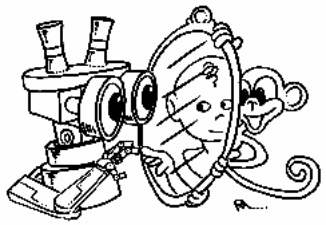

MIRROR

IST–2000-28159

Mirror Neurons based Object Recognition

Deliverable Item 1.9
Technology Implementation Plan

Delivery Date: November 15th, 2004
Classification: Internal
Responsible Person: Prof. Giulio Sandini – University of Genova
Partners Contributed: ALL

Contract Start Date: September 1st, 2001 Duration: 36 Months

Project Coordinator and Partners:
DIST - University of Genova (Prof. Giulio Sandini and Dr. Giorgio Metta)
Department of Biomedical Sciences – University of Ferrara (Prof. Luciano Fadiga)
Department of Psychology – University of Uppsala (Prof. Claes von Hofsten)
Instituto Superior Técnico – Computer Vision Lab – Lisbon (Prof. José Santos-Victor)

Project funded by the European Community under the "Information Society Technologies" Programme (1998-2002)

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Part 1 Overview and description of your project and its results

EC PROGRAMME :	IST
PROJECT TITLE & ACRONYM:	MIRROR - Mirror Neurons based Object Recognition
CONTRACT NUMBER :	*IST–2000-28159*
PROJECT WEB SITE (if any) :	http://www.lira.dist.unige.it/projects/mirror/
PARTNERS NAMES :	DIST - University of Genova (Prof. Giulio Sandini and Dr. Giorgio Metta) UNIFE - Department of Biomedical Sciences – University of Ferrara (Prof. Luciano Fadiga) UU - Department of Psychology – University of Uppsala (Prof. Claes von Hofsten) IST - Instituto Superior Técnico – Computer Vision Lab – Technical University of Lisbon (Prof. José Santos-Victor)

Executive summary

Please, synthesise (in 1 or 2 pages) your project original objectives and final outcome.

a) Original research objectives

The goals of MIRROR are: 1) to realize an artificial system that learns to communicate with humans by means of body gestures and 2) to study the mechanisms used by the brain to learn and represent gestures. The biological base is the existence in primates's premotor cortex of a motor resonant system, called mirror neurons, activated both during execution of goal directed actions and during observation of similar actions performed by others. This unified representation may subserve the learning of goal directed actions during development and the recognition of motor acts, when visually perceived. In MIRROR we investigate this ontogenetic pathway in two ways: 1) by realizing a system that learns to move AND to understand movements on the basis of the visually perceived motion and the associated motor commands and 2) by correlated electrophysiological experiments.

The project will investigate the association between visual information and motor commands in the learning, representation and understanding of complex manipulative gestures. The reference scenario is that of a person performing goal driven arm/hand gestures such as pointing, scratching a body part, bringing food to the mouth etc. At the end of the project the artifact will be able to learn how to perform and recognize this kind of actions. We intend to proceed with two different methodologies: 1) implementation and use of an artificial system and 2) electrophysiological and behavioral experiments. In the initial part of the project the experimental set-ups will be realized namely 1) the artificial system (robot) and 2) the biological data acquisition. The robot is composed of a binocular head, a torso, an anthropomorphic arm with a hand. Most of these components are already available and we will concentrate on the realization of an arm and hand with elastic properties (possibly included in the actuators) and with torque/force sensors at the joints. The biological set up will consists, initially, of a "dataglove-like" and a pair of cameras. Experiments will be carried out to better understand the role of the unified visuomotor representation formed by mirror neurons in learning and recognizing motor acts, and how these acts are matched onto the observer motor repertoire. The degree of modulation of mirror neuron discharge recorded when the monkey sees its own hand will be contrasted with neuronal discharge evoked by observation of other's hand, and during the execution of hand actions without visual feedback. The biological data will guide the artifact implementation. Finally the "artificial neurons" of the artifact "brain" will be analyzed in terms of motor, visual and visuomotor properties and the data will be compared with those obtained during recording experiments performed in monkey parietal and frontal cortices.

