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D3.1 Initial list of gestures and syntax

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PU	Public	x
PP	Restricted to other programme participants (including the Commission Services)	
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Contents

1 Introduction

Divers operate in harsh and poorly monitored environments in which the slightest unexpected disturbance, technical malfunction, or lack of attention can have catastrophic consequences; they manoeuvre in complex 3D environments, carry cumbersome equipment, while performing their mission. These issues are usually dealt with by pairing up divers and adopting well defined rules for diving operations to reduce the chance of accidents. The CADDY project replaces a human buddy diver with an autonomous underwater vehicle and adds a new autonomous surface vehicle to improve monitoring, assistance, and safety of the diver's mission. The resulting system plays a threefold role similar to those that a human buddy diver should have: the buddy "observer" that continuously monitors the diver; the buddy "slave" that is the diver's "extended hand" during underwater operations performing tasks such as "do a mosaic of that area", "take a photo of that" or "illuminate that"; the buddy "guide" that leads the diver through the underwater environment.
In this scenario, communication and correct reception of messages between humans and robots is essential for the success of the proposed goals. However, due to the high conductivity of sea water, radio communication technology is of little or no use in subsea applications and optical communication has very limited range due to scattering by sediment, bubbles etc. [1].
Hence we are generally reliant on underwater acoustic technology for communication and navigation over significant distances. However acoustic modems have got high prices and they can't set up an acoustic communication network with high data rate and high reliability. [2] [3] [4]
Within this background a language of communication between the diver and the buddy based on gestures, called CADDIAN, was therefore developed.

2 CADDIAN: a human-robot interaction language based on gestures

The creation of the language of human-robot interaction (hereinafter referred to as H) was based on the use of sign language, however, for better readability, signs have been mapped with easily writable symbols such as the letters of the Latin alphabet: this bijective mapping function translates from the domain of signs to our alphabet and vice versa (see Fig. 1).

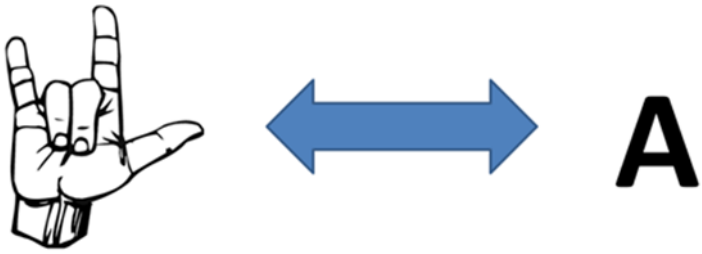


Fig. 1 A bijective function translates from the domain of signs to our alphabet and viceversa

The gesture or sequence of gestures of language H and the corresponding characters or sequences of characters of the alphabet Σ are also mapped to a semantic function that translates them into commands / messages (see Fig. 2).

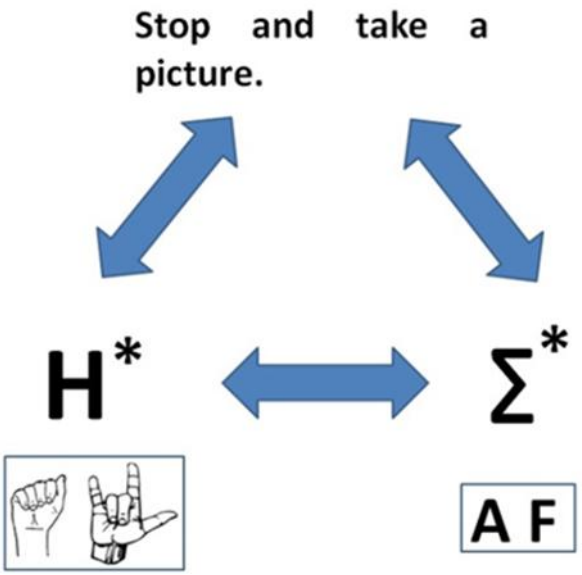


Fig. 2 Gestures can be translated into written form and have their own semantics

The encoding and decoding of gestures are assigned to a classifier: the cardinality of the alphabet and therefore of gestures depends on the ability of classification. The more dimensions the classifier can discern, the more gestures / symbols of the alphabet we can have: however, the gestures should be feasible in the underwater environment and should be as intuitive as possible (it is not recommended that an open palm in the direction of the robot have the meaning of "Come ahead").

