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COMMUNICATION MODEL FOR THE USER INTERFACE OF A SHAPE CONCEPTUALIZATION SYSTEM

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ABSTRACT

It is commonly recognized that the user interfaces of recent CAD systems do not effectively support creative man-machine communication in the conceptual phase of the design process. At the same time, speech, hand sketching, claying, etc. are appropriate tools for communicating ideas among designers. The inherent vagueness of verbalism and hand movement is both tolerable and requested for the human-computer interaction, as well. However, the natural format of communication may also permit unnecessary uncertainty, which can easily lead to significant failures in the understanding.

The aim of the paper is to investigate how we can find those particular formats of natural communication that offer the benefit of communication of vague concepts and help to prevent failures of understanding. We have decided to use a simplified model of Gitt's [5] information theory. We have selected three evaluation criteria (i.e., effectiveness, efficiency, and comfort) to facilitate the ranking of different ways of communication for a particular purpose. As a future work, we intend to accomplish the evaluation prove the evaluation by pilot implementation.

INTRODUCTION – PROBLEM STATEMENT

The computer aided conceptualization process cycle has four main activities, namely the (a) mental processes (i.e. ideation and reasoning), (b) communication of the concepts to the computer, (c) processing the input, and (d) communicating the result to the user. The second activity, communication towards the computer, is a usual bottleneck in the cycle. The lack of possibility of creative man-machine communication in the conceptual phase of the design process significantly decreases the effectiveness. Recent user interfaces hardly use advanced communicating means, they are often stacked with the mouse and the keyboard.

Dreamed manner of man-machine communication

In our opinion, the ideal computer system for conceptual shape design would behave like the integration of a smart drafts-man and one of the recent CAD software (Figure 1).

The two most critical requirements for systems supporting conceptualization are the speed and the vagueness. The new ideas of the designers pop up very fast time after time and they may require drastic changes on the actual model. If the designers are not able to communicate their ideas to the system with the speed of the ideas coming, then the system is a burden since the designers have to focus on let the system know what they want instead of concentrating on the design task. Therefore, communication facilities of such a system must "think" fast enough together with the designers. The other characteristic point of conceptualization is the vagueness of the new concepts. Since conceptualization does suppose to define everything in a preliminary form, constraining the truly creative processes with inflexible representation schemes should be avoided. A system supporting conceptualization must be able to

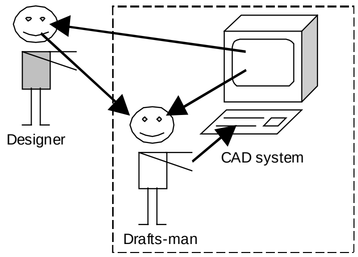

Figure 1 The ideal CACD system should behave like a smart drafts-man and one of the recent CAD software together

handle the design concepts in their vague form because specific information about the concepts is not available for the designer.

The ideal system should have an intelligent user interface, which understands the high-level natural communication of the human being, corrects minor errors without notifying the user, and advises and proposes solutions. It should be able to interpret those communication formats, which are preferred by humans to express shape concepts, including talking, gesturing, physical examples etc. The most natural expression form of human being is the verbal communication. Verbalism can take the benefits of high-level and efficient communication, which is often difficult with other forms of interaction. It has a broad and widely used vocabulary to express vague concepts and it can be fast enough to express the thoughts of the designers with the speed of the ideation process.

Uncertainty of the natural communication

Most probably nobody doubts that free talking is the most effective mode of communication as long as we consider it in general scope. However, is this also true in the specific field of shape conceptualization? The inherent vagueness of verbalism and hand movement is both tolerable and requested. On the other hand, permitting unnecessary uncertainty, as it appears frequently in spoken language (e.g. think of a bad oral presentation), can easily lead to significant failures in understanding and may diminish the effectiveness of the communication. How can we find those particular forms of natural communication that offer the benefit of communication of vague concepts and help to prevent failures of understanding caused by uncertainty of the format of the communication?

