EUROPEAN COMMISSION

Community Research

REVIEW REPORT

FP6-IST-34107

ARTTS

Action Recognition and Tracking based on Time-of-flight Sensors

Project period 12 to 24

Contract start date:	1st October 2006
Contract end date:	30th September 2009
Review date:	16 December 2008
Review location:	Lubeck, Germany

Project Officer:	Philippe Gelin
Reviewers:	Vaclav Hlavac
	Andrew Stoddart

Report version:
Revision History 1.0, 17/11/2008

1. Overall Assessment

1.1. Executive Summary

The project is making good progress towards the goals set out in the annex. The consortium has satisfactorily implemented the recommendations of the 2007 review. There has been a delay of approximately 6 months in the development of the TOF sensor, but the consortium has successfully adapted the project plan to cope with the delay. All partners continued work without significant interruption and it is expected that the delay will not diminish the project outcome significantly. The project is contributing to the state of the art, notably in the area of algorithms and sensor development. In line with the annex, it is anticipated that two public software toolboxes will deliver ARTTS technologies to the wider R&D community.

In year 2 the consortium has shown early results leading towards applications of the technology. Key work in this area remains to be completed in year 3. It is hard to judge the economic relevance of TOF sensors and their wider applicability, but for now the field seems able to sustain four small companies worldwide.

ARTTS organized a workshop at the CVPR conference in June 2008. The workshop was a landmark dissemination event, and has led to substantial public awareness about TOF sensors, the ARTTS project and ARTTS research output. The consortium has created a database of TOF images; this will be a valuable resource to the research community but they need to be made aware of it.

It is recommended that the project continue.

1.2. Review Result

It was observed that the project team is more homogeneous than in Year 1.

The reviewers agree with the project coordinator that the main technical highlights of the Year 2 were:

- Fabrication of new image sensor and controller chip (the latter replaces FPGA, ADC and RAMs). Additional minor delays have been mitigated.
- The first TOF camera on has been delivered on a test board with illumination and sensor capable of modulation frequencies up to 80 MHz.
- New theoretical model for multiple reflections to improve range map. More work is required to fully exploit the apparent potential of these ideas.
- Algorithms based on the shading constraint have been shown to yield substantially improved range data. The method has considerable potential, however further development is needed and it would be good to see it properly exploited.
- Encouraging results based on optimal features from sparse coding have been presented.
- Preliminary results on gait analysis using articulated human models were shown. This will need further effort to be practically used.
- Person tracking in smart rooms was demonstrated with a partner outside of ARTTS consortium (after-effect of NoE Similar).
- The first SMI multimodal demonstrator was shown at the review, and the detailed design for second demonstrator has been completed.
- SMI has further investigated potential applications for the multimodal prototype.

- The consortium has generated an extensive TOF video and still image database. This database is currently not well known to the community. The consortium should consider ways to improve awareness; possibly organizing a competition on this data could help?
- The consortium has had organized a landmark dissemination event, the TOF-CV workshop at CVPR 2008, and also successfully exhibited at ICT 2008.

1.3. Main Conclusions

The overall review result is that the project performs well and should continue. There was fruitful discussion at the review. The review panel concluded that the project progress can be classified as acceptable to excellent.

2. Objectives and Work plan

There has been some well documented slippage related to sensor development delay, but it seems to have been mitigated satisfactorily. In general the project is proceeding according to the plan in Annex I.

2.1. Future Work

Quite a lot of activities are expected to come together in the 3rd year. The new hardware will become available and there will be a relatively concentrated time to evaluate the sensor and test the signal processing techniques.

The multimodal prototype will appear in the 3rd year and there will be very limited time to obtain results from it.

The application scenarios will be further addressed in the remaining time. The potential scenarios include monitoring a sleeping patient and physical rehabilitation by exercises. SMI proposes to gather datasets for further evaluation and also to gather more information about the application domain.

3. Resources

The deviations with respect to the planned resources, mainly the increase of work effort from CSEM, was induced by the delay of the chip development (already foreseen in last review) and the required additional effort to keep the project in track. It is deemed necessary to ensure the objectives of the project.

The reported resources have been utilised for achieving the progress and in a manner consistent with the principle of economy, efficiency and effectiveness.

The effort spent is commensurate with the work carried out and results achieved so far.

The related major cost items were appropriate and required for the success of the project.

On the question raised on the very large numbers of people involved in UPB (17 people) with respect to the small amount of effort (29 PM) the partner successfully answered that most of the participants were used in a very short time based for very systematic work.

The large amount of DTU travel expenses was explained by their co-organisation of the CVPR workshop.