The commands/messages are:

Problems	I have an ear problem	I'm out of breath
	I'm out of air [air almost over]	Something is wrong [diver]
	I depleted air	Something is wrong [environment]
	I'm cold	I have a cramp
	I have vertigo	
Movement	Take me to the boat	You lead (I follow you)
	Take me to the point of interest	I lead (you follow me)
	Go X Y X ∈ {ahead, back, left, right, Up, Down} Y ∈ ℕ	Return to/come X X ∈ {point of interest, boat, here}
	Stop [interruption of action]	Abort mission
	Let's go [continue previous action]	General evacuation
Setting variables	Slow down/Accelerate	Set point of interest (henceforth any action may refer to a point of interest)
	Level Off (CADDY cannot fall below this level, no matter what diver says: the robot interrupts any action, if the action forces him to break this rule)	Keep this level (any action is carried out at this level)
		Free level ("Keep this level" command does not apply any more)
	Give me air (switch on the on board oxygen cylinder)	Give me light (switch on the on board lights)
	No more air (switch off the on board oxygen cylinder)	No more light (switch off the on board lights)

Feedback	No (answer to repetition of the list of gestures)	I don't understand (repeat please)
	Ok (answer to repetition of the list of gestures)	
Works	Wait n minutes n ∈ ℕ	Tessellation X * Y area X,Y ∈ ℕ
	Tell me what you're doing	Photograph of X * Y area X,Y ∈ ℕ
	Carry a tool for me	Stop carrying the tool for me [release]
	Do this task or list of task n times n ∈ ℕ	Photograph of point of interest/boat/here
		Tessellation of point of interest/boat/here

2.1 Communication protocol and errors handling

To develop the communication protocol and therefore its language, we took into consideration that the issued statements have to be sequential, thus allowing synchronization between human and robot, and have to be defined with boundaries to ensure efficient interpretation.
We suppose that CADDY has got three light emitters (red, green, orange) or something similar with the same attributes (i.e. we can discern three statuses from it). Let it be:

- Green = finished work, waiting for orders STATE IDLE
- Orange = work in progress STATE BUSY
- Red = FAILURE/ERROR STATE

The protocol development takes into account these three possible scenarios:

1. CADDY does not understand a gesture of the command: the classifier identifies the gesture as not belonging to the alphabet. An error signal is emitted and the gesture has to be repeated by the diver: the sequence/command is not aborted. In this scenario, the error provides information on the effectiveness of the classifier and the state of health of the diver (if I'm feeling wrong I have a higher probability of missing a gesture).

2. CADDY understands the gesture (i.e. the gesture belongs to our alphabet), but the message is not semantically true. An error signal is emitted (different from the one of the first case): the sequence of gestures is aborted and must be repeated. In this scenario, the error mainly provides information on the health status of the diver (if I'm feeling bad I have a higher probability of a wrong gesture).

3. CADDY understands the gesture (i.e. the gesture belongs to our alphabet), and the message is semantically true (it has a meaning consistent with our environment), but it is not what the diver wanted (i.e. diver changes his mind or did a wrong gesture).

To treat this third case we have to introduce the definition of "mission" such as a series of arbitrary commands. The diver teaches CADDY the mission to be performed and CADDY, before starting it, repeats what it understood waiting for confirmation from the diver. More specifically, once the mission is taught, Caddy repeats every command (syntactically or semantically true) and waits for

confirmation of correct reception: in case of error, the diver does not confirm the command and repeats the series of gestures that form the command (see mission number 2 in 2.5).
For optimization and disaster recovery reasons every mistake and every action of the robot are logged.
In the definition of the language two aspects of interrogability of the robot were also taken into account:

1. The diver must understand if the task / mission entrusted to CADDY has been terminated.

2. The diver must be able to query CADDY on the progress of a lengthy mission.

In the first case, CADDY just turns on a green light and remains stationary. In the second case we suppose that, when CADDY is in operation and executes a task, if the diver approaches within a predefined range of X meters (i.e. 5 meters), it stops, remaining however in the BUSY state. In this situation it can:

- Be questioned on the progress of the work (see command "CHECK").

- Return to the IDLE state, erasing the current mission (see "STOP" command).

- Return to the IDLE state and report an emergency (see section 2.4.1 Problems and the semantic value of ƀ = clear mission).

- Return to the assigned mission if the diver moves away at a distance greater than X meters.