"INFORMATION" AND "COMMUNICATION" IN THE LITERATURE

Definition of information

Merriam - Webster's collegiate dictionary [7]: (1) The communication or reception of knowledge or intelligence. (2) Knowledge obtained from investigation, study, or instruction. (3) The attribute inherent in and communicated by one of two or more alternative sequences or arrangements of something (as nucleotides in DNA or binary digits in a computer program) that produce specific effects. (4) A signal or character (as in a communication system or computer) representing data. (5) Something (as a message, experimental data, or a picture) which justifies change in a construct (as a plan or theory) that represents physical or mental experience or another construct. (6) A quantitative measure of the content of information; specifically: a numerical quantity that measures the uncertainty in the outcome of an experiment to be performed.
Shannon [8]: The communicated information is a sequence of symbols to be transmitted and it is no matter whether it has semantic content.
W. Strombach: Information is a structure that produces a change in a receiving system.
Aamodt [1]: Data is perceived but not interpreted symbol, pattern, or signal. Information is the interpreted data thus it has meaning.
W. Gitt [5]: Only that chain of symbols, which carries semantics, is information.

Levels of information/communication

Information, communication and communicated information are three notions, which are often mixed up and used ambiguously. In this chapter, we try to give an overview by looking at them from several perspectives.

As the common sense interpretation of the most widely accepted aspects of information, we have checked out the words "syntax", "semantics", and "pragmatics" in the Merriam - Webster's collegiate dictionary: *Syntax*: (1) The way in which linguistic elements (as words) are put together to form constituents (as phrases or clauses). (2) A connected or orderly system: harmonious arrangement of parts or elements. *Semantics*: the meaning or relationship of meanings of a sign or set of signs. *Pragmatics*: relating to matters of fact or practical affairs often to the exclusion of intellectual or artistic matters: practical as opposed to idealistic.

W. Gitt [5] (information theoretical aspect)**:** Although he uses the word "information" consistently, he considers the communicated information, since he states no information can exist without transmitter. He differentiates five levels of information, which are always present in the communication. *Statistical level*: Shannon's information theory is well suited to an understanding of the statistical aspect of information. This theory makes it possible to give a quantitative description of those characteristics of languages that are based intrinsically on frequencies. At the *syntactical level*, we require a code system in order to represent the information. *Semantic level* is the decisive aspect of the transmitted information, it shows the message that the information contains. *Pragmatic level*: To achieve the intended result, the transmitter considers how the receiver can be made to satisfy his planned objective, what kinds of actions should be accomplished. He differentiates between modes of actions (a) without any, (b) with a limited, and (c) with the maximum degree of freedom. *Apobetic level* expresses the purpose of the information. The result of the communicated information at the receiving end is based at the transmitting end on the purpose, the objective, the plan, or the design.

Max Black [3] (linguistic aspects of the spoken information): The continuum of voices that can be produced is dissolved to finite number of phonemes, and they form the system of *phonemes*. Above this, there is

- the *morpheme* system, which is the inventory of words of the language,
- the *grammatical* system, which regulates the order and the alters of the words,
- the *semantic* system, which determines the meanings attached to the words and phrases,
- the *pragmatic* system, which specifies the implicit preconditions of the linguistic situations.

M. Sharples [9] (language processing aspects of information:): "*Syntax* … deals with the structure of language: how words form into phrases and sentences, how parts of words form into words." "The intention of the expression is what connects that expression to an object of the world, and might be considered the meaning (*semantics*) of the sentence. " "*Pragmatics* is concerned with the relation of utterances to the context in which they are uttered, including identity of the speaker and hearer, their interest and intentions, the state of their knowledge, their physical surroundings and so on. " He involves the aims also in the pragmatics, e.g. by speech acts.

A. Hoffman [6] (abstraction aspects of the communicated content): He demonstrates the abstraction levels on an example of the operation of a computer system (microchip). He shows device level, circuit level, logic level, program level etc. The number of levels of abstraction is theoretically unlimited, it is restricted by semantic necessity, only. "Each level is characterized by specific set of elementary functional units. …These functional units can be combined in certain ways in order to compose a larger and more complex system. By appropriately composing groups of such units, the units at the next higher description level are constructed."

Comparison of different approaches

Since Gitt's information theory is the most exhaustive, we have chosen it as a base of comparison (Table 1). The linguistics differentiate three quantitative aspects of the natural languages (phoneme system, morpheme system, grammatical system), Gitt used two levels to express the quantitative aspects of the information (statistical, syntactical levels). From language processing view, all the above mentioned categories are considered as syntax. Semantics is the notion, where each considered aspect of the literature analysis resulted the same.

