skrzyżowanie dwóch dróg		samolot						
1	jedź w prawo								
1	przejdź w prawo								
1	skręt w lewo								
1	mały		wzrost		miara		skręt w lewo		
1	stop		jedź w prawo						
30									

10	w prawo, skręt w prawo, jedź w prawo
2	zatrzymaj sie i skręć w prawo
3	stop
2	pokazuje wysokość, wzrost
3	kierunek lewo, w lewo, skręt w lewo
2	skrzyżowanie
2	brak przejścia
3	wskazywanie kierunku
2	do przodu, do boku
2	wskazanie wysokości
2	mały

figure 12. Gesture semantic field

The semantic field of a gesture refers to a particular image seen by the test subject. The analysis of research data reveals that meaning can change depending on the angle of viewing the gesture. The illustration below shows the changing meaning for each of five viewing angles.

	Meanings
	13% - up 6% - open road 6% - height, indicating height 6% - high
	19% - straight angle 19% - up and to the left 11% - hands of a clock 8% - to the left
	12% - pointing to something above; up; something is high; high level 12% - up and to the right 9% - height; indicating height 6% - to the right

	11% - up to the side
	21% - jump; jump into the swimming pool 17% - top; high 10% - up 10% - straight line

figure 13. Gesture meaning change depending on the viewing angle.

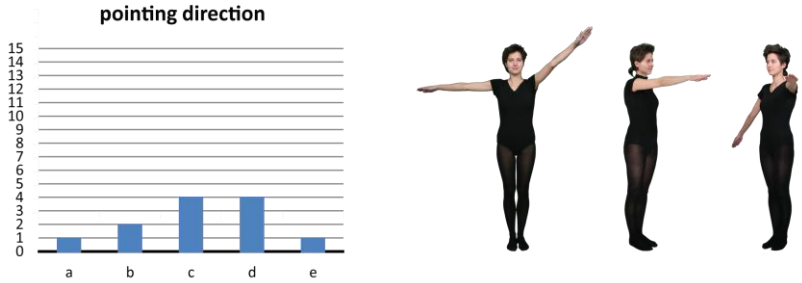
The meanings for each gesture were collected in a table, where occurring meanings and corresponding gestures are presented. The table includes the division of gestures according to the viewing angle (set A, B, C, D, E). The table was constructed in a way that allows to analyze data both according to gesture and meaning. It enables to observe how the meaning of a gesture changes depending on the viewing angle and how a given meaning refers to different gestures.

	pozycja a			pozycja b			pozycja c			pozycja d			pozycja e		
znaczenia	numery gestów	ilość odpowiedzi	procent	numery gestów	ilość odpowiedzi	procent	numery gestów	ilość odpowiedzi	procent	numery gestów	ilość odpowiedzi	procent	numery gestów	ilość odpowiedzi	procent
WSKAZYWANIE KIERUNKU															
wskazywanie kierunku	33a (A25)	2	9.	40b (b5)	8	36.	177c (C30)	4	16.	226d (D23)	5	19.	65e (E2)	2	9.
				98b (B43)	2	8.	81c (C14)	4	12.	209d (D28)	3	12.			
							2c (C9)	3	9.	161d (D29)	3	14.			
							17c (C4)	2	6.	227d (D1)	2	8.			
kierowanie ruchem, policjant na skrzyżowaniu	66a (A35)	5	22.	78b (B40)	2	9.	102c (C19)	5	20.	115d (D5)	2	8.	66e (E23)	6	26.
				130b (B34)	2	9.	177c (C30)	4	16.	67d (D2)	2	7.			
				89b (B7)	2	7.	65c (C22)	3	10.						
rozwidlenie, rozgałęzienie, skrzyżowanie							188c (C31)	2	8.						
							35c (C35)	2	7.						
							7c (C32)	2	6.						
							2c (C9)	2	6.						
w prawo	115a (A9)	6	18.	11b (B30)	5	16.	6c (C18)	12	36.	227d (D1)	3	11.	38e (E10)	3	10.
				98b (B43)	2	8.	2c (C9)	10	30.	67d (D2)	2	7.			
							81c (C14)	8	23.	14d (D8)	3	9.			
							227c (C36)	5	16.	161d (D29)	8	36.			
							42c (C18)	4	15.						
							87c (C13)	4	12.						
							102c (C19)	3	12.						
							7c (C32)	2	6.						
							8c (C34)	2	6.						
							5c (C26)	2	6.						

figure 14. Fragment of a table with test results of a personal interview and the Internet survey for extended arm gestures.