2.2 Language definition

The language up to now described is a set of strings of finite length constructed over a finite alphabet Σ and consequently can be defined as a formal language. A formal language can be described by a formal grammar [5] [6]. A formal grammar is a quadruple <Σ, N, P, S> as follows:

1. A finite set Σ of terminal symbols (disjoint from N), the alphabet of the language, that are assembled to make up the sentences in the language.
2. A finite set N of non-terminal symbols or syntactic categories or variables, each of which represents some collection of subphrases of the sentences.
3. A finite set P of productions or rules that describe how each nonterminal is defined in terms of terminal symbols and non-terminals. The choice of non-terminals determines the phrases of the language to which we ascribe meaning. Each production has the form A → β, where A is a non-terminal and β is a string of symbols from the infinite set of strings (Σ U N).
4. A distinguished nonterminal S, the start symbol , that specifies the principal category being defined—for example, sentence or program or mission.

We can formally define the language L_G generated by grammar G as the set of strings composed of terminal symbols that can be derived from the start symbol S.

$L_G = \{w / w \text{ is in } \Sigma^* \text{ and } S \rightarrow^* w\}$

The creation of an alphabet, or better the choice of symbols of the alphabet is irrelevant as long as the symbols that compose it can be mapped to the available gestures and in turn it is possible to give these gestures an unambiguous meaning (unambiguous semantics). In this document the signs of the

alphabet Σ are the set of letters of the Latin alphabet mixed with some words, Greek letters, math symbols and natural numbers (also used as subscripts) defined as follows:

Σ = {A, B, C, D ... Z, ∀ ,const, limit, check,…, 1,2 …}

The nonterminal symbols, for traditional notation, are indicated with the form "<category-name>" and are used in the productions together with the terminal symbols (in bold red in the example) in the following way:

<declaration> ::= **var** <variable list> **:** <type> **;**

This notation is called Backus-Naur Form (BNF) and is used to describe the syntax of the language. The syntax is a set of rules to build the messages, however a message built according to the rules of syntax assures us that the message belongs to our language, but not that the message has a meaning (i.e. the sentence "David eats the sun" belongs to the English language, but it is semantically "wrong" because David is not able to eat the sun). In other words, only syntax, and not semantics, is addressed by the grammar.
It has been preferred a mixed logographic approach: in diver signs language we have a strict one-to-one function between a command/message to a sign; in CADDIAN, to address a higher expressive capability, a command/message is made up of one or more morphemes.
The grammar that we have built is a context-free grammar by definition because on the left side of the productions we find only one non-terminal symbol and no terminal symbol [7] [8]. In addition, with the current productions the resulting language is an infinite language given that the first production (i.e. < S >) uses recursion: this can also be seen from the dependency graph of the non-terminal symbols (the graph contains a cycle).

Here the BNF productions follow:

<S> ::= A <α> < S > | ∀

<α> ::= <agent> <m_action> <object> <place>

| ƀ <feedback> <p_action> <problem>

| <set_variable> | <feedback> | <interrupt> | <work> | Ø | Δ

<agent> ::= I | Y | W

<m_action> ::= T | C | D | F | G <direction> <num>

<direction> ::= forward | back | left | right | up | down

<object> ::= <agent> | Λ

<place> ::= B | P | H | Λ

<problem> ::= E | C_1| B_3 | P_g| K | V | Λ

<p_action> ::= H_1| B_2 | D_1| Λ

<feedback> ::= ok | no | U | Λ

<set_variable> ::= S <quantity> | L <level> | P | L_1 <quantity> | A_1 <quantity>

<quantity> ::= + | -

<level> ::= const | limit | free

<interrupt> ::= Y < feedback > D

<work> ::= Te <area> | Te <place> | Fo <area> | Fo <place> | wait n | check
|<feedback> carry |for <num> <works> end |Λ

<works> ::= <work> <works> | Λ

<area> ::= <num> <num> | <num>

<num> ::= <digit> <num> |Ψ

<digit> ::= 1|2|3|4|5|6|7|8|9|0

NOTE: into the CADDIAN **written** form, to let the language more natural and intuitive, the productions "I" and "Y" are sometimes substituted by "M" and "R" ("Me" and "Robot") depending on whether the <agent> is subject or direct object of the verb (see for example Mission 1 in 2.5 Use cases).