Table 1 Comparison of different views on the levels of information communication

W. Gitt	Merriam-Webster	A. Hoffman (content abstraction)	M. Black (Linguistics)	M. Sharples (NLP)
statistics			phoneme system	syntax
syntax	syntax		morpheme system grammar system pragmatic system	syntax pragmatics
semantics	semantics		semantic system	semantics
pragmatics	pragmatics	abstraction level1 abstraction level2 abstraction level3		pragmatics
apobetics				pragmatics

The most confusing point is the pragmatics. There are two kinds of actions of the receiver following the transmission of the information. The first group of actions is processing and interpreting the arrived information. The second one is the evoked reactions by the interpreted information. In some cases, the distinction is not done, and this causes significant deviations. Let us take an example. A boy can say to his daddy:

- "I want to go to Mars."
- "I want to go to the fourth planet orbiting the Sun."
- "I want to go to my favorite planet."

In the first sentence the boy specified the location by using its unambiguous identifier, its name. In the second case, we need commonsense knowledge, namely Mars is the fourth planet orbiting the Sun. The third version is situation dependent, it matters who says it. According to M. Sharples, these so-called deictic expressions like "my favorite planet" and the need for commonsense knowledge in the interpretation process are concerned by pragmatics. However, Gitt's pragmatics definition focuses on the freedom of the receiver, what kinds of actions can be accomplished. From Gitt's viewpoint, the father has a large amount of freedom to react. He can decide what to do e.g. explaining that the trip is not possible, or calling a travel agency to get information. If we look at the freedom of the father how he can react, the three example sentences differ only in the syntax identifying Mars. The father needs different commonsense knowledge for the differently complex interpretation processes. On the other hand, Sharples includes speech acts (J.L. Austin [2]) into pragmatics, which refer both to the expected actions (pragmatics of Gitt) and to the purpose (apobetics) of the communication.

Just like natural language processing, linguistics is not interested in the reaction, but in the expression mode. Pragmatics is concerned with the linguistic situation in order to interpret a particular expression mode.

We can observe similarity between the pragmatic level of Gitt and the abstraction aspects of Hoffmann. On the lowest abstraction level according to Hoffman, we can have only one way to implement an action, which means there is no degree of freedom of the action. On higher abstraction level, we can have more choices, but in a limited range. A very high abstraction level facilitates a high level of freedom.

COMMUNICATION MODEL FOR SHAPE DESIGN

The five levels of communication in Gitt's model form a five-dimensional space. We would rather name the levels as aspects, since levels in common sense (like layers) can be achieved and skipped. In our case, they are always present like dimensions, and the communication can be different when we look at it from another viewpoint (dimension). When we communicate something on a particular way, we actually designate a place of our communication in the five-dimensional space.

As a starting point, the transmitter has an aim to achieve by the communication, this indicates the place of the communication in the apobetic dimension. From the pragmatic aspect, he can decide how much freedom he wants to give to the receiver for choosing the appropriate reaction. From the semantic aspect, the question is how abstracted objects are used to express the content. From the syntactic and statistic aspect, he can decide which language and how strictly will he use it to communicate.

The chosen communication model

For categorization and evaluation of the ways of communicating shape, we have chosen a simplified version of Gitt's information model. The aspects of information communication can be split based on two questions: why to communicate and how to communicate. The apobetic aspect expresses why to communicate, the other aspects express how. In the user interface design we are not interested why the user want to communicate something, therefore we skip apobetic aspect from our model. We have also simplified the Gitt model by merging the syntactic, statistic aspects and the physical transmission aspects. This is done, because we would like to use existing communication modes/technologies, which usually integrate these three aspects. (E.g. English language: It can be spoken or written [physical layer], we must use the phoneme system of the English language [statistics], and the English grammar [syntax]. If we change anything, then it is not English anymore.) From now on, we will refer to this merged axis as syntax.

By the simplification, a three-dimensional model remained with syntax, semantics, and pragmatics on the axes (Figure 2). By specifying the possible syntactical, semantic, and pragmatic modes, all combination of possible communication modes is automatically offered, therefore the model forces a kind of global view. Although we try to establish an exhaustive description of all reasonable mode of shape communication, we cannot be sure that really everything is considered. The completeness of the description depends on what kind of communication features we list on the axes of the model.

