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MODULINSPEX

Contract NMP2-CT2005- 016882

STREP Project 016882 MODULINSPEX

**Modular High Speed X-ray Detection and Sorting Systems for Production Process
Control and Packaging Quality Control**

EXECUTIVE SUMMARY

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Organisation name of lead contractor for this report: InnospeXion ApS

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Project Completion Date 30th April 2008**

Partners:

InnospeXion ApS (lead partner)
AJAT OY
Cavendish Instruments Ltd
ZENON SA
Detectronic A/S
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EXECUTIVE SUMMARY (Publishable)

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OVERVIEW

The **MODULINSPEX** project concerned the development of a **modular concept** for design, implementation and use of innovative state-of-the-art X-ray based inspection systems for industrial manufacturing. The basic objectives concerns (i) the **design conceptual approach** development, as an entirety, involving **demand-driven specifications**, hardware, software, documentation, user interface, data analysis packages, etc., and (ii) the implementation to this modular approach of **more sensitive, fast and high resolution detection technology** developed within the project.

The projects unites a **multidisciplinary** but small consortium where each partner contributed with specific know-how relative to the modular thinking.

The efforts have resulted in the elaboration, construction, testing and performance demonstration of **four demonstrator systems**, including the related hardware developed within the project (innovative detectors, control hardware, new design philosophy, etc.). The results obtained have shown the **viability of the novel detector types** even at high speed (up to 30 m/min), with high resolution and with sufficient sensitivity for low energy imaging, hence providing for a new and large market for X-ray inspection technologies. The innovation level relative to industrial demands has been important, and the success of the project is testified by the **Innovation Award 2007** presented by His Royal Highness, Prince Joachim of Denmark at the FoodPharmaTech exhibition for the most innovative and exploitable product (awarded to the **MCIS system**).



Presentation of the Innovation Award 2007 towards the MCIS system by His Royal Highness Prince Joachim of Denmark at the FoodPharmaTech2007 exhibition

PROJECT CONSORTIUM

The project involves 5 SME's:

InnospeXion ApS (DK; Coordinator), AJAT OY (FI), Cavendish Instruments Ltd (UK), ZENON SA (GR) and Detectronic A/S (DK). The Latvian institute of computer science and electronics (IECS) is the only research organisation involved.

PROJECT WORK SUB-DIVISION

The project was divided into 6 technical work packages comprising (main partners in parentheses): (1) specifications (INOSPX; ALL), (2) detectors (AJAT), (3) manipulation (DTIC & ZENON), (4) radiation (INOSPX, DTIC), (5) software & control (CAVIT; ALL), (6) data analysis & image processing (IECS, INOSPX), (7) Testing and demonstration (ALL), and (8) Co-ordination (INOSPX).

OVERALL PROJECT PROGRESS

The project has made significant progress beyond the state-of-the-art, with a vast amount of concrete achievements, i.e. in the form of demonstrators, hard- and software. With the exception of a late deliverable concerning the 300 mm CdTe CMOS TDI detector, all deliverables are completed and the milestones have been achieved. The project also succeeded in accomplishing a 4th demonstrator that was not foreseen in the work programme; - this demonstrator ended up being very useful for the electronic board inspection and was finally realised as a very modular concept both regarding hard- and software.

Based upon initial specifications, elaborated taking into account industrial demands and solutions as offered by competing companies, the project developments were initiated. The X-ray hardware was selected and design modules elaborated and a simple expert system for the selection of matching hardware to a specific inspection task was set-up.

For the different X-ray sources, software modules for control were developed. A specific X-ray controller was developed for RS232 control of sealed X-ray sources, mini- and microfocus types. The controller is one of the commercially exploited results, receiving attention for design, function and costs.

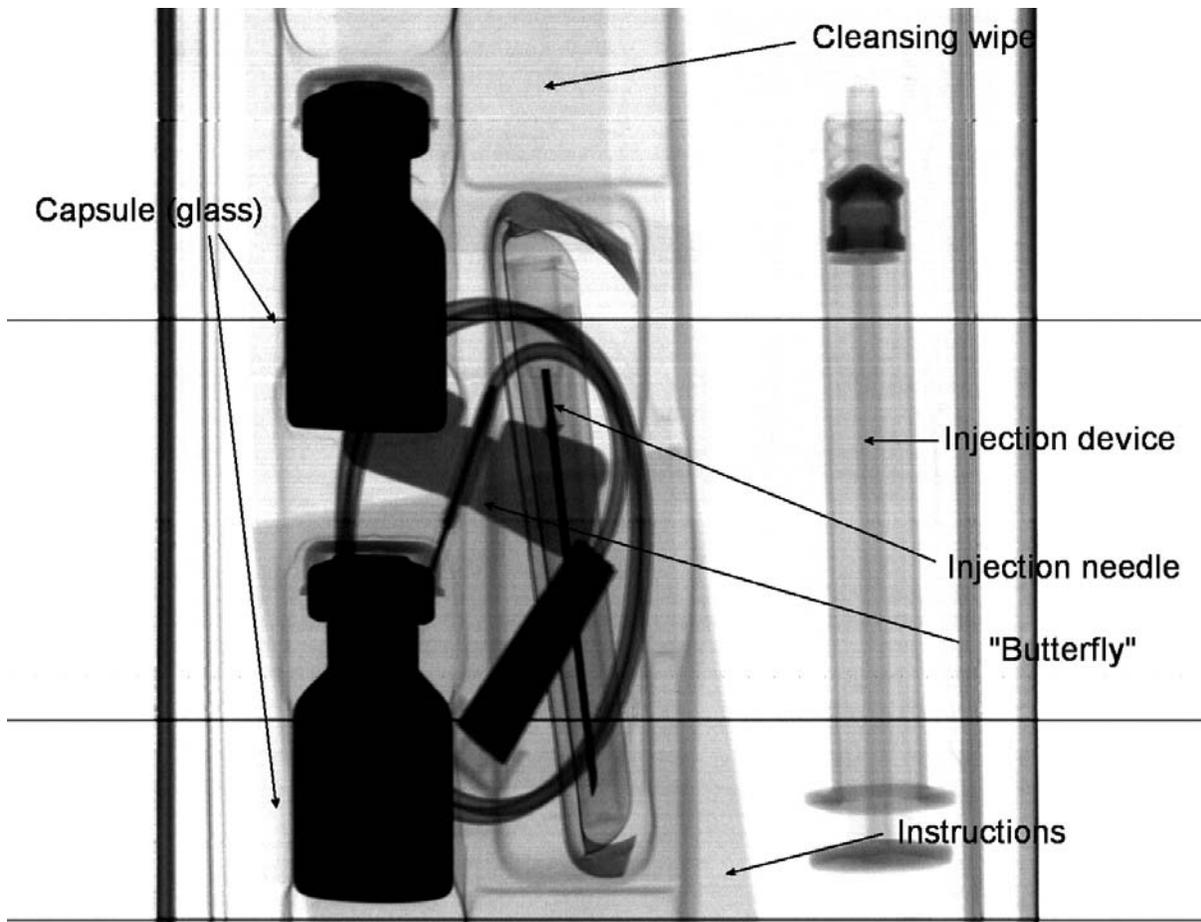
Various state-of-the-art detectors were selected as modules and software for their control was developed. This concerns e.g. standard X-ray image intensifiers for stationary imaging and linear arrays in commercial usage. The main efforts on detection technology were attributed to the development of new CdTe CMOS detectors, particularly linear arrays operating in time-delay integration (TDI) mode. This work was initiated with the supply of an area imaging device (implemented into the SMIS system; small manipulator-based inspection system), and a 150 mm TDI mode linear detector was supplied after the 2nd year. This detector was tested and subsequently implemented to the so-named MCIS system (medium conveyor inspection system). The technology was integrated with other soft- and hardware and ultimately received the Innovation Award owing to its extreme performance.

In addition to the 150 mm array, a 300 mm long linear array operating in TDI mode was aimed for integration as a module to the conveyor prototype systems (the MCIS or the CTIS). The work encountered a number of difficulties, leading to substantial delay and the unit was only completed by the end of the project. Instead, the CTIS (conveyor – tube inspection system) was fitted with a commercial array for the assessments.

A 4th demonstrator was aimed at following re-structuring of the work. This demonstrator includes a modular manipulator suitable for the inspection of electronics. The system hardware is based on state-of-the-art technology, making the system affordable, flexible and tailored.

The modular concept to a large extent involves the integration of the hardware modules of the system(s) to an overall modular software architecture. The concept is based on that the exchange of a hardware components requires a minimum effort of the software adjustments. This is novel thinking relative to present systems. The software also integrates a number of specific detection algorithms developed within the project for various tasks, e.g. bone detection in fish products, metal rings and other impurities in meat products, etc.

The conception of an X-ray system as a modular entity is innovative and meets the markets demands for modularisation in many aspects of manufacturing. The project results are to a high degree market-oriented, and assessments have included a number of application areas where the novel technology can provide a fast taking-up of the technology. The work has been focused on dissemination and demonstrations of the concept towards the public. Demonstrations have been conducted specifically into the food packaging and food inspection sector, where significant improvement relative to the present state of the art is obvious. Other application areas are in the Pharma sector, and a number of industrial inspection tasks involving light and/or thin materials.



MCIS acquired image at 20m/min of a pharmaceutical dosage package. Note the clear definition of the instruction leaflet and the cleansing wipe, details that would have been undetected by ordinary X-ray systems.

OVERVIEW OF PROJECT MAIN ACHIEVEMENTS

CONCEPTS

Modular design concept

SYSTEMS

CTIS

MCIS

SMIS

4th DEMONSTRATOR – Electronics

SYSTEM MAIN COMPONENTS

150 mm CdTe TDI mode linear array

300 mm CdTe TDI mode linear array

X-ray controller; IXC

Manipulator (s)

SOFTWARE & METHODOLOGY

Image processing & analysis software

Detector modules

Source modules

Conveyor modules

Manipulator modules

Overall user interface

Overall control interface

DISSEMINATION ACTIONS

Fairs & exhibitions (4)

Demonstrator(s) (many)

Articles, conference presentations (1)

News advertisements (many)

Poster(s) (2)

Innovation Award 2007 (1)

COMMERCIAL RESULTS

Sales of MCIS – derived systems (3)

Offers made on MCIS technology (many)

Sales of CTIS – derived systems (0)

Offers made on CTIS technology (1)

Sales of SMIS-derived systems (0)

Offers made on SMIS technology (3)

Sales of 4th Demonstrator system (0)

Offers made on 4th Demonstrator technology (1)

Sales of CdTe TDI technology detectors (?)

Offers made on CdTe TDI technology detectors (?)

Sales of manipulators – 4th demonstrator (0)

Offers on manipulators – 4th demonstrator (0)

Sales of IXC controller (0)

Offers made on IXC controller (10)

Sales of software licences (0)

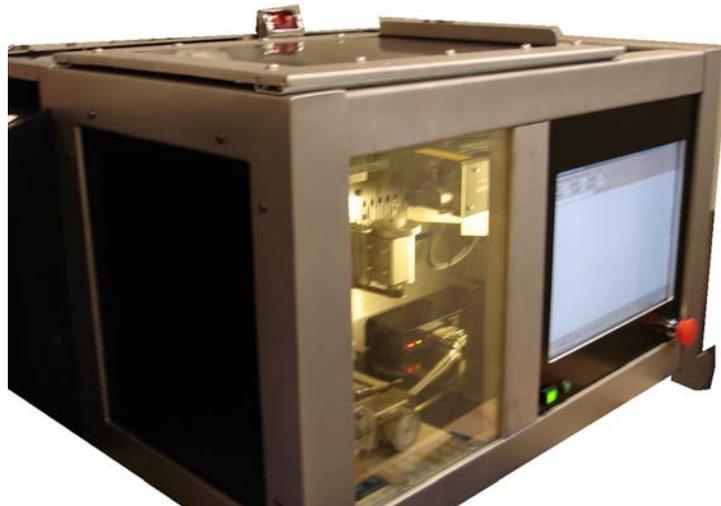
Offers made on software licences (1)

Design

- An application-based selection software has been developed to enable the selection of system modules to suit a particular application
- The modular concept has been developed and lead to definition and implementation of a number of hardware components as modules including related software
- The modular concept has been documented by four demonstrators, all of industrial standard

SMIS

- The SMIS was completed at an early stage, allowing it to rigorously tested concerning robustness and function.
- The SMIS integrates an INOSPX supplied manipulator instead of the targeted ZENON manipulator.
- The SMIS has been on display at a number of exhibitions, is eye-catching and provides real-time X-ray images of extreme quality
- A full modular software is implemented
- The SMIS final exhibitions involved its modularization in the area of can seam inspection (MetPack2008). This was a large success.



The SMIS is an ultra compact and robust high performance X-ray system



The MCIS hardware modules fitted into a cabinet, featuring robustness, ease of cleaning and improved integration of cooling and peripheral I/O

MCIS

- The MCIS is an innovative system tailored in particular for low energy imaging to an industrial standard
- The MCIS provides world class images, even at high conveyor speed
- The MCIS enables the inspection of light and thin products, but also of e.g. food and similar products
- The MCIS is the only industrial X-ray system which is suited for e.g. plastics, foils and other materials used for sealings (e.g. of food)
- The MCIS has been on display at the FoodPharmaTech2007 exhibition where it was nominated and subsequently was awarded the prestigious Innovation Award.

CTIS

- The CTIS hardware was completed at an early stage, allowing it to be rigorously tested concerning robustness and function.
- The CTIS integrates state of the art detector technology but is designed so that the basic technology modules can be exchanged
- The CTIS enables its use for either conveyor type inspection or for tube inspection (fluids, pulp, etc)
- The CTIS modular software was developed and implemented by the end of the project (WP5), but it also integrates traditional non-modular software which has been used for data acquisition

4th demonstrator

- The system soft- and hardware follows the MODULINSPEX modularity principle – in particular, it can be configured easily for a large number of inspection tasks
- The 4th demonstrator serves as demonstrating competitive modular X-ray technology for electronics inspection
- The system developed in the project is of suitable industrial robustness and is close to the market

Detector developments

- Three novel detectors based on CdTe – CMOS (directly bonded) have been delivered, implemented and successfully evaluated: one area imaging detector (SMIS system), one linear array (SCAN 100TDI) and one long linear array (SCAN5000TDI). The latter was delayed and not entirely industrially tested within the framework of the project, but this work is going on after the project conclusion.
- The detectors conform to the initially set objectives, in particular they provide a superior performance considering sensitivity & resolution, relative to industrial scanning speeds
- The software for the detectors has been well integrated
- There are some issues however, in particular regarding density variations among the tiles when imaging objects of varying contrast (varying thickness or composition). This needs to be resolved for some future applications

Manipulation developments

- CTIS extractable belt with complete motion control (drum motor) developed and integrated soft- and hardware wise
- MCIS conveyor (servo motor) developed, tested and interfaced soft- and hardware wise
- Speed stability problems investigated and assessed – solutions identified
- Conveyor tapes investigated, assessed and selected
- SMIS 3 degrees of freedom (DOF) X-Z-rotation manipulator integrated soft- and hardware-wise
- 4th demonstrator 5 DOF manipulator developed, installed, tested and assessed relative to the application within the electronics quality control
- All modules available as DLL's (WP5)

Hygienic design

- MCIS design re-considered
- Competitive advantage to be gained relative to existing X-ray systems
- Modules re-fitted into hygienic designed system for initial tests

Multi-axis manipulation

- A 5 DOF modular manipulator has been integrated hard- and software wise in the 4th demonstrator
- The concept is modular and easily re-configurable hard- and software-wise.

X-ray source modularisation

- A novel multiple X-ray source controller (the IXC) was refined and further developed, tested and implemented soft- and hardware wise
- The IXC is an exploitable item by itself
- Software modules for control of other RS232, RS422 and RS485 interfaced X-ray sources has been developed, tested and integrated.