2.2.1 Quick reference tables

<agent>	**<m_action>**	**<object>**	**<place>**	**<problem>**	**<p_action>**	**<feedback>**
I	T = take	See **<agent>**	B = boat	E = ear	H_1= to have	Ok
R = you/robot	C = come	Λ = no op	P = point of interest	C_1 = cold	B_2 = to be out of	No
W = we	D = do		H = here	B_3 = breath	D_1 = to deplete	U = don't understand
	F = follow		Λ = no op	P_g = generic problem	Λ = no op	Λ = no op
	G = go			K = cramp		
				V = vertigo		
				A_1 = air		
				Λ = no op		

<set_variable>	**<level>**	**<work>**	**<α>**
S = speed	const = constant	Te = tessellation	Ø = abort mission
L = level	limit = limit	Fo = photograph	Δ = general evacuation

L_1 = light	free = free movement	Wait = wait	
A_1 = air		Check = check what the robot is doing	
P = point of interest		Carry = carry a tool upon diver request	
		For = do a task or a list of task a number of times	

2.3 Translation table

By applying the syntax to messages and commands identified we obtain the following translation table.

	Message/Command	Translation into CADDY language	
Problems	I have an ear problem	A ƀ H_1 E ∀	
	I am out of air [air almost over]	A ƀ B_2 A_1 ∀	
	I depleted air	A ƀ D_1 A_1 ∀ = A ƀ no H_1 A_1 ∀	
	I'm cold	A ƀ H_1 C_1 ∀	
	I'm out of breath	A ƀ B_2 B_3 ∀	
	Something is wrong [on me]	A ƀ H_1 P_g ∀	
	Something is wrong [environment]	A ƀ P_g ∀	
	I have a cramp	A ƀ H_1 K ∀	
	I have vertigo	A ƀ H_1 V ∀	
Movement	Take me to the boat	A Y T M B ∀	A I F Y Y C B ∀
	Take me to the Point of interest	A Y T M P ∀	A I F Y Y C P ∀
	Return/come to X X ∈ {point of interest, boat, here} i.e. go to point of interest, boat, come here	A Y C P ∀ A Y C B ∀ A Y C H ∀	
	Go X Y X ϵ {forward, back, left, right, up down} Y ϵ ℕ	A Y G forward n ∀, A Y G back n ∀, A Y G left n ∀, A Y G right n ∀, A Y G up n ∀, A Y G down n ∀	
	I follow you	A I F Y ∀	
	You follow me	A Y F M ∀	
Interrupt	Stop [interruption of action]	A Y no D ∀	
	Let's go [continue previous action]	A Y ok D ∀ = A Y D ∀	
	Abort mission	A Ø ∀	
	General evacuation	A Δ ∀	
Setting variables	Slow down (during a stop decrease default	A S - ∀	

	movement speed)	
	Accelerate (during a stop increase default movement speed)	A S + ∀
	Keep this level (any action is carried out at this level)	A L const ∀
	Free level ("Keep this level" command does not apply anymore)	A L free ∀
	Level Off (CADDY cannot fall below this level, no matter what diver says: the robot interrupts any action, if the action forces him to break this rule)	A L limit ∀
	Set point of interest (henceforth any action may refer to a point of interest)	A P ∀
	Give me light (switch on the on board lights)	A L_1 + ∀
	No more light (switch off the on board lights)	A L_1 - ∀
	Give me air (switch on the on board oxygen cylinder)	A A_1 + ∀
	No more air (switch off the on board oxygen cylinder)	A A_1 - ∀
Communication Feedback	No (answer to repetition of the list of gestures)	A no ∀
	Ok (answer to repetition of the list of gestures)	A ok ∀
	I don't understand (repeat please)	A U ∀
Works	Tessellation X * Y area	A Te n m ∀ or A Te n ∀ [square]
	Tesselation of point of interest	A Te P ∀
	Photograph of X * Y area	A Fo n m ∀ or A Fo n ∀ [square]
	Photograph of point of interest	A Fo P ∀
	Wait X minutes	A wait n ∀
	Tell me what you're doing	A check ∀
	Carry a tool for me	A carry ∀
	Stop carrying a tool for me [release]	A no carry ∀
	Make a photograph of this area n*m X times	A for X Fo n m end ∀

2.4 Semantics

All commands/messages can be grouped into set: each set addresses tasks which refer to a common topic. So all commands in Problems section refer to the communication of problems to the robot while the Movement section refers to command that make the robot move. In the following paragraphs we explain more in detail these commands set.