b) Expected deliverables

Expected project results were:

1) artificial system able to interact with humans by means of gestures;
2) better understanding of visuomotor representation and learning in humans;
3) new technology for actuation/control/sensing.

c) Project's actual outcome ***(in terms of technical achievements or if appropriate task per task)***

The project actual outcome is close to the predicted one, the main difference being that the level of integration in the robotic platform did not go as far as initially thought. Nevertheless, we believe to have uncovered many elements of a biologically "compatible" architecture. MIRROR's main scientific contribution is a plausible explanation of the development of mirror neurons. This explanation was constructed by means of mathematical models, and of the contributions from engineering and neural sciences.

We proposed a methodology for gesture recognition based on motor representation where object affordances play a role. In addition, we developed several approaches for acquiring models both of the objects that the robot encounters and of its hand. The acquisition of the model of the hand and of objects is based on the exploitation of visuo-motor associations while the robot generates repetitive hand movements. In addition, we performed electrophysiological recording of single neurons in the monkey ventral premotor (area F5) and primary motor (area F1) cortices, a psychophysical assessment of critical factors for biological data acquisition systems, and investigated the role of the mirror system in inter-individual communication. Finally, we have studied the ability of children to adjust the orientation of objects with various shapes in order to fit them into holes, the development of infants' predictive reaching to moving objects and the development of predictive visual tracking.

d) Broad dissemination and use intentions for the expected outputs *(such as industrial development, standards, regulations and norms, improvement of environment, health, working conditions, employment, net economic benefits, etc)*

1.2 Overview of all your main project results

No.	Self-descriptive title of the result	Category A, B or C*	Partner(s) owning the result(s) (referring in particular to specific patents, copyrights, etc.) & involved in their further use
1	Methodology for gesture recognition based on motor representation considering also object affordances	C	
2	Approaches for acquiring models objects by virtue of active manipulation	C	
3	A developmental approach for grasping	C	
4	Design and construction of an experimental setup for the acquisition of grasping visuo-motor data	C	
5			
6			
7			
8			
9			
10			

* A: results usable outside the consortium / B: results usable within the consortium / C: non usable results

1.3 Quantified Data on the dissemination and use of the project results

Items about the dissemination and use of the project results (consolidated numbers)	Currently achieved quantity	Estimated future* quantity
# of product innovations (commercial)		
# of process innovations (commercial)		
# of new services (commercial)		
# of new services (public)		
# of new methods (academic)	6	
# of scientific breakthrough	1	
# of technical standards to which this project has contributed		
# of EU regulations/directives to which this project has contributed		
# of international regulations to which this project has contributed		
# of PhDs generated by the project	1	2
# of grantees/trainees including transnational exchange of personnel	3	

*# = number of ... / * "Future" means expectations within the next 3 years following the end of the project*

1.4. Comment on European Interest

All projects are expected to meet European interests. This section should provide an appraisal of your project in terms of European added value and support to the implementation of European Union policies.

1.4.1. Community added value and contribution to EU policies

a. European dimension of the problem
(The extent to which the project has contributed to solve problems at European level)

The project contributes to the objectives of the Community mainly by creating a joint team of neuroscientists and engineers, to follow a synergistic approach to the creation of both a new tool for the study of the brain functions and on the other hand to the development of a new biologically inspired design technique for artificial systems.

In the long term, we expect the outcome of the project to be really applicable beyond the boundaries of the specific robotic artefact. We might imagine employing robotics to generate even more faithful models of "biological brains". On the other side, perhaps in the long term, a new comprehension and design technique (in this case mimicking biological development) could be applied to a large range of possible artefacts (beyond the gesture recognition task).