Due to the imposed delay and reshuffling of tasks, the consortium efficiently redistributed the resources. It is however foreseeable that further redistribution will be necessary.

While CSEM has consumed the main part of their budget (87%), it has been acknowledged that they have sufficient resources to complete the project as their most intensive participation will be finalised by early 2009 and they will only be involved in supporting, maintenance and documentation thereafter.

4. Implementation of the Project

4.1. General

In general, the project is well managed and the reports are clear and coherent. The coordinator has coped with delays. Using the testbed as an evaluation platform was a good idea and was well implemented.

In the previous review report it was mentioned “it may be that in Year 2 the consortium should intensify physical meetings so that the algorithm development is maximally focussed and integrated across the consortium”. An additional full PCC meeting might have further increased project integration?

4.2. Scientific and Technical

- The consortium is composed of complementary groups and the necessary integration work seems to have taken place, leading to high quality technical work.
- Some partners (UPB, UL) have produced some exceptional academic results. However, more efforts are needed to make these results practically applicable.
- The activities towards actual applications could have been more intensive and better thought out. The demonstration of action recognition has been limited.
- The consortium created knowledge and software, some of which should be provided to the community according to the Annex I. This work remains to be done, i.e., algorithms for range data preprocessing and analysis should be put into one toolbox, algorithms for activity analysis from range images video into the second toolbox.
- As the project matures, intellectual property rights issues should be carefully considered. Patenting is expected to be covered mainly by CSEM (or MESA).

4.3. Administrative and Financial

As presented during the review process, MESA, the CSEM start-up, is willing to actively participate to the project. This would ensure take-up of the project results. This however may imply a modification of the legal and financial basis of the contract as well as its annex.

5. Use and Dissemination of Foreground

5.1. Exploitable Knowledge and its Use

It is likely that CSEM & SMI will develop exploitable technology in the form of prototypes. There is no mention of patenting so far, although the activity report suggests that more attention will be paid to IP protection in year 3.

The licensing plans for academic partners' IP remain unclear.

The move of technology from CSEM to MESA is seen as an important step towards exploitation of project results. It is acknowledged that the legal aspects of this transfer has not been easy to negotiate between the partners and MESA, but was eventually achieved.

5.2. Dissemination of knowledge

As far as conference publications are concerned, the consortium dissemination is outstanding.

The website is satisfactory, although there are no listed ARTTS news items. Some photos or video from the IST demo in Lyon on the ARTTS website would be good publicity. The website front page could be much improved in order to address the general public. There needs to be a more accessible summary of what the project is about.

The consortium organisation of the Time-of-Flight Workshop at the CVPR conference has been a very valuable effort as it allowed the ARRTS project to take a leading position in the community. This was the first meeting attended by all the 3D TOF system vendors.

6. Other Issues (if applicable)

None.

7. Recommendations

The ARTTS consortium has made a number of technical advances and these have been duly published in academic conferences. The consortium is invited to consider way of 'marketing' these advances by producing less technical material that highlights practical benefits of the research work. In the same vein, research work should be carefully evaluated and practical results translated into a more 'user centred' perspective. This could find its way into a white paper that could be used at trade shows or on the website. Finally, if the consortium were to

select and polish a presentable demonstrator, this could be used to generate media interest in a final press release.

Following the review process, the following recommendations are issued:

Recommendation 1: The consortium should concentrate academic efforts to enhance precision using the shading constraint, refine the method, evaluate the performance and explore it practically.

Recommendation 2: The development of the Falie model for improving distance measurement should be pursued and implemented within the final demonstrator.

Recommendation 3: The public 3D-TOF video and image database needs promotion within the R&D community. The possibility of initiating a competition of algorithms on the data from the database should be considered.

8. Annexes

I Deliverables

DELIVERABLES LIST STATUS			
No.	**Title**	**Status***	**Remark**
D4	**TOF database**	**Approved**	
	Management Report	**Approved**	
	Activity Report	**Approved**	

* Status: Approved in full
Approved in part
Approved subject to the conditions listed under remarks
Rejected.

II Review Agenda

ARTTS Review Meeting
Lübeck, December 17, 2008
Agenda

09:30 – 09:45	Private meeting of reviewers and PO
09:45 – 10:30	Project management (Coordinator) Overview of the project status Detailed work progress Use of resources Next six months work plan
10:30 – 10:45	*Coffee break*
10:45 – 11:05	TOF signal processing (WP2, LAPI)
11:05 – 11:30	Model-based pose and person tracking (WP3, DTU)
11:30 – 11:45	Feature extraction and face detection (WP2, WP3, UL)
11:45 – 12:00	TOF database, action recognition and tracking (WP4, UL)
12:00 – 13:00	*Lunch*
13:00 – 13:30	TOF camera (WP5, CSEM)
13:30 – 14:00	Multimodal demonstrator camera (WP6, SMI)
14:00 – 14:20	Dissemination and use plan
14:20 – 15:00	Demonstrations
15:00 – 15:30	*Coffee break*
15:30 – 16:00	Financial Assessment (PO)
16:00 – 16:30	Questions from reviewers
16:30 – 16:45	Reviewers' private meeting
16:45 – 17:00	Reviewers' comments

Location

Universität zu Lübeck
Institut für Neuro- und Bioinformatik
Haus 64, EG, Raum 5657 (Dijkstra)
Ratzeburger Allee 160
23562 Lübeck

III Summary of review Organisation and Logistics

- Review process (rolling review, on the premises of a contractor, etc.).
- Review timing, location, attendees.
- Comments on the review process: timely reception of necessary documentation, had the reviewers enough time to study the documentation?
- See list of participants, list of reports and deliverables, agenda (appended to this report).

IV List of participants contributing to the review

European Commission
Philippe Gelin, Project Officer
Reviewers
Vaclav Hlavac
Andrew Stoddart
Technical University of Denmark
Rasmus Larsen
Rasmus Ramsbøl Jensen
Sigurjon A Gudmunsson
University Politehnica Bucuresti
Vasile Buzuloiu
Mihai Ciuc
Dragos Falie
Swiss Center for Electronics and Microtechnology
Claus Urban
Christiane Gimkiewicz
SensoMotoric Instruments GmbH
Oliver Kersting
Jürgen Wieser
University of Lübeck
Erhardt Barth
Martin Haker
Martin Böhme
Thomas Martinetz (part time)
Annette Dünninger

V. Report(s) from previous review or pre-review

Luxembourg, 10th December 2007.
DG Infso/E1/PhG D(2006)
ADONIS 10/12/07:851623

Draft report on the 1st ARTTS Periodic Review.

Berlin 4th December 2007.

The reviewers and I were overall satisfied with the quality and quantity of work achieved this year. Whilst numerous examples of the progress were provided and should be duly acknowledged, this document, as draft report, focuses on the detected weakness of the project, in order for the consortium to be able to implement immediately the requested modification and thus, not lose any momentum.

The scientific work of the project has been appreciated and is in line with the work plan. However, the reviewers and I would have preferred being presented with better established camera measurements and evaluation methodologies. The coordinator is therefore requested to revise the WP7 and implement measurement campaigns on a well established and agreed plateform. This should cover the needs for all work packages.

As expressed during the review, the development of the new chip has been delayed by approximately 3 months. The coordinator is requested to revise the work plan and the other work package interconnections in order to take into account this chip availability delay.

The definition of the multimodal prototype is to be maintained on month 18 and should have back-up plan in case of further delay of the chip availability. I also request deliverable D15 to be delivered to the Commission.

In term of dissemination, the scientific dissemination effort has been appreciated. However, in light of the industrialisation potentiality of the project, the consortium is requested to further elaborate the dissemination plan, including the participation to trade shows.

(signed)
Philippe Gelin
Project Officer

VI. Report(s) from previous review or pre-review

PRIORITY 2
INFORMATION SOCIETY TECHNOLOGIES (IST)

REVIEW REPORT

ARTTS – FP6 - 034107

Project full title: Action Recognition and Tracking based on Time-of-flight Sensors

1st Review covering project month 1 to 12, from 1st October 2006 to 30th September 2007

Contract start date:	1st October 2006
Contract end date:	30th September 2009
Review date:	11 December 2007
Review location:	Berlin

Project Officer:	Philippe Gelin
Reviewers:	Vaclav Hlavac Andrew Stoddart
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9. EXECUTIVE SUMMARY

ARTTS is a 3 year STREP with a budget of €1.8M. The objectives of the project are to:

- Develop an improved Time-of-flight (TOF) camera.
- Improve the low level processing of the raw data for enhanced range and intensity data.
- Develop exemplar applications that can showcase the technology
- Develop a multimodal prototype with TOF and high resolution video.

This review covers the first year of the project. The review meeting took place in Berlin as planned.
Overall the project has been functioning well and is proceeding according to plan. Overall the scientific quality is high. The quality of project deliverables is high. The smaller problems were pointed to by the review. However, they do not undermine the very good results of the project in the first year. The project resources and major costs were appropriate and economic. There are no significant cost issues.
The principal recommendations relate to keeping the TOF prototype and multimodal sensor on track. The 1st year review find a few items which deserve additional attention.
The implementation plan for the next period is accepted.