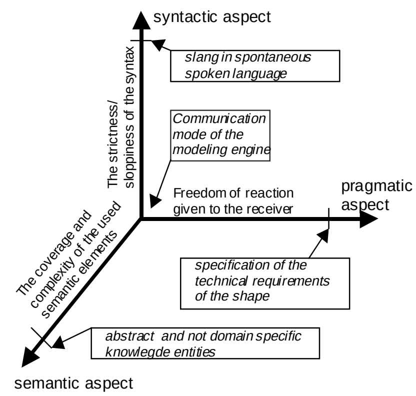

Figure 2 The chosen model for evaluating possible communication modes of a shape conceptualization system

In the rest of this chapter, we present our view what kind of communication features have to be represented on the syntactic, semantic, and pragmatic axes of the model, and what is the minimum and maximum on these axes. Figure 2 indicates the extremes in text boxes. In the origin, we can find the sort of communication provided by the modeling engine. In our case, it happens by triggering the operators of the modeling engine. We have defined it as the lowest level of communication from any aspect, because there is not practical reason to go below it. Now, let us look at the axes respectively.

Table 2 gives examples of the possible ways of communication. Each way of communication has the same aim: object1 should fit in the hole of object2. Since we tried to show the extremes of the syntactical, semantic and pragmatic axes, the examples may sound contrived and the table exaggerates the

Table 2 Example for different way of communication with the same aim

Syntactically	**Semantically**	**Pragmatically**	
		Low	*High*
Low	*Low*	[rotate(object1, axis1, speed1)] [cut(object1, tool1, path1)]	[requirement(shape1(object1.region1) = shape2(object2.region1)] [requirement (diameter(object1.region1) < diameter (object2.region1), 0.05mm]
	High	[turning machine(object1, path1)]	[requirement(fitting(this_object.top, object(cylindrical), tolerance = tight))]
High	*Low*	Rotate it around this axis. Let's cut it. (describing the tool path by pointing device)	The shape of this part of object has to be the inverse of that region of that object and the size should be smaller by 0.05mm
	High	I want to change this object by turning. (describing the tool path by pointing device)	The top should fit into that cylindrical hole tightly.

independence of the axes. Now, let us look at the axes respectively.

The pragmatic axis

On the pragmatic axis, we represent the freedom of actions for the receiver. This freedom is proportional to the abstraction level of the communicated information. Looking at a particular abstraction level, the level below it tells us how (solution), a level above it tells us why (aim) should we accomplish the action of the chosen level. For one problem we can have multiple solutions, and one solution can be suitable for multiple aims. On the other hand, an aim can be a solution, a solution can be an aim by looking at them from different abstraction level. That means, that the aim/solution entities may build a network structure. Figure 3 shows a simplified example of a network of aims/solutions. The entities of the network can be classified based on their semantics. We are interested in the shape-related group. We distinguished three levels of pragmatics related to shape. The lowest one is when the user communicates the process of shape building, namely he specifies what the modeling engine should do. A pragmatically higher level is applied if the expected result of the shape building process is communicated. The highest level is if the user specifies the requirements for the expected results. If we go above this abstraction level, the level is not shape related anymore. These three levels can be shown by an example of travelling by taxi. In our case, the receiver is the intelligent user interface of our shape conceptualization system, which controls the modeling engine to represent or modify a shape. On the other hand, we have a taxi driver and a car, controlled by the driver. In the first case, the result is a shape, in the second case a destination.

The first level of the pragmatics is if the passenger or the user specifies the process that the driver or the user interface should accomplish to achieve the result. The driver has no idea where the passenger goes and the system does not know, what the user wants to get. For instance, the passenger or the user can say, "turn left here" or "calculate the union of the two objects". Since the user input on the lowest pragmatic level can be used to modify the computer model directly, it is easy to make more detailed categories based on the influence on the entities and relationships of the shape model:

- generating new entities or relationships (e.g. sweeping a new freeform surface),
- composing the model or a part of the model from known entities and relationships (e.g. adding a shape feature on a base surface),
- changing the parameters of an entity or a relationship of the model (e.g. changing diameter of a hole),
- model independent actions (e.g. zoom).

