A European Project SysPAQ

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SUMMARY

The European research project Innovative Sensor **Sys**tem for Measuring **P**erceived **A**ir **Q**uality and Brand Specific Odours (SysPAQ) is started under the VIth framework programme under the work programme “New and Emerging Science and Technology” (NEST PATHFINDER "Measuring the Impossible"). The Kick-off of the project was on the first of September 2006. Ten partners (3 Companies, 4 Universities, 3 research Institutes) from 5 countries are involved.

The main goal of this project is to develop an innovative system to measure indoor air quality as it is perceived by humans to be used as an indicator and a control device for the indoor air quality. The system will also be able to detect brand specific odours and it will serve as a novel interior odour design tool for the vehicle industry.

INTRODUCTION

This innovative sensor system is highly demanded by the European society considering that humans spend about 90% of their time indoors, either at work, at home or when commuting between work and home. Recent data shows that improved indoor air quality will result in fewer complaints, increased comfort, less health problems and higher productivity. Consequently, quality of life will be improved.

Up to now, the indoor air quality has been quantified applying three different measurement methods separately. The three methods are based on the human perception of indoor air quality, chemical measurements and sensors for specific odours. Considering measuring perceived air quality human assessments are still being superior to chemical measurements because of the unmatched sensitivity to many odorous indoor air pollutants. One of the reasons is that in most cases the chemical measurements or signals from chemical sensors designed to detect special odours could not be correlated with the assessments made by

humans. They do obviously not measure the relevant indoor air pollutants triggering human sensory response. This project will build upon current knowledge on the perceptual effects of indoor air pollutants and on the experience gained in using chemical measurements and sensors for specific odours. The approach of the project will be to enhance the present state of the art of sensor systems, the perceptual methods and the software tools for modelling human response, and integrate them into one innovative system for measuring indoor air quality as it is perceived by humans. A bridge will consequently be created between the previous works in this area and progress will be achieved by integrating measurements, sensors and modelling by a holistic approach.

The main challenges are the finding of a perceptual space by using different reference odours, the measuring procedure for perceived air quality, and a characterisation method of brand specific odours. This work requires advanced knowledge in perception psychology and technical excellence in sensor system design and indoor environment research, knowledge and experience which the project partners contribute. It is still an open question how to mimic the human perception of odours and air quality. A certain risk of failure is involved in this project's unsolved problem of how to define an adequate system of reference odours for human perception of odours. In any case the project will provide new insight to the human perception of odours and indoor air quality, and will deliver a new approach to assess the perceived air quality and brand specific odours by an advanced sensor system.

PROJECT OBJECTIVES

The main goal of this project is to develop an innovative system to measure indoor air quality as it is perceived by humans based on perception modelling combining measurements of sensors and assessments of perceived air quality by sensory panels. The innovative sensor system can be used as an indicator, monitor and control device for the indoor air quality in buildings and vehicles. Furthermore, the system will be able to detect brand specific odours and it will serve as a novel interior odour design tool for the vehicle industry. The main objectives of the project are:

1. Definition of a method for measuring the perceived air quality and perceived odour intensity in buildings and vehicles. This method will be used by all different labs using sensory panels.
2. To find an advanced perception model for indoor air assessments. The model will be the major input to the software design for the innovative sensor system and it provides new insight to the human reaction to odours.
3. Development of an innovative sensor system for measuring, correspondingly, the perceived air quality and brand specific odours quality.
4. Calibration and test of the innovative sensor system for measuring, correspondingly, the perceived air quality and brand specific odours. The final version of the system is intended for the following applications :
    - Monitoring of the ambient air within buildings and vehicles.
    - Monitoring of the quality of the inlet air to buildings to ensure health and comfort for occupants.
    - Labelling of materials based on emissions from buildings and vehicles.
    - Control of the production process of building and vehicles materials.

Along with human activities, emissions from building materials, furnishing and equipment are main contributors to air pollution indoors. To reduce indoor air pollution loads it has been recommended to use low-polluting materials and to increase outdoor air supply rates. The new EU Energy Directive requires substantial reduction of energy use which may lead to reduction of ventilation rates and increased indoor air pollution enhancing the need of low-emission materials. In addition to measurements of indoor air quality as perceived by humans the system developed in the project can be used to control the emission rates from building materials already at the production stage. At present, manufacturers generally reduce the emissions from building materials by monitoring the emission rates of a few compounds in practice, but not necessarily the most relevant odour active compounds for perceived air quality. The pollution mixture affects the perceived air quality indoors. It is not taken into account so far. The proposed system can be used by the producers of building materials, furnishing and equipment materials to ensure that the emissions from their products would not negatively affect the perceived air quality indoors. In many countries labelling systems of building materials exist, so that the end-users can select the materials with reduced emissions. The suggested system for measuring the perceived air quality can also be used to quantify whether a material can get a label.