2.4.1 Problems

All the commands inside the Problems set refer to troubles happening to the diver or to the environment around the area of action of the mission. All the productions contain the ƀ symbol which denotes that there is a problem and that the mission must be aborted.

2.4.2 Movement

All the commands inside the Movement set make the robot move or tell the robot how to move (this second case refers to the "I follow you"/"You follow me" commands). Two productions ("Take me to the boat" and "Take me to the point of interest") can be replaced by other productions with a similar meaning, however the replacement extends the length in term of signs of the mission.

2.4.3 Interrupt

All the commands inside the Interrupt set make the robot stop doing the current task/mission. The "Stop" and "Let's go" commands are used when the diver wants to stop the robot from doing something and currently can be used only when the robot is following the diver [remember that we assume that the robot stops if the diver approaches within a predefined range of meters and that during a "Follow me" task the robot respects this distance even if the diver approaches, the robot steps back]. "Abort mission" cancel the current mission, while the "General evacuation" tells the robot to abort the mission and to issue any possible warning signals to the boat and to any diver all around (i.e. switches on flashing lights).

2.4.4 Setting variables

All the commands inside the Setting variables section set an internal variable inside the robot. At this moment we have eight internal variables: only seven can be set by the diver (the boat position is excluded).

Speed: the robot speed has discrete value. With the "+" or "-" signs the diver increases or decreases this variable by a quantum.

Level:

- off: the robot cannot fall below this level, no matter what diver says: the robot interrupts any action, if the action forces him to break this rule.
- const: any following command is carried out at this level.
- free: "Keep this level" (i.e. "const") command does not apply anymore.

Point of interest: set the point of interest.

Light:

- "+" switches on the on board lights.
- "-" switches off the on board lights.

Air:

- "+" switches on the on board oxygen cylinder.
- "-" switches off the on board oxygen cylinder.

We assume that for any need CADDY is equipped with a backup oxygen cylinder.

Here: set the point where CADDY stays when the mission is entrusted.

Boat: this is the boat position, can't be set by the diver.

Point of interest: set the point where CADDY stays as a Point of interest which you can refer to inside later commands.

2.4.5 Communication feedback

All the commands inside the Communication feedback set refer to the acceptance of the mission. With these command the diver can accept or not a command. The diver can also ask the robot to repeat the command if he didn't understand it (by distraction or by accident).

2.4.6 Works

All the commands inside the Works set refer to the possible task the robot can executes. The "Tell me what you're doing" command (i.e. mission progress) is used when the diver approaches the robot (and the robot consequently stops anything is doing). The "Wait X minutes" command tells the robot to float and wait X minutes then proceed with the next command (useful when we have sandy bottom). The "Carry a tool for me" command tells the robot to carry equipment upon diver request: after the equipment has been placed into the compartment, the robot waits for a physical confirmation (we assume that for this special case there is a button to press to give confirmation). The "Do this task or list of task n times" allows repeating a task or a list of tasks a number of times: it is very useful combined with the "Wait" command to monitor an area or a point of interest. The command "Make a photograph" is overloaded, taking two different set of parameters: the first one is an area (described with length and width); the second one is an area around a given point such "Point of interest", "Here" or "boat" [the area, in this case, is defined a priori].

2.5 Use cases

Mission 1

Follow me. [The diver goes to the point of interest]. Set point of interest. Tessellation of X x Y area. Return to the boat.

Diver: A Y F M ∀

Robot: *I have understood* A Y F M ∀ *Is it correct?*

Diver: A ok ∀

[the diver goes to the point of interest].

Diver: A P A Te n m A Y C B ∀

Robot: *I have understood* A P ∀ *Is it correct?*

Diver: A ok ∀

Robot: *I have understood* A Te n m ∀ *Is it correct?*

Diver: A ok ∀

Robot: *I have understood* A Y C B ∀ *Is it correct?*

Diver: A ok ∀

Mission 2 (error handling example)

Go faster. Go to point of interest. Make photographs of n x n area. Tessellation of n x n area. Come here.