From the neuroscience point of view, for instance, robotics could allow testing theories that are otherwise quite difficult to prove (for example, it is very simple to try ablation experiments in robots). Of course, we expect this approach to shed some light on how our brain understands and generates body gestures. Furthermore, we do not see any theoretical difficulty in applying the same approach to modelling other brain functions.

For such ambitious goals, it would not be possible to gather the required competences at the level of a single European country.
.

b. Contribution to developing S&T co-operation at international level. European added value
(Development of critical mass in human and financial terms; combination of complementary expertise and resources available Europe-wide)

One of the goals of this project or, at least one of its consequences, is the strengthening of a multidisciplinary S&T community putting together neuroscientists and IT researchers.

c. Contribution to policy design or implementation
(Contribution to one or more EU policies; RTD connected with standardisation and regulation at Community and/or national levels)

1.4.2. Contribution to Community social objectives

a. Improving the quality of life in the Community :

For what regards the Quality of life, it is worth to note that the possibility to build artefacts capable of communicating with humans in a human-like way could provide access to a wider audience to the services and benefits of the IT society. Once we comprehend how we recognize and communicate (by means of gestures, but not only that), we can build machines, which seamlessly integrate in our daily lives. Machines that would possess knowledge of our motor repertoire and thus could "behave" as if they were in our bodies and thus better understand our requests.
It is far too easy to imagine a system to help people with disabilities by, for instance, interpreting body gesture although perhaps using a different motor repertoire depending on the kind of disability (e.g. hand gesture recognition and interpretation, sign language, etc)

b. Provision of appropriate incentives for monitoring and creating jobs in the Community (including use and development of skills) :

N/A

c. Supporting sustainable development, preserving and/or enhancing the environment (including use/conservation of resources) :

N/A

1.5. Expected project impact (to be filled in by the project coordinator)

<u>Remark:</u> by replying to the following questions, the coordinator is asked to express his best estimation regarding the impact of the project.

Overall Policy Impact[1]

EU Policy Goals	I SCALE OF EXPECTED IMPACT OVER THE NEXT 10 YEARS[2] -1 0 1 2 3	II other Not applicable to project	II other Project Impact too difficult to estimate
1. Improved sustainable economic development and growth, competitiveness Θ	2		
2. Improved employment Θ	0		
3. Improved quality of life and health and safety Θ	2		
4. Improved education Θ	2		
5. Improved preservation and enhancement of the environment Θ	0		
6. Improved scientific and technological quality Θ	2		
7. Regulatory and legislative environment Θ	0		
8. Other _____ Θ			

[1] Coordinator should respond to section I or, if appropriate, to section II. If the project has had no impact, a "0" should be entered in section I. Scores other than zero in section I will prompt a more detailed subquestion on a separate screen. However, you may access in any case the subquestions by clicking on the symbol" Θ "following each main question.

[2] Indication for scale as follows: -1 represents negative impact, 0 no impact, 1 small positive impact, 2 medium positive impact , 3 is a strong positive impact

Indicate your replies below by putting in each box the number corresponding to the score you chose:

1. Economic development and growth, competitiveness	Scale of Expected Impacts over the next 10 years (2)	
	By Project End -1 0 1 2 3	After Project End -1 0 1 2 3
a) Increased Turnover for project participants - national markets	0	
- international markets	0	
b) Increased Productivity for project participants	0	
c) Reduced costs for project participants	0	
d) Improved output quality/high technology content	2	

2. Employment	Scale of Expected Impacts over the next 10 years (2)	
	By Project End -1 0 1 2 3	After Project End -1 0 1 2 3
a) Safeguarding of jobs	0	
b) Net employment growth in projects participants staff	0	
c) Net employment growth in customer and supply chains	0	
d) Net employment growth in the European economy at large	0	