The selection of interior materials is a very important factor for the vehicle and transportation industry (train, car, boat, airplane etc.). The goal of the selection process is to create a high-standard perceived air quality in vehicles combined with a brand specific odour impression. To meet this goal the system measuring the perceived air quality seems indispensable.

The interdisciplinary structure of the project consortium will enable innovative research and it will provide new insights to the human perception of air quality and brand specific odours. The project management will ensure a strong interaction between new perception models, hardware development as well as software design for the innovative sensor system.

APPROACH AND METHODOLOGY

The overall approach of the project and the priorities of the different work-packages are shown in figure 1. The figure illustrates the parallelism of the human perception of air quality and brand specific odours on the left hand side and the sensor system development on the right hand side.

The two arrows in the centre of figure 1 indicate the coupling of sensory panel experiments and the sensor system hardware and software development. The innovative sensor system has to detect all relevant odour active substances. Based on the knowledge of the project partners and experiments of the project a list of relevant substances is submitted to the two sensor specialists. The second arrow indicates the input of the new perception model of the perception specialist to the software development. The mathematical model of the new software for the sensor system will apply a reference odour system to reproduce an odour space that covers perceived air quality and brand specific odours in buildings and vehicles.

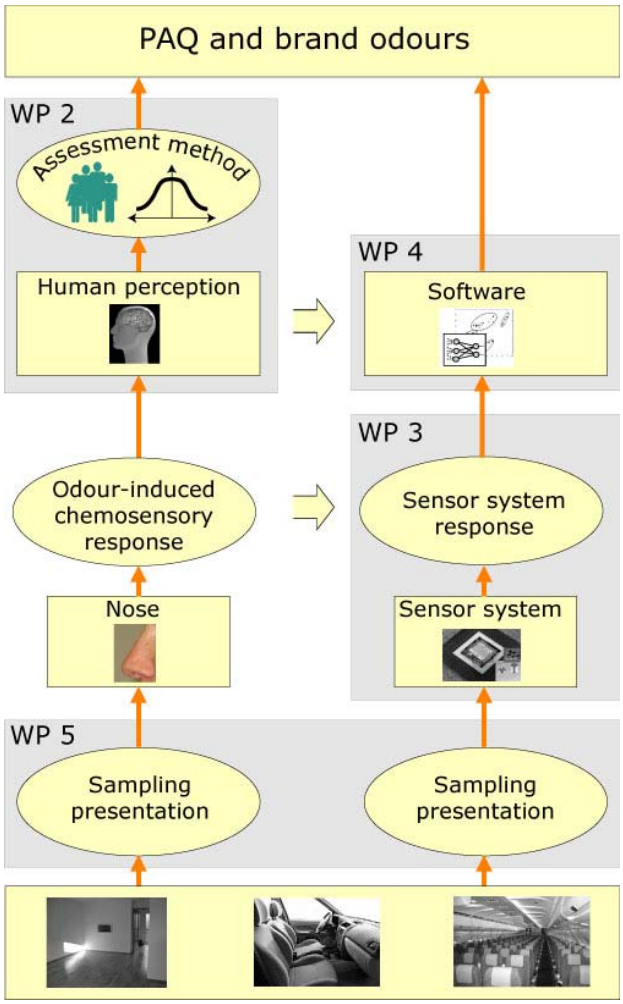

Figure 1: Parallelism of the human perception of air quality and brand specific odours on the left hand side and the sensor system development on the right hand side

WORKPLAN OF THE PROJECT

Introduction - general description

The work of the project is divided into two main tasks. The first task is focused on human perception of odours. This part includes the definition of a method to measure perceived air quality and odour intensity by sensory panels. The used assessment methods can have a major influence on the assessment results itself. Besides the assessment method the main challenge of the human perception task is the definition of an odour space using reference odours. The multidimensional odour space has to account for all interior odours in buildings and vehicles.

This new odour space is the major input to the second main task of this project. This part is focused on the hard- and software development for the innovative sensor system. The contribution of two sensor specialists enables the application of the most advanced sensor technology. The sensitivity and selectivity of the sensors is adapted to odour active substances and the new odour space. The combination of different sensor types leads to novel sensor system that covers considerable more substances than any present stand alone system. The data processing for this sensor systems combines advanced statistical pattern recognition methods with the novel reference odour systematic. The link between the sensor signals and

the perceived air quality consists of a classification process in terms of the reference odours followed by a regression method calibrated by the experimental data of the project.

This two main tasks **human perception** and **system development** break down to 4 work-packages (human perception and odour space, sensor system, data processing and pattern recognition, system calibration). The management process and the dissemination activities control and link these four work-packages, see figure 2.

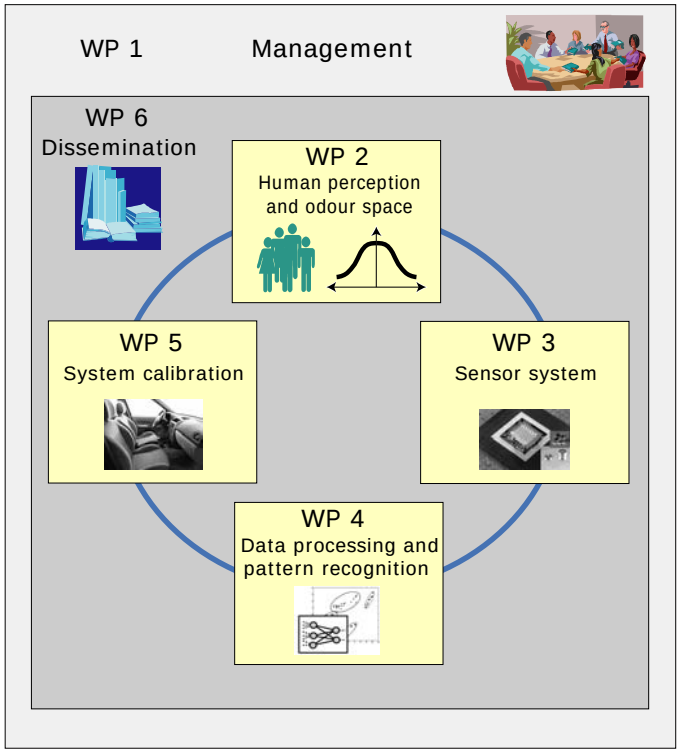

Figure 2: Work-package structure

Work planning

All overall **management** activities are included in WP1. The duration of the management activities covers the whole project life time. The main management activities are directed to the organisation of the project meetings and the knowledge transfer between the different work-packages. The management of the project insures a punctual delivery of all reports to the European Commission and it checks milestones and deliverables of all work-packages. The management also handles the global risk management of the project. The risk management includes the call for extra expert meetings in case of unsolved project tasks and the adjustment associated work-packages in the case of missing milestones or deliverables.

The **human perception** task of the project is mainly handled in WP2. Starting point of WP2 is the definition of a method for all sensory panel assessments of perceived air quality and odour intensity. The method is based on the knowledge of the experimentally experienced project partner and the input of new multidimensional psychophysical perception models. This common standard for the assessment method guarantees comparable measurements at all labs for the innovative sensor system calibration data. The second and the most important part of WP2 is the definition of a new odour space based on reference odours. The new odour space has to cover all relevant odours of indoor air related environments. All project partners of WP2 have been working on the characterisation of odours in the past. The work-package leader Karolinska Institute (KI) will provide a human perception model as a theoretical base

for the new odour space. First experiments of KI will examine the useability of the new odour space based on reference odours to reproduce indoor air odours from building and vehicle environments. The quality of the odour space is the critical factor for the innovative sensor system and it will influence the software design process. A continuous knowledge transfer between WP2 and WP4 will insure a fast translation of new findings into the software system.

WP3 covers all activities related to hardware improvements for the **innovative sensor system**. This work-package includes the improvement and adaptation of single multi-gas sensors as well as the combination of different multi-gas sensor technology. The adaptation process and the selection of sensors are based on literature review and some analysis of indoor air environment of buildings and vehicles in terms of odour active compounds. The sensor development and sensor combination is handled by two experienced sensor specialist Alpha MOS and Forschungszentrum Karlsruhe (AM, FZK). The two partners can provide gas chromatography/mass spectrometry combined with sniffer experiments to prove the response of the multi gas sensor system to odour relevant substances. The check and minimisation of cross sensitivity (to other chemical compounds, relative humidity and temperature of sample air) of the sensors provides reproducible measurements. The sensor specialists (AM, FZK) manufacture three similar measurement devices for the calibration and validation measurements. The three systems will be jointly used by all partners. Additionally, the partner AM und FZK will provide all necessary hardware information and prototypes to the partner Centre Scientifique et Technique du Bâtiment (CSTB) and Technical University of Berlin (TUB) to insure a parallel development of the data processing and pattern recognition software (WP4).

The set-up of the general software layout for the **data processing** will be handled in WP4. The work package leader Technical University of Berlin (TUB) contributes many years of experience in pattern recognition methods and software development to calculate the perceived odour intensity based on multi gas sensor systems. The separation of software and hardware (WP3 and WP4) enables a company independent and extendable mathematical modelling of low-concentration odour mixtures as regards sets of critical odours for building and vehicle materials and products and their combination. The task of the computational data processing is to model the human odour perception of air samples. The method shall consider existing theories of perception and it shall link the measurements with psychophysical aspects of odour sensing. The response values of the sensor device will act as the stimuli and the software shall mimic the human perception and evaluation process. The core of the data processing method will be the “memory”, the calibration database. This database will have a major influence on the performance of the method, especially on the classification of the investigated odour sample. Therefore the data shall span the whole odour space which is developed in WP2. The principle components of this odour space will be the basic odours. The data of the database consists on a combination of sensor response values and air quality assessments according to the methods of WP2 for a specific odour sample and concentration. The database shall contain for each odour class data for different stimuli concentrations. The system shall be adaptive which requires the database to be expandable and open for new data of odour investigations. The calculation models will always refer to the current data and therefore the algorithms will be adjusted to the extended data set.

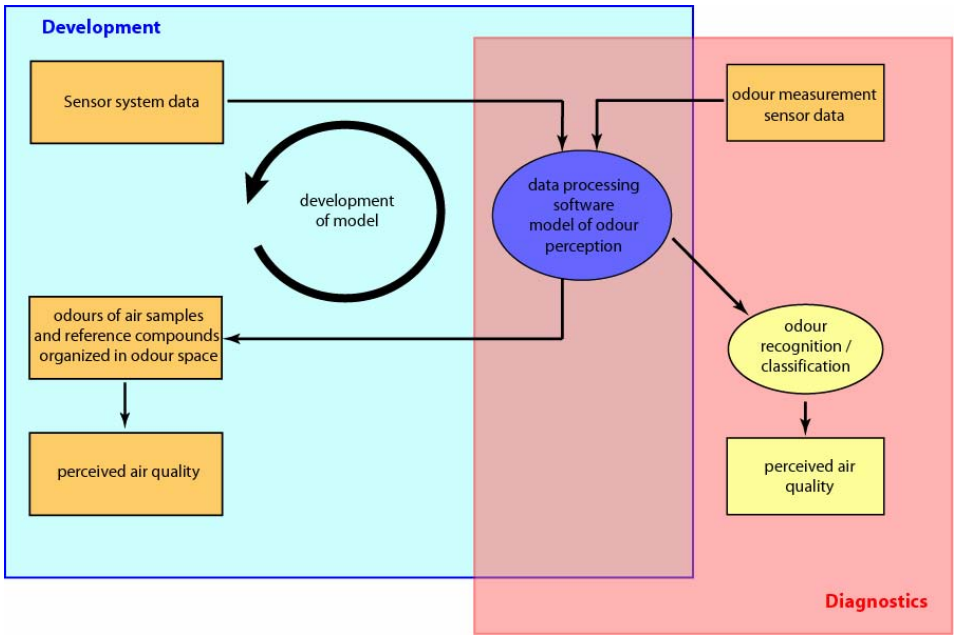

Figure 3: The software will handle the development/calibration process and it provide the final version for diagnostics of unknown odours

The unknown investigated odour shall be positioned inside the odour space which is a classification process for “odour recognition”. Unknown odours shall be expressed by a combination of the basic odours. Once the sample is classified the quantitative and qualitative parameters of the perceived air quality shall be estimated. This step of the data processing uses the calibration data of the basic odours, the regression and calculation algorithms for this odours as well as weighing algorithms which consider the position of the unknown odour sample in the odour space. Data of odour samples other than the basic odours is needed to develop, test and optimize the weighing algorithms and to estimate the perceived air quality of different odours. Most of the odour space and combinations of basic odours should be covered. During the validation process of the software the new collected data will be included in the database which may further improve the performance of the data processing method.