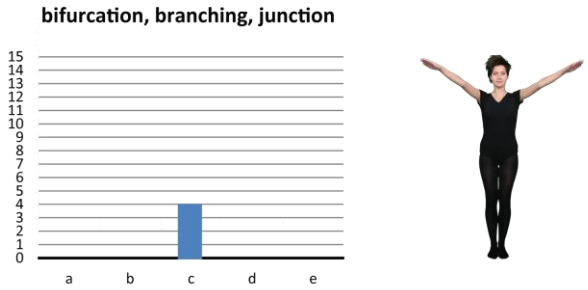
For instance, in the table we can observe that the meaning “direction pointing” is attributed to the gesture when it is viewed from angles c and d. When the same gesture is viewed from angles b and c, it is perceived as indicating “measure” and “height”. Seen from angle a it is understood as “at attention”.

Selected examples – graphs and gesture photographs present the change in meaning depending on the viewing angle.



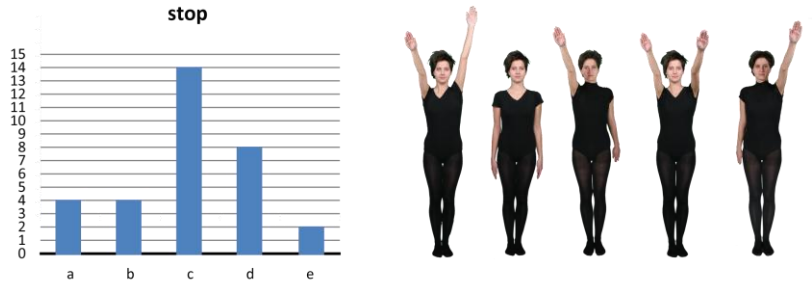
Number of gestures with specific meaning. Gestures with the highest frequency of occurrence of a given meaning.

figure 15. The meaning of “pointing direction” is best recognized from the viewing angles c and d.



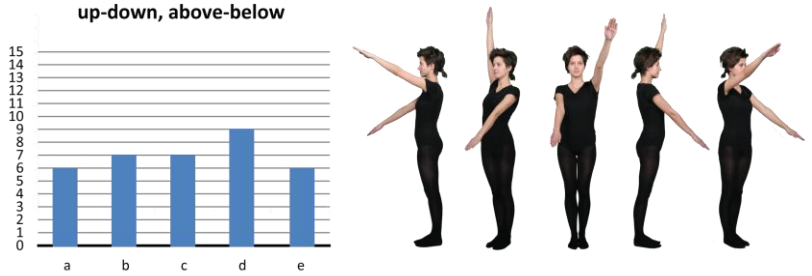
Number of gestures with specific meaning. Gestures with the highest frequency of occurrence of a given meaning.

figure 16. The meaning of “bifurcation, branching, junction” was attributed to gestures observed from angle c.



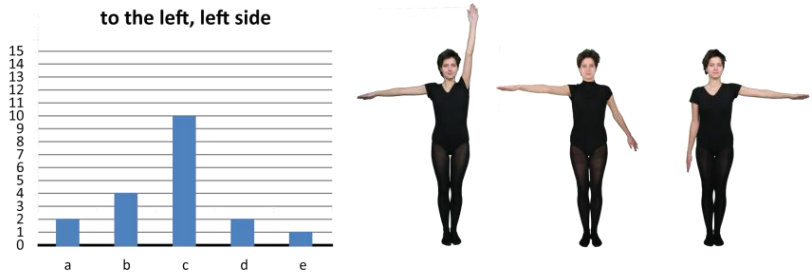
Number of gestures with specific meaning. Gestures with the highest frequency of occurrence of a given meaning.

figure 17. The meaning of "stop" was most frequently attributed to gestures presented from angles c and d.



Number of gestures with specific meaning. . Gestures with the highest frequency of occurrence of a given meaning.

figure 18. The meaning of "up-down" "above-below" was attributed equally to gestures presented from all angles with a slight advantage of angle d.



Number of gestures with specific meaning. . Gestures with the highest frequency of occurrence of a given meaning.

figure 19. The meaning of "to the left" was best recognized at angle c.

Conclusions

The analysis of data acquired in semantic tests allows to delineate the semantic field of a static gesture with extended arms, depending on the viewing angle. Further tests concerning gestures with arms bent at the elbow and hands will enable to determine the full semantic field for each gesture.

Observing the behavior of test subjects, especially those making gestures on the basis of given meanings, leads to two conclusions that we consider particularly noteworthy. They are related to the notions of natural gesture and linear perception of gestures.

The notion of "natural gesture". The frequently appearing notion of "natural gesture", in the context of interaction connected with interface is usually not associated with instinct. A definition of natural gesture should establish the relation between instinctual and natural gesture. If human instinctual features are assumed as departure point, it has to be stated that these features must have some "gesture space" where their purposes are materialized.

Three manifestations of human instinct: self-preservation, mating and family life, and the development of spiritual faculties all refer to some gesture space, although for each area the number of gestures is different. It seems that the number of gestures for the mating instinct would be the biggest, as it relates to interpersonal communication. The second biggest, when it comes to the number of gestures, is the expression of escape from death. Here gestures are, by nature, very animated, since their purpose is to inform about the person's vitality. In case of the third feature, inclination to spiritual growth, the number of gestures is at first sight the smallest.