We are on the second level of the pragmatic aspect, if the passenger or the user communicates the expected result of the process (e.g. "Hotel Hilton" or "phone shape with a hole in the middle"). We have introduced freedom of the receiver by

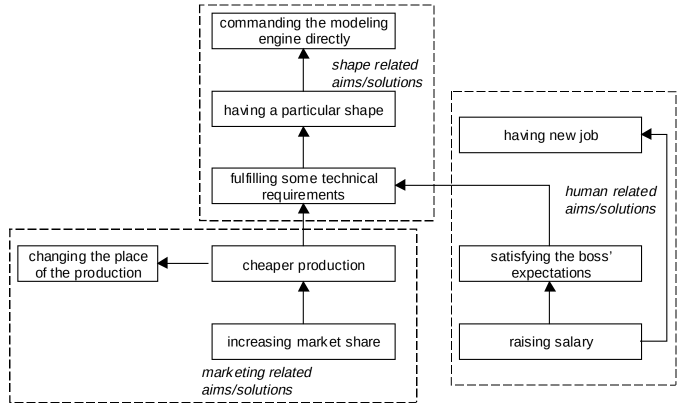

Figure 3 Simplified example of a network of aims/solution

leaving the decision to the driver/system, which route to choose or which operations to apply.

From route planning / shape description viewpoint, the third pragmatic level is if we define what we expect of our destination/result (e.g. "to a cozy restaurant" or "phone we can hang on a key case"). Hence, we gave the freedom to the driver/system to devise the destination/resulting shape, as well.

It would worth to make more detailed categories on the second and third pragmatic levels, but it depends much more on the human style and preferences. Such a categorization may need observation-based experiments.

The semantic axis

The semantic axis indicates the coverage and the complexity of knowledge of the communicated content. We categorize the knowledge into four groups based on the size of the coverage. The minimum knowledge of the user interface covers exact quantities, the operators and parameters of the modeling engine, and the parts of the model to be built. This knowledge provides the minimal ability of communication. The second group includes the knowledge related to shape-modification, like basic and archetypical forms, fuzzy quantities, shape modification technologies, or general shape parameters (left side, length) etc. If the system possess this knowledge, it is already able to communicate on a more intelligent way. The next group covers the mechanical engineering related knowledge. (Physical phenomena, functions related to the phenomena, mechanical constructions, manufacturing technologies, etc.). With such a knowledge, the system is able to give advices, warnings, and proposals. The last group is the general knowledge. In this case the system could communicate like a human.

The syntactic axis

On this axis, we try to categorize the expression mode of the communication. The two extremes are the syntax of the interface of the modeling engine, and the most flexible style of natural language. Based on this we can give three fuzzy categories:

- Strict syntax (E.g. artificial languages like C++)

- Lenient syntax (E.g., written form of natural languages)
- Sloppy syntax (E.g., spontaneous speech and slang)

There are plenty of syntactic features (e.g. grammatical rules) of natural communication, which may make the communication either convenient or rather unnecessarily complex. We have collected such a features from the frequently used communication modes of the conceptualization process, e.g., talking, sketching, gesturing. We considered only these kinds of natural interaction techniques, since they will dominate in the user interface of an effective shape conceptualization system according to our hypothesis. The collected features of expression modes are independent, there is no hierarchical connection among them. That means that we can build our artificial language from existing languages by excluding (or including) features after their role and usefulness having evaluated. Table 3 presents the typical syntactic features of natural communication on a sentence level.

Table 3 Most frequent sentence styles

Body language	Spoken or written language
Commonly accepted body movements as incomplete sentences(OK, no, bye-bye)	Use of incomplete sentences e.g. OK Active/passive sentences Polite formulas Dialects, accent
Repetition of gestures (like spontaneous speech)	Slang, local conventions Spontaneous speech (false start, hesitation, repairs, fragments)

Table 4 focuses on the expression mode of shapes. We have three semantic categories: (1) shapes known by the system, (2) existing shapes that are not known by the system, and (3) shapes existing mentally only. Shapes of the first case are expressed by references (e.g. recalling it by its name). In the second case, this is done by presenting the shape to the system (e.g. 3D scanning of a physical object) and in the third case the user specifies the shape with a process (e.g. sweeping).

EVALUATION CRITERIA FOR COMMUNICATION MODES

We consider three basic evaluation criteria for ranking possible communication modes, namely the effectiveness, the efficiency, and the comfort. In this chapter, we discuss these criteria in more details.