The innovative sensor system has to identify all reference odours and their combination in indoor environments. Additionally, the system shall link the pattern recognition method for the identification process to the sensory panel results. Due to the multidimensional character of the problem a large effort is needed to calibrate the innovative sensor system. WP 5 handles the **collection of the calibration data**. It consists of simultaneous measurements of perceived air quality as well as the perceived odour intensity by a sensory panel and measurements with the sensor systems using the most relevant sensory methods selected in WP2 and the most promising innovative system/technical device selected in WP3. All data of WP5 iterates back to the software enhancement of WP4. The odours for calibration measurements of WP5 are produced in emission chambers. The air flow through the chambers is polluted by a series of building and cabin materials. The concentration of air pollutants will be varied within an indoor realistic range to ensure and test if the system works appropriate. The variation in concentration will be achieved by varying the material loading and the ventilation rate and by selecting high and low emitting materials. Measurements will be performed for individual materials in a laboratory setting, for combinations of materials in a full-scale setting, and in real buildings and vehicles. All data of WP5 is stored in a database. A final test run of the innovative sensor system after calibration will show the ability to predict perceived air quality and to characterise brand specific odours. During the sensor

development WP5 will provide preliminary test set-ups of building materials in order to secure reasonable sensitivity and discrimination power of the novel sensor system.

The **dissemination** task of WP6 provides the publication of all project results. The main communication medium of the project is an advanced internet portal that offers a public and a non public information area (www.syspaq.eu). The public area publishes all non confidential findings of the project partner during the project life time. The non public area handles the data exchange of all project partners. All project related findings will be open for the public after the completion of the project. The project will provide a final workshop in order to discuss and disseminate all findings of the project. The consortium will prepare a brief project presentation in English which is written in a style which is accessible to non-specialists, avoiding technical language, mathematical formulae and acronyms as much as possible. Publication will be done via the NEST www page.

A more detailed information on the major work package interdependencies is given in figure 4.

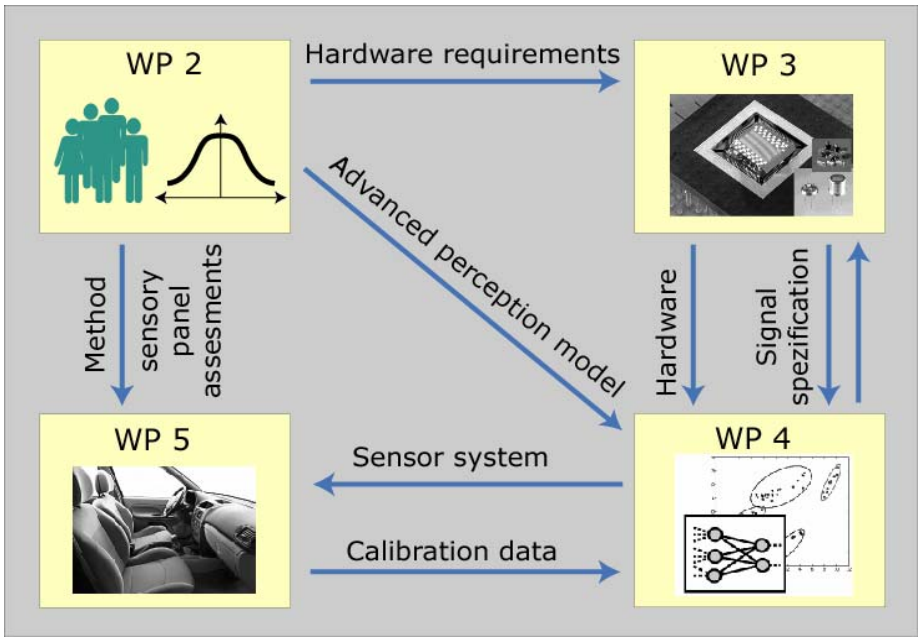

Figure 4: Major work-package interdependencies

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REFERENCES

1. Müller, B. et. al 2006. ANNEX I, Description of work, SysPAQ Contract.