The notion of "natural gesture" refers us to human nature. Nature is reflected in the three features of instinct mentioned above, therefore it can be inferred that a natural gesture is an instinctual gesture.

Linear perception of gesture. What we call a gesture in the common sense is both a photographic image of a gesture – static gesture, and a dynamic gesture, changing in time. According to our definition that "A gesture is movement endowed with meaning", a photograph of a gesture should not be called a gesture. A gesture has to be connected with movement on the one hand, and meaning on the other. A photographic image has meaning, but it does not include movement.

A photographic image of a gesture cannot be, in the strict sense, called a gesture. Therefore it has to be called "a position of hands, arms or body", "position" in short. The difference between gesture and position is the difference between movement and lack thereof.

Simplifying, we can assume that a gesture is constructed of a specific sequence of positions. Capturing one such position in a still frame separates the position from the gesture movement and in consequence places the position outside of the gesture. The only possibility of inferring the meaning on the basis of a still image of a position is in the context of movement, an amount of time it occupies. The temporal reference for a still image of a position is the movement (time) of the gesture that remains the viewer's memory. It could be called mental movement (time). The cause effect relations between subsequent positions enable combination of position sequences into gestures performed in time. It can be said that while observing a gesture we see not only the particular sequences, but also cause-effect relations. In the memory of the viewer, a number of sequences and combinations of cause-effect relations between sequences are recorded.

Experience of the viewer allows storing sets of sequences and relations among them in long-term memory. The greater the experience in viewing gestures, the bigger the "collection" of sequences and their combinations. Observing a gesture has a linear character, that is, from the first to the last sequence. The speed of inferring the meaning of a gesture is connected with the speed of anticipating possible cause-effect relations between subsequent positions and sequences. This means that skilled gesture "readers", for instance deaf-mutes, are able to anticipate the meaning of a gesture on the basis of an incomplete number of positions making up this gesture. They can easily fill in the missing sequences.

Conclusions drawn from observations made during semantic tests for making gestures on the basis of supplied meanings produced another comment. These tests consist in inferring the meaning of a moving image. Test subjects watch a video recording of a person making a previously unknown gesture. After viewing it, they are asked to give the meaning of this gesture. We noticed hesitation in test subjects to give the meaning of the gesture. We assumed that this hesitation is connected with the character of gesture presented in the film.

What may cause hesitation in a recorded gesture? The most common cause is the complex structure of the gesture. Simplifying, one can say that a gesture is an action which has a beginning, development and end. If subsequent positions clearly point to the three action elements, the gesture's construction can be considered simple. Another important factor is uniform distribution of positions with relation to action phases. If too many elements relate to the beginning of the gesture, and few to the development and end, it causes hesitation. The most intriguing puzzle is hesitation followed by saying "I don't know".

Observing test subjects during semantic tests allowed us to discover one more, perhaps the most important, feature of gesture. Namely, we had the impression that test subjects “see” the structure of the gesture before they are able to infer its meaning. This might mean that information about the structure of a gesture “starts” simultaneously or even before the information on its meaning. If it were the case, this would lead to the necessity of verifying the linear conception of gesture time, and in consequence gesture as an action with a beginning, development and end.

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Bibliography

King, Barbara J. (2004). The dynamic dance: Nonvocal communication in African great apes. Harvard University Press.

Poggi Isabella (2007). Mind, hands, face and body: A goal and belief view of multimedial communication. Weidler Buchverlag.

Streeck Jürgen (2009). Gesturecraft: the manufacture of meaning. John Benjamins B.V.

Ott Amherst Rdward (1892). How to gesture. Hinds&Noble.

Bacon Albert (1872). Manual of gesture. J.C.Buckbee&Company

Lange R. (1975). Podręcznik kinetografii według metody Labana-Knusta. Polskie Wydawnictwo Muzyczne.

Wexelblat. A. (1995). An Approach to Natural Gesture in Virtual Environments. MIT Media Laboratory

Jarmołowicz. E. (2005). Niewerbalne elementy aktów mowy. Institute of Linguistics, Adam Mickiewicz University Poznań, Investigationes Linguisticae, vol. XII, Poznan,

Ampel-Rudolf. M. (1999). Konwecjonalne gesty i mimika we współczesnej literaturze. Bulletin de la Société Polonaise de Linguistique, fasc. lv,

Eisenstein. J; Davis. R. (2003). Natural Gesture in Descriptive Monologues. MIT Cambridge

Francuz. P. (2007). Obrazy w umyśle. Wydawnictwo Naukowe Scholar Warszawa

Eco. U. (1996). Nieobecna struktura. Wydawnictwo KR Warszawa

Wittgestein. L. (2004) Tractatus logico-philosophicus. PWN Warszawa

Ruesch J., Kess W.(1956). Nonverbal Communication. Notes on the Perception of Human Relations. Berkley

McNeill. D. (1992). Hand and Mind. The University of Chicago Press.