Diver: A S+ A Y C P A Fo n A Te n A Y C H ∀

Robot: *I have understood* A S+ ∀ *Is it correct?*

Diver: A ok ∀

Robot: *I have understood* A Y C B ∀ *Is it correct? [ERROR]*

Diver: A no ∀ [Robot changes state and now is listening]

Diver repeats the command A Y C P ∀

Robot: *I have understood* A Y C P ∀ *Is it correct?*

Diver: A ok ∀

Robot: *I have understood* A Fo n ∀ *Is it correct?*

Diver: A ok ∀

Robot: *I have understood* A Te n ∀ *Is it correct?*

Diver: A ok ∀

Robot: *I have understood* A Y C H ∀ *Is it correct?*

Diver: A ok ∀

Mission 3

Give me light. You lead. Go to archaeological site (i.e. previous point of interest). [Diver follows the robot to archaeological site. The robot illuminates the way.]. At the point of interest diver doesn't need light, but a tessellation of X x Y area. At the end of the task robot must return to the boat.

Diver: A L + A I F Y A Y C P ∀

Robot: *I have understood* A L + ∀ *Is it correct?*

Diver: A ok ∀

Robot: *I have understood* A I F Y ∀ *Is it correct?*

Diver: A ok ∀

Robot: *I have understood* A Y C P ∀ *Is it correct?*

Diver: A ok ∀

[The robot switches on the on board lights and goes to the point of interest. Diver follows the robot to the point of interest].

Diver: A L - A Te n m A Y C B ∀

Robot: *I have understood* A L - ∀ *Is it correct?*

Diver: A ok ∀

Robot: *I have understood* A Te n m ∀ *Is it correct?*

Diver: A ok ∀

Robot: *I have understood* A Y C B ∀ *Is it correct?*

Diver: A ok ∀

[The robot switches off the on board lights and executes the task of tessellation, then goes to the boat].

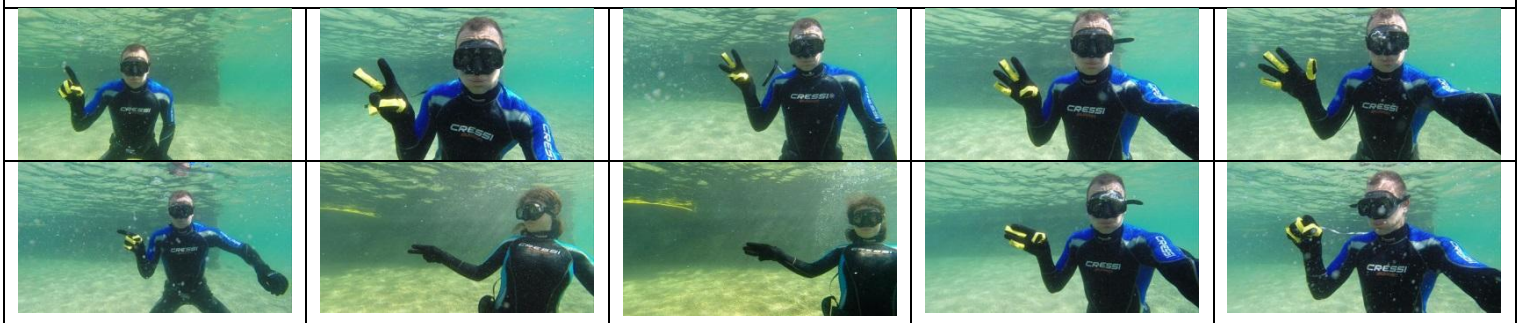
It can be seen by these use cases that CADDY uses the limiters (i.e. "A" and "∀") even for the answers: this choice has been made in anticipation of a possible collaborative mission only between AUVs, with the total absence of man. Using limiters, in fact, assures us good segmentability and sequentiality: in this way issued statements have defined boundaries to ensure efficient interpretation and the recipient is able to synchronize with the issuer.

3 Initial list of gestures

Gestures were chosen in part from those common to divers and in part from everyday ones: in fact the gestures should be feasible in the underwater environment and should be as intuitive as possible. However all diving agencies or organizations around the globe teach their divers hand signals, making some of them to vary from region to region: we chose the most famous and common ones [9] [10] [11] [12] [13].

The following list contains only static gestures. Dynamic gestures will be introduced lately according to classifier performance. In fact the encoding and decoding of the gestures are assigned to the classifier: the cardinality of the alphabet and therefore of gestures depends on the ability of classification. The more dimensions the classifier can discern, the more gestures/symbols of the alphabet we can have: movement or better dynamics can be seen as one of these dimensions and also the more massive use of two hands instead of only one (see for example the "Get with your buddy" signal in [10]).