➢ Organisation and Logistics

The review meeting was well organized and the presentations were of a high quality.
The reports and deliverables have been delivered on time with the exception of D12 "Specifications of the multimodal prototype". The apparent reason for the delay relates to the physical specifications for the TOF sensor. This is not seen as a serious problem, although it would be good to see that deliverable produced in the coming months. However it does highlight a lack of clarity on what the specific benefits that will derive from the multimodal sensor and the target applications that the consortium will address using the multimodal sensor.
There has also been some slippage on the production of the new TOF prototype. The delay was explained at the review. This is understandable given the difficulties of producing an entirely new prototype with some novel technologies. The downside is that most of the algorithm development will be based on the SR3000, and further slippage will mean that only a few months of the final year will be available for algorithm development tailored to the new sensor.

➢ Assessment of Objectives

The objectives of the project are clear and concise. If implemented they will give TOF technology in Europe a big boost.

It seems likely that TOF technology will progress into market and this is underlined by the formation of a spin-off company, MESA by partner CSEM. In the USA, Canesta is the leading TOF sensor vendor. The robustness and reliability of the sensor will need to progress if it is to be adopted in a wide range of applications.

➢ Workplan and Resources

While there are some minor deviations in resourcing and expenditure, overall resources are being deployed consistent with the Annex. Good progress is being made on all workpackages and the new sensor is eagerly awaited!
SMI have deployed 16 PM out of a planned 68. Their PM are distributed among quite a large number of staff. It may be advantageous for work at SMI to be concentrated on fewer people, in order to generate more progress on the multimodal demonstrator in the 2nd year.
Promising work has already been completed in WP2 on improving and characterizing the accuracy of the TOF sensor. In the course of the review there was a wider discussion on sensor characterization, and it is felt that a wider range of scenes could be used during sensor characterization. One of the objectives of the project is to find methodology for validating measurements provided by the TOF sensor and designing algorithms for sensor data preprocessing. The experimental evaluation was also planned. The first year results of validation efforts were demonstrated at the review. The reviewers observed that the verification methodology could be improved for both precision validations and properties of preprocessing methods. The assumptions of the studied algorithms and methods should be explicitly stated. For instance, the suggested preprocessing methods could miss thin objects in the 3D scene because of the regularization involved. Also, it is recommended to perform experiments on scenes for which ground truth is available. Such scenes could include objects that challenge assumptions in the signal processing algorithms. Validation experiment should also allow to compare the results on both hardware and software side with the state-of-the-art and competitors. There is clearly scope to expand and further systematize the sensor characterization.

At the same time the sensor characterization should lead to a technical specification that can easily be explained to a moderately technical person – for example a project reviewer. Such a specification should ideally encompass questions such operating performance in sunlight, highly textured objects and in the presence of an identical sensor.

➢ Future Work

The project objectives remain valid and achievable. A significant risk factor would be further slippage of the hardware TOF prototype. At present the budget is expected to be adequate for the work planned.
Demonstrators seem to be progressing well, and the reviewers look forward the future demos. The scientific content of this work ranges from satisfactory to excellent.
The important part of project goals is to find application scenarios for the new TOF sensor the development of which is approximately from one third supported by the EU taxpayers. The reviewers recommend that the ARTTS project consortium spends more effort on application scenarios. After collecting ideas and initial specifications, it is suggested to work more intensively on fewer studies. The role of the partner SMI should be more pronounced in these efforts.

➢ Project Management

The coordinator UL-INB is providing effective management in this project. All partners appear committed to the project.

Thus far the consortium has met twice, and it may be that in year 2 the consortium should intensify physical meetings so that the algorithm development is maximally focussed and integrated across the consortium.
The coordinator should review the plan in the light of slippage on the hardware prototype, to ensure that the overall project remains on track.

➢ Use and Dissemination (Art.II.10.3, Art.II.34)

The dissemination of knowledge in the project has so far been very good. A number of papers have been published by many partners. There has already been one workshop and there will be a second workshop at CVPR 2008. This will provide high profile dissemination within the computer vision community.

The project exploitation will be a success if the TOF prototype leads to wider commercialization. The plan and route to commercialisation of ARTTS project outcomes was difficult to assess. The split between companies MESA and CSEM made the understanding more complicated. Reviewers understand that it is the new development and the project consortium needs time to adapt to it. Nevertheless, it would be of interest to hear the consortium position on this issue at the next project review.