3. Quality of Life and health and safety	Scale of Expected Impacts over the next 10 years (2)	
	By Project End -1 0 1 2 3	After Project End -1 0 1 2 3
a) Improved health care	0	
b) Improved food, nutrition	0	
c) Improved safety (incl. consumers and workers safety)	0	
d) Improved quality of life for the elderly and disabled	2	
e) Improved life expectancy	0	
f) Improved working conditions	2	
g) Improved child care	0	
h) Improved mobility of persons	0	

4. Improved education	Scale of Expected Impacts over the next 10 years (2)	
	By Project End -1 0 1 2 3	After Project End -1 0 1 2 3
a) Improved learning processes including lifelong learning	0	
b) Development of new university curricula	2	

5. Preservation and enhancement of the environment	Scale of Expected Impacts over the next 10 years (2)	
	By Project End -1 0 1 2 3	After Project End -1 0 1 2 3
a) Improved prevention of emissions	0	
b) Improved treatment of emissions	0	
c) Improved preservation of natural resources and cultural heritage	0	
d) Reduced energy consumption	0	

6. S&T quality	Scale of Expected Impacts over the next 10 years (2)	
	By Project End -1 0 1 2 3	After Project End -1 0 1 2 3
a) Production of new knowledge	3	
b) Safeguarding or development of expertise in a research area	2	
c) Acceleration of RTD, transfer or uptake		
d) Enhance skills of RTD staff	2	
e) Transfer expertise/know-how/technology		
f) Improved access to knowledge-based networks		
g) Identifying appropriate partners and expertise		
h) Develop international S&T co-operation	3	
i) Increased gender equality		

7. Regulatory and legislative environment	Scale of Expected Impacts over the next 10 years (2)	
	By Project End -1 0 1 2 3	After Project End -1 0 1 2 3
a) Contribution to EU policy formulation	0	
b) Contribution to EU policy implementation	0	

8. Other (please specify)	Scale of Expected Impacts over the next 10 years (2)	
	By Project End -1 0 1 2 3	After Project End -1 0 1 2 3

I, **project co-ordinator**, confirm the published information contained in this part 1 of the TIP.

Signature: **Name: Giulio Sandini**

Date: Nov. 23rd, 2004. **Organisation: DIST – University of Genova, Italy**

Part 2 Description of each result

A separate part 2 must be completed for each result. This may be done by the partner responsible for the result or by the project co-ordinator.

The part 2 must be consolidated at the consortium level and transmitted to the Commission by the co-ordinator.

PARTS 2 WILL BE DISSEMINATED BY THE COMMISSION

2.1 : Description of the result(s), one form per result

No. & TITLE OF RESULT (same as in table 1.2)

No.	Self-descriptive title of the result
1	A methodology for gesture recognition based on motor representations considering also object affordances.

CONTACT PERSON FOR THIS RESULT

Name	Giulio Sandini
Position	Full Professor
Organisation	Lira Lab, DIST – University of Genova,
Address	Viale F. Causa, 13 - I-16145 Genova, Italy
Telephone	+39 010 353 2779
Fax	+39 010 353 2948
E-mail	sandini@dist.unige.it
URL	http://www.lira.dist.unige.it/projects/mirror/
Specific Result URL	

SUMMARY *(200 words maximum)*

Provide an overview of the result which gives the reader an immediate impression of the nature of the result, its relevance and its potential; Briefly describe the current status/applications of the result (if appropriate) with non confidential information on entities potentially involved.

This is the main result of the entire project. Starting from the inspiration provided by mirror neurons, we investigated the role played by motor information and object affordances in the (goal-oriented) recognition of gestures.

The approach is based on a probabilistic approach whereby the gesture recognition results from both observations regarding the hand as well as the object being manipulated. We have shown that, by performing the analysis in motor terms, we overcome the problem of view dependency as found in purely image-based methods.

In addition this main result encompassed other sub-results (or building blocks) as described in Table 1.2: approaches for obtaining image-based descriptions of the object/hand; a developmental approach to grasping objects, based on findings in developmental psychology and the design and construction of a biological setup for collection visuomotor data.