Mechanical – electrical realisation of demonstrators

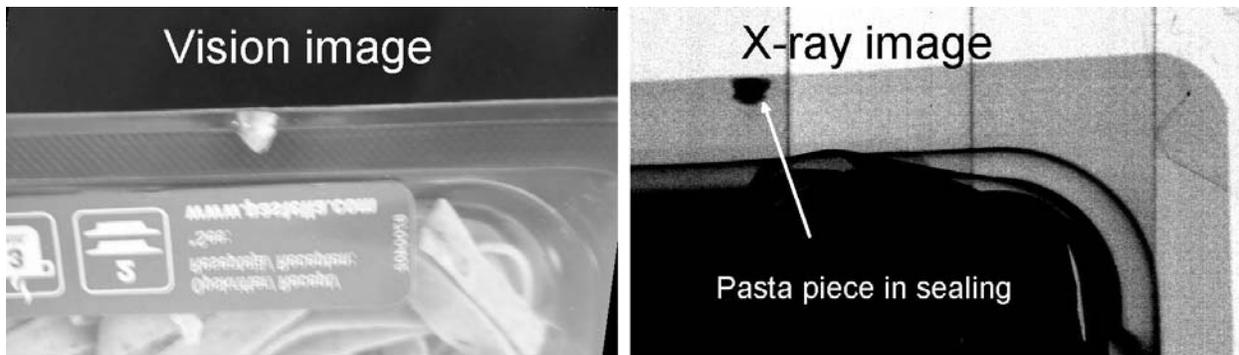
- Four demonstrator systems of industrial standard have been realized

Software

- All hardware control modules have been implemented as software modules
- Image analysis modules have been implemented enabling fast, intuitive and on-line assessment with easy configuration
- All critical set-up and interfacing parameters e.g. of X-ray source and detector are integrated and displayed continuously
- The modular software architecture is implemented fully on the MCIS and the SMIS
- The CTIS software implementation was not achieved in full due to late hardware problems upon testing and problems remote interfacing , - however the necessary modules are present and will be implemented post-project.
- The 4th demonstrator has a specific but yet modular software, principally built upon the same modules as the other 3 demonstrators.

Data analysis modules

- A complete data analysis library has been established, specifically suitable for processing of X-ray images
- The IMM library contains some tools for automatic defect detection which can be easily configured
- Further development of the library is relevant if a full image analysis package with multiple sorting and exclusion criteria must be implemented



Much interest has been expressed concerning the MCIS ability to unveil defects in the packaging of food products, and many tests have been conducted towards this demonstration. Above is seen a pasta pouch from Danish manufacturer, with obvious contamination of the seal. This leads to possible air ingress to the product, which may become unedible after very short time.

MCIS demonstration activities

- The system scanning speed is generally adequate- at 0.1 mm resolution there is seldom a requirement to inspect at higher speed than 0.5 m/s ;
- The system design maybe appropriate for some applications, but in most applications a further robust and user-friendly design (e.g. for cleaning) is mandatory
- The users are generally pleased with the software user interface, however most users have special needs and requirements.
- The system being based on a PC is not commercially viable in an industrial environment – a PLC master must be implemented
- Cooling as installed (in various options) is robust and sufficient, both for the source and the overall electronics (including the detector)
- The system is very robust (e.g. road transport and handling during set-up at various places, etc)
- The system price structure is at the high end, but competitive due to the quality of acquired images. The system shall not be regarded as a competitor to existing low-end X-ray systems e.g. for food inspection.

SMIS dissemination activities

- The system is a superb eye-catcher
- The SMIS is compact and easy to carry along and set-up. Plug-and-play
- The SMIS has proven very robust
- Feed-back received has resulted in numerous sales leads of the technology involved – for a great variety of applications

PROJECT CONCLUSIONS

The project has resulted in 4 unique and new demonstrators, systems with a high degree of novelty and which are of immediate interest to the market. In addition, individual soft- and hardware modules of both academic and industrial exploitation interests have been developed. The project is concluded on schedule, with the vast majority of the work conducted at or close to the plan.