Effectiveness

We consider a communication effective if the receiver understands the same of the communicated information as the transmitter. Communicated information is often ambiguous. The ambiguity may come from two sources. (1) The apobetics, the aim of the communication can be vague. This is very typical in the conceptual phase of design, since the designer does not know exactly what the end result will be (i.e. if he knows exactly, then the concept is ready and it is not conceptualization anymore). No matter what kind of communication mode we use, the aim of the communication can be vague and computer systems will have to be prepared for that. (2) The format of the communication can be uncertain, as well. This uncertainty may distort the apobetics of the communication and leads to misunderstandings. Here, we want to emphasize that if the transmitter's understanding is uncertain then in case of effective communication the receiver's understanding should be as uncertain. Unfortunately, we cannot restrict the uncertainty issue to the format of the communication. In order to transmit uncertain information, both the communication mode and the receiver's model representation have to be able to handle the uncertain information. We can conclude from our definition that the communication is effective if it is not distorted by the uncertainties. Hence, we could estimate the effectiveness by estimating the caused uncertainties of the features of the communication modes.

Experiments [10] provide excellent examples of how uncertain (therefore ineffective) human communication can be. The intent of the transmitter was very well-determined, since he could look at and even touch the real clay object to be communicated. However, the communication modes that the subjects used are extremely uncertain. The example in Figure 4 contains about 50-70% "junk speech" and repetition, which is completely unimportant from shape description viewpoint and even disturbing for a computer system. (This ratio is true for most tests in the experiment.). The extreme uncertainty in the natural communication mode of humans caused a high failure rate. Subjects failed to recognize the right shape, although they had to choose from only six shown cases and not from infinity all possible shapes, as a computer system should do in a real design process. According to Buxton [4], "speech is effective in communicating many concepts, but spatial and temporal relationships are often far better articulated with gestures or markings". The results of the experiments clearly certify this statement.

On the other hand, the experiments also show that the subjects took advantage of the high-level entities provided by the natural language. Although, in the experiment the mental

Table 4 Most frequent expression modes of shapes

Shapes known by the system	Shapes not known by the system	Undefined shapes (mentally defined)
Identity number or sign	Physical objects	2D shape by 2D process
Names and synonyms	3D digital models	2D shape by 3D process
Situation dependent and incomplete reference e.g. the tire [of the car] [of the bike]	2D sketches Photo Technical drawings	3D shape by 2D process (projection) 3D shape by 3Dprocess
Pronouns (this, here, you, now)		
Spatial reference (by hands)		

concepts were not vague, subjects often used vague concepts (e.g. "…a sort of nose…" see Figure 4) to explain their mental image, which can be very advantageous in real conceptualization process.

Efficiency

The main aim is to achieve the required model of the mental concept as fast as possible. Speed is the criterion of communication that seems to be measurable the easiest way. We can look at the speed of communication from different scopes. Of course, we are mostly interested in the global scope, namely the speed of achieving the complete required model of the concept. The problem is that the model generating process in the conceptualization phase is influenced by several effects. The most dominant effect is that during the process, not only the model but also the mental concept changes significantly. The other alternative is evaluating the speed of the parts of the model building process. This comparison is more feasible, and promising. The drawback of it is that we cannot be sure that superposition of the fastest parts of the model building process produces globally the fastest results, due to effects mentioned above.

The model building process can be decomposed into actions, which are usually represented by one or a couple of sentences. E.g. adding a new shape feature to the model is regarded as an action. It is worthwhile to go deeper, to the local scope of the actions, as well. Here, we can investigate the basic elements of the communication, how to express an object, a shape or an action. Depending on the semantic content of an element, the fastest expression mode can be very different.

Wiegers' experiment [10] is not suitable to compare the speed of different expression modes of the same content because the effectiveness is different for each test. From the viewpoint of the uncertainty of the format, it is visible: if we just leave out the unnecessary parts from the speech of the subject in Figure 4, we get significantly shorter text to be communicated. On the other hand, the application of high-level vague concepts compressed the shape definition very much. E.g. the spoken definition (Figure 4) of the amorphous shape of Figure 5 can be summarized in two statements: "It looks like this one, but it is rounded from this direction, too" and "Here, there is a sort of nose on it".

Comfort

This aspect is a not clearly independent factor, because people prefer to use those methods, which are effective and fast. On the other hand, there can be communication modes that provide the same result but are more appropriate for one person than for someone else.

We can characterize communication from the viewpoint of comfort by impartial and subjective factors. The main impartial factor is that the user likes to apply his available knowledge if possible. This is the case if we use natural language to communicate (comfort of syntax). An other case is, when the system imitates the behavior of a physical object, and the user can anticipate what shape he will get without having experience with that system (comfort in semantics).

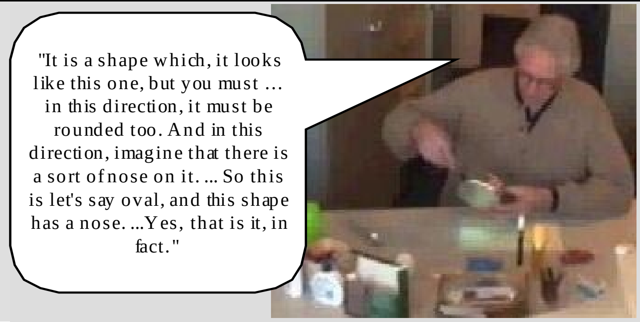

Figure 4 Exteriorizing shape by speech, physical example, and hand gestures.

Figure 5 Object to be exteriorized in Figure 4

The experiments [10] show examples how people exteriorize shapes. The aim of the experiments was to explore the natural way of shape communication. In the experiment, a clay model has been shown to subject A. He explained the shape of the clay model to subject B and B had to choose the appropriate one from six examples. Subject A was allowed to use several means, but he did not get feedback from subject B. The experiment had twelve sessions, each contained four tests using different modalities (i.e. speech + gesture, speech + physical objects, speech + sketch, everything). A panel of five reviewers scored each test how much understandable the explanation was. Based on the scoring, each session had a most and a least effective test. Among the twelve most effective tests, seven of them (58.3%) applied sketches and only two of them (16.6%) used gestures. On the other hand, among the twelve least effective tests, only one (8.3%) used sketches in contradiction to the seven tests (58.3%), which used gestures. In the 20.8% of all tests, subject B failed to hit the intended shape. This test above is among the ten most understandable ones.

The subjective factors cannot easily be considered when comparing different communication modes.

CONCLUSIONS AND FUTURE WORK

There is a significant need for a new type of user interface for CAD systems, which is able to fulfill the requirements of conceptual design. Natural communication has promising opportunities in this field, since it is able to transmit vague concepts, as well. However, the use of natural communication (e.g. verbalism) also raises new problems like failures of understanding caused by unnecessary uncertainty in the format of the communication.

We have compared several views from literature on the levels of information. There is a consistent commonly accepted interpretation on syntax and semantics, but there are significant differences in the case of pragmatics. We have used a simplified version of Gitt's communication model for classification of the characteristic features of natural communication. We ha0ve also defined three criteria (i.e., effectiveness, efficiency, and comfort) that facilitate the evaluation of the classified features and may help choosing the most appropriate way of communication for a particular purpose.

The next step is the execution of the evaluation. We intend to prove the validity of the evaluation by pilot implementation of the top ranked and feasible communication modes.

REFERENCES

[1] Aamodt, A. and Nygard, M., "Different roles and mutual dependencies of data, information, and knowledge - An AI perspective on their integration", Data and Knowledge Engineering 16: 191-222, 1995

[2] Austin, J.L.: "How to Do Things with Words" Oxford: Oxford University Press 1962

[3] Black, M.: "The Labyrinth of Language" 1968

[4] Buxton, W. "Speech, Language & Audition" Chapter 8 in R.M.Baecker, J. Grudin, W. Buxton and S. Greenberg: Readings in Human Computer Interaction: Toward the Year 2000" (1995) San Francisco, Morgan Kaufman Publishers

[5] Gitt, W.: "Information: The Third Fundamental Quantity". Siemens Review, 6/89., pp.36-41

[6] Hoffmann, A.: "Paradigms of Artificial Intelligence - A Methodological & Computational Analysis "Springer-Verlag Singapore 1998

[7] Merriam - Webster's collegiate dictionary: http://www.m-w.com/

[8] Shannon, C. E., Weaver, W., “The Mathematical Theory of Communication” The Board of Trustees of the University Illinois 1949

[9] Sharples, M., Hogg, D., Hutchison, C., Torrance, S., Young, D.: "Computers and Thought - A Practical Introduction to Artificial Intelligence" The MIT Press, Cambridge, Massachusetts, 1989

[10] Wiegers T, Kuczogi G and Horváth I, "Expressive interaction for conceptual design of shape - An empirical study on methods and their effectiveness", Proceedings of the ICSC Symposia on Intelligent Systems and Application (ISA'2000), December 11-15, Wollongong, Australia, F. Naghdy e.a. (eds), Published by ICSC Academic Press, Canada/Switzerland, CD-ROM, paper nr. 1523-275, 7 pages.