Even if these results are mainly of scientific interest, it may have an impact in the future for the development of novel human-computer interfaces or robotic assistant devices to provide social assistance to the elderly or children.

Please categorise the result using codes from Annex 1

Subject descriptors	427	129	601	47	84

CURRENT STAGE OF DEVELOPMENT

Please tick one category only

Scientific and/or Technical knowledge (Basic research)	☒
Guidelines, methodologies, technical drawings	☐
Software code	☐
Experimental development stage (laboratory prototype)	☐
Prototype/demonstrator available for testing	☐
Results of demonstration trials available	☐
Other (please specify.):	☐

DOCUMENTATION AND INFORMATION ON THE RESULT

List main information and documentation, stating whether public or confidential.

Documentation type	**Details (Title, ref. number, general description, language)**	**Status: *PU*=Public *CO*=Confidential**
Project final report	PPR3 – Deliverable 1.10	PU

INTELLECTUAL PROPERTY RIGHTS

Type of IPR	**KNOWLEDGE:** **Tick a box and give the corresponding details (reference numbers, etc) if appropriate**					**Pre-existing know-how** **Tick a box and give the corresponding details(reference numbers, etc) if appropriate**	
	Current				**Foreseen**	**Tick**	**Details**
	Tick	**NoP [1)]**	**NoI [2)]**	**Details**	**Tick**		
Patent applied for	☐				☒ X	☐	
Patent granted	☐				☐	☐	
Patent search carried out	☐				☐	☐	
Registered design	☐				☐	☐	
Trademark applications	☐				☐	☐	
Copyrights	☐				☐	☐	
Secret know-how	☐				☐	☐	
Other - please specify :	☐				☐	☐	

1) Number of **P**riority (national) applications/patents
2) Number of **I**nternationally extended applications/patents

MARKET APPLICATION SECTORS

Please describe the possible sectors for application using the NACE classification in Annex 2.

Market application sectors					

2.2. Quantified data about the result

Items (about the results)	**Actual current quantity [a]**	**Estimated (or future) quantity [b]**
Time to application / market (in months from the end of the research project)	10	
Number of (public or private) entities potentially involved in the implementation of the result :		
of which : number of SMEs :		
of which : number of entities in third countries (outside EU) :		
Targeted user audience: # of reachable people		
# of S&T publications (referenced publications only)	6	
# of publications addressing general public (e.g. CD-ROMs, WEB sites)	2	
# of publications addressing decision takers / public authorities / etc.		
Visibility for the general public	Yes / No	

[a] *Actual current quantity = the number of items already achieved to date.*
[b] *Estimated quantity = estimation of the quantity of the corresponding item or the number of items that you foresee to achieve within the next 3 years.*

2.3. Further collaboration, dissemination and use of the result

(Optional; to be completed if partner is willing to set up new collaborations, and seeking dissemination support from the CORDIS services.)

COLLABORATIONS SOUGHT

Please tick appropriate boxes (🗐 corresponding to your needs.

R&D	Further research or development	☒	**FIN**	Financial support	☐
LIC	Licence agreement	☐	**VC**	Venture capital/spin-off funding	☐
MAN	Manufacturing agreement	☐	**PPP**	Private-public partnership	☐
MKT	Marketing agreement/Franchising	☐	**INFO**	Information exchange	☐
JV	Joint venture	☐	**CONS**	Available for consultancy	☐
			Other	(please specify)	☐

POTENTIAL OFFERED FOR FURTHER DISSEMINATION AND USE

Please, clearly describe your input, the value and interest of the applications and the dissemination and use opportunities that you can offer to your potential partner.

PROFILE OF ADDITIONAL PARTNER(S) FOR FURTHER DISSEMINATION AND USE

Please, clearly describe the profile and the expected input from the external partner(s).