Natural numbers



Other signs

A	***Start of a command***	**∀**	***End of communication***	**B**	***Boat***	**E**	***Ear***	**F**	***follow***

H_1	***To have***	**No**	***No***	**L**	***level***	**const**	***constant***	**I**	***I***

									
Y	***You/robot***	**Ok**	***Ok***	**B_2**	***To be out of***	**P**	**Point of interest**	**ƀ**	***Starting a problem***
									
+	***increase***	**-**	***decrease***	**To be assigned**		**Fo**	***Take a photograph***	***To be assigned***	
									
To be assigned		**To be assigned**							

Table 1 Initial list of gestures

As can be seen in Table 1, some of these gestures are not assigned, yet. In most cases the gestures have been chosen so as to be affine to natural/instinctive meaning. In other cases, the memorization of the meaning of a gesture is possible, through the association of objects pertaining to the action you want to perform such as in the "Take a photograph" case: the diver shows three fingers which can be associated to the tripod used to stabilize and elevate a camera.

3.1 Mapping gestures to syntax, syntax to semantics: examples

As already said, a bijective mapping function translates from the domain of signs to our alphabet and vice versa. Accordingly a gesture or a sequence of gestures and the corresponding characters or sequences of characters are also mapped to a semantic function that translates them into commands/messages (Fig. 3).

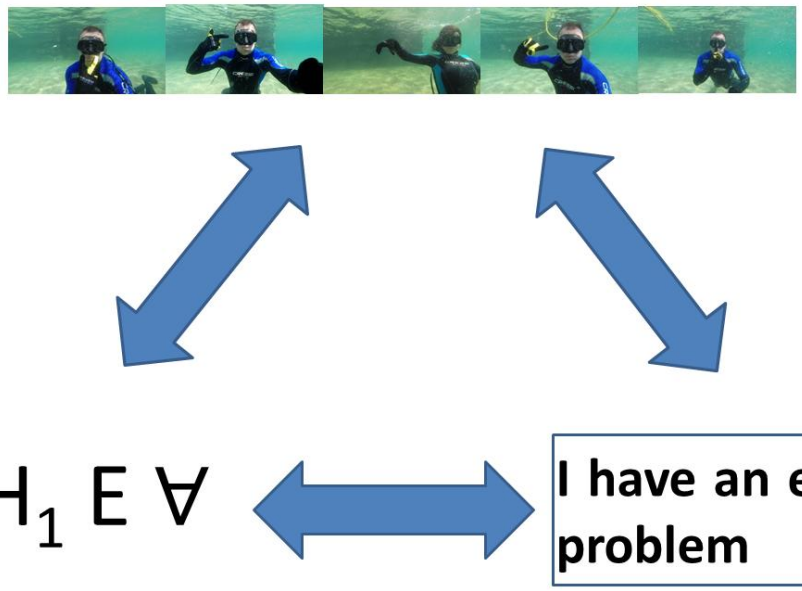


Fig. 3 The connections among gestures, syntax and semantics

Examples of translation of some commands/messages into CADDIAN follow:

"I have an ear problem" ↔ A ƀ H_1 E ∀

SYNTAX	A	ƀ	H_1	E	∀
GESTURES					
SEMANTICS	I have an ear problem				

"Ok" (answer to repetition of the list of gestures) ↔ A ok ∀

SYNTAX	A	ok	∀
GESTURES			
SEMANTICS	Ok		

"Keep this level" ↔ A L const ∀

SYNTAX	A	L	const	∀
GESTURES				
SEMANTICS	Keep this level			

"Set point of interest" ↔ A P ∀

SYNTAX	A	P	∀
GESTURES			
SEMANTICS	Set point of interest		

"I follow you" (i.e. You lead) ↔ A I F Y ∀

SYNTAX	A	I	F	Y	∀
GESTURES					
SEMANTICS	I follow you				

4 Conclusion

A description of a human-robot interaction language based on gestures, called CADDIAN, was given. Syntax and an initial list of gestures are described: the language gestures at this stage are static. A transcription of the gestures is also given: for better readability, signs have been mapped with easily writable symbols. Also a communication protocol has been given: the language has been defined so that the interpreter may rely on a good level of redundancy to prevent from misunderstanding of issuer commands. Semantics and some related use cases are reported in order to clarify the use of the language.

The next step is the development of a hand gestures classifier in order to see how many signs can be identified and if dynamics can be added to them allowing in this way a higher cardinality of the hand signals set. The higher cardinality will allow a full translation of the defined commands/messages into CADDIAN. Along with this, it will be very important to receive feedback on the usability of the language in order to fix it according to the needs of final users.

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