The route to exploitation within ARTTS would be enhanced by two additional things. Firstly it would be good if the demonstrators developed within ARTTS could be shown at trade shows or technology fairs where they could be seen by a wide range of people from industry. Secondly it would be good to get a sense of marketing information filtering into ARTTS from this kind of exposure. For example towards the end of the project some demonstrators might be refined and targeted at markets that are likely to take up the technology.

It may be possible to exploit the relationship of CSEM and MESA to improve the two-way flow of information between the technology work and potential markets? At present it seems as if CSEM is one step removed from marketing activity in this field. The reviewers believe that closer (or more visible) ties would benefit the consortium.

The existing demonstrators are very promising in showcasing the TOF technology. Progress has been made in scientific content of these demonstrators. It would be good to see the demonstrators developed and refined within ARTTS. For example once nose detection has been achieved some robust least squares fitting could refine position estimates of the nose. In this way the maximum accuracy could be achieved, thus showing the TOF technology to maximum advantage.

It would be interesting to see some discussion in D7, the final dissemination report, of exploitation prospects in high volume low cost applications vs low volume high cost applications? In the early phases of new technology it is sometimes easier to operate in high cost applications.

There has been relatively little analysis of the exploitation potential of the multimodal prototype and it would be good to see the future development of this shaped by specific market opportunities.

➢ Recommendations

Recommendation 1: The development of the new chip has been delayed by approximately 3 months. The coordinator is requested to revise the work plan and the other work packaged interconnections in order to take into account this chip availability delay.
Recommendation 2: Deliverable 15 should be maintained on month 18 as planned and delivered to the Commission.
Recommendation 3: The consortium is requested to further elaborate the dissemination plan to take account of the points relating to trade shows and exploitation in section 7 above.
Recommendation 4: The coordinator is requested to revise the Workplan and dependencies to take account of the 3 month delay on the hardware prototype.
Recommendation 5: The sensor characterization work should be reviewed with a view to a more systematic approach and a wider set of input data. It is suggested to revise the WP7 and implement measurement campaigns on a well established and agreed platform. This should cover the needs for all work packages.

➢ Review conclusion

Overall this is a well run project and all partners are fully involved. It is recommended to continue funding of this project.

Reviewer's signatures:

Vaclav Hlavac
Date:

Andrew Stoddart
Date:

➢ APPENDIX - Status of project reports and deliverables

List of all project reports and deliverables as described in the contract and in Annex I. Fill in comments on the deliverables presented at the review meeting. If the work performed is delayed or missing, include the revised date (if known) within the project plan. A detailed discussion for each deliverable and recommendations should be formulated in section 4.

Del. No.	Deliverable name	person-months	Nature	Dissemination level	Due date	Proposed Status	Remarks
D1	Specifications new 3D-camera	9,2	R	RE	6	Accepted	
D2	Dissemination Plan	3	R	CO	6	Accepted	
D3	Periodic progress reports	17	R	CO	12	Accepted	
D4	3D TOF database	5	P	PU	24		
D5	Final progress report	13	R	CO	36		
D6	Final report and documentation	10	R	CO	36		
D7	Dissemination Report	1	R	CO	36		

Del. No.	Deliverable name	person-months	Nature	Dissemination level	Due date	Proposed Status	Remarks
D8	Presentation of prototypes	14,7	D	PU	36		
D9	Project website	8	O	PU	2	Accepted	
D10	Algorithms for pre-processing and denoising	2	O	RE	12	Accepted	See review report for more detailed comments
D11	Design of imager and controller chip	5	R	RE	12	Accepted	
D12	Specifications multimodal prototype	6	R	RE	12	Delayed	Due to sensor delay. Expected in Month 15.
D13	Algorithms for face finding	3	O	RE	18		
D14	Design of improved 3D-TOF camera	5	R	RE	18		
D15	Design multimodal prototype	6	R	RE	18		
D16	Algorithms for feature extraction	2	O	RE	24		
D17	Algorithms for object tracking	3	O	RE	24		
D18	Feature evaluation	4	R	RE	24		
D19	Classifiers evaluation	4	R	RE	24		
D20	Miniaturized, low-power 3D-camera	5	P	RE	24		
D21	First evaluation report	7	R	CO	24		
D22	SP toolbox	2	D	RE	36		
D23	OT toolbox	3	D	RE	36		
D24	AR toolbox	4	D	RE	36		
D25	Multimodal prototype	6	P	RE	36		
D26	Final evaluation report	7	R	CO	36		