I confirm the information contained in part 2 of this Technological Implementation Plan and I authorise its dissemination to assist this search for collaboration.

Signature: **Name:**

Date: **Organisation:**

Part 3 Description of the intentions by each partner

This part 3 must be completed by each partner who is essential for the dissemination and use (i.e. result owners and/or major project contributors and/or major dissemination and use contributors). Each will detail its own use and dissemination intentions concerning the result(s) they are involved with. This description must be made result by result.

These different parts may be transmitted to the Commission either assembled at the consortium level, or individually by each partner to safeguard confidential matters if necessary (through any appropriate media). Obviously, when all partners are implementing a single dissemination and use scheme all together, a single part 3 is needed.

PARTS 3 WILL ALWAYS BE KEPT CONFIDENTIAL BY THE COMMISSION

3.1 : Description of the use and the dissemination of result(s), partner per partner

MANDATORY INFORMATION :

CONTRACT NUMBER :	
PARTNER's NAME :	IST - University of Genova (Prof. Giulio Sandini, Dr. Giorgio Metta) Department of Biomedical Sciences – University of Ferrara (Prof. Luciano Fadiga) Department of Psychology – University of Uppsala (Prof. Claes von Hofsten) Instituto Superior Técnico – Computer Vision Lab – Lisbon (Prof. José Santos-Victor

CONTACT PERSON(S):

Name	
Position/Title	
Organisation	
Address	
Telephone	
Fax	
E-mail	

No, TITLE AND BRIEF DESCRIPTION OF MAIN RESULT(S)

1	Starting from the inspiration of mirror neurons, we investigated the role played by motor information and object affordances for (goal-oriented) recognizing gestures performed by a demonstrator, either biological or artificial. The approach is based on a probabilistic approach whereby the gesture recognition results from both observations regarding the hand as well as the object being manipulated. We have shown that, by performing the analysis in motor terms, we overcome the problem of view dependency as found in purely image-based methods.
2	
3	
4	
5	

FOR EACH MAIN RESULT:

TIMETABLE OF THE USE AND DISSEMINATION ACTIVITIES WITHIN THE NEXT 3 YEARS AFTER THE END OF THE PROJECT

Mention the use and dissemination related activities, the main associated partners, the related milestones and give an indicative timescale		
Activity	**Brief description of the activity, including main milestones and deliverables (and how it relates to data in sections 2.2 and 3.2).**	**Timescale (months)**

FORESEEN COLLABORATIONS WITH OTHER ENTITIES

Please tick appropriate boxes (☑) corresponding to your most probable follow-up.

R&D	Further research or development	☒	**FIN**	Financial support	☐
LIC	Licence agreement	☐	**VC**	Venture capital/spin-off funding	☐
MAN	Manufacturing agreement	☐	**PPP**	Private-public partnership	☐
MKT	Marketing agreement/Franchising	☐	**INFO**	Information exchange, training	☐
JV	Joint venture	☐	**CONS**	Available for consultancy	☐
			Other	(please specify)	☐

3.2 : Quantified data for each partner's main result

Items	Currently achieved quantity [a]	Estimated future quantity [b]
Economic impacts (in EURO)		
# of licenses issued (within EU)		
# of licenses issued (outside EU)		
Total value of licenses (in EURO)		
# of entrepreneurial actions (start-up company, joint ventures…)		
# of direct jobs created [c]		
# of direct jobs safeguarded [c]		
# of direct jobs lost		

[a] *The added value or the number of items already achieved to date.*
[b] *Estimated quantity = estimation of the quantity of the corresponding item or the number of items that you foresee to achieve in the future (i.e. expectations within the next 3 years following the end of the project).*
[c] *"Direct jobs" means jobs within the partner involved. Research posts are to be excluded from the jobs calculation*
 # = number of ...

I confirm the information contained in part 3 of this Technological Implementation Plan and I certify that these are our exploitation intentions

Signature: **Name:**

Date: