LOEWE-Zentrum AdRIA –
An important step towards the commercialization of adaptive systems

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Introduction

The "LOEWE-Zentrum AdRIA" (Adaptronik – Research, Innovation, Application) [1] is one of five so-called LOEWE centers which were selected to be funded in the framework of the research grant program „LOEWE" (Landes-Offensive zur Entwicklung Wissenschaftlich-ökonomischer Exzellenz – State Initiative for the Development of Scientific-Economic Excellence) of the government of the German federal state Hessen [2]. It aims at the creation and sustainable implementation of an internationally leading adaptronics (smart structures) research institution in Darmstadt, Germany. Eventually, it will lead to the foundation of a new Fraunhofer Institute for Adaptronics and of four new university institutes. This paper describes the structure and the goals of this research project.

Figure 1: LOEWE-AdRIA project building in Darmstadt-Kranichstein (present state).

Project budget and project management

LOEWE-AdRIA is a large interdisciplinary research project funded mainly by the government of the German federal state Hessen with a duration of three years and a budget of 17.7 million Euros for the first project phase ("start-up phase"), which ends in the summer of 2011. A subsequent second phase with a duration of three more years ("operating phase") and with a tentative budget of 20 million Euros is planned. Furthermore, the government of Hessen, the government of the Federal Republic of Germany, and the Fraunhofer-Gesellschaft support the project with additional 11.5 million Euros for building activities and civil works and for basic equipment such as office furniture, computers, or laboratory equipment.

The project involves the Fraunhofer Institute for Structural Durability and System Reliability LBF, 22 institutes from five different departments of the Technische Universität Darmstadt (Mechanical Engineering, Electrical Engineering and Information Technology, Materials and Geo Sciences, Computer Science, Chemistry) as well as one department of the University of Applied Sciences (Mechanical and Plastics Engineering), all located in Darmstadt, Germany.

The LOEWE-Zentrum AdRIA is located in a separate building in Darmstadt-Kranichstein next to the Fraunhofer Institute LBF (see Fig. 1), which was bought by the Fraunhofer-Gesellschaft just for the purpose of the LOEWE-Zentrum. When the growing staff size of the project or the foundation of the new Fraunhofer Institute for Adaptronics to be founded after the end of the current project require more office and laboratory space, it is possible to enlarge the building by adding one or two more floors.

The AdRIA project is managed by a project coordinator, who is supported by a secretariat and who chairs the steering committee. There is also an advisory board and a project partners assembly. Furthermore, the leaders of the ten technology areas, of the three application scenarios, and of the education and advanced training section all report to the steering committee.

Research topics and scientific goals

The main goal of the project is the advancement of the scientific-technological fields of adaptronics required to achieve a systematic, holistic development and a high readiness level of adaptronic products. The most important technological goal is to enable a sustainable lightweight design of technical structures by means of adaptronic approaches, incorporating an improved energy efficiency during the product life cycle, an increased functionality (e.g., by means of integrated active safety and monitoring systems), as well as an increased performance (e.g., precise, noise-reduced, vibration-reduced). In order to attain these goals, both basic research and technology development and technology demonstration by means of three exemplary application scenarios are pursued.

During the start-up phase (first three years of the total duration of the project) the project focuses on the basic research-oriented technology areas, whereas during the operating phase (second three years) the project focuses on the application scenarios. The technology areas promote innovative research topics that are of strategic importance for adaptronics in such a way that they eventually exhibit the same technology readiness level and that their marketing potential can be demonstrated in the application scenarios. In the long run these activities will lead to the establishment of the key technology adaptronics in the product development for the mass market and to the sustainable development of the adaptronics location Darmstadt.

The main research goals are defined as follows:

- provision of an efficient development tool for the design of adaptronic system solutions,
- development of new transducer materials, adapted to specific applications,
- new sensor and actuator concepts that enable a high degree of integration into adaptronic systems,
- inexpensive, compact, and robust solutions for electronic components of adaptronic systems,
- innovative control concepts for complex systems and broad-band perturbations,
- inexpensive, flexible manufacturing processes for limited-lot production and mass production,
- methods for the assessment and monitoring of system reliability,
- demonstration of the technology readiness level of adaptronic systems by means of selected examples.

The project is organized in ten technology areas (see Fig. 2):

- material science (e.g., new or improved sensor and actuator materials, high-temperature, transparent, or lead-free piezoelectric materials),
- numerical simulation methods (e.g., integrated development tools, modeling, simulation, simulation-based design of adaptronic systems, nonlinear and discrete optimization, product data management),
- sensors and actuators (e.g., decentralized sensors and actuators, special manufacturing methods for inexpensive mass production, autonomous sensor networks, silent actuators, electro-active polymers),
- embedded systems (e.g., general methodology and platform for control systems and distributed sensor networks, centralized and decentralized control, integration of hardware and software, wire-connected and wireless networks for data communication),
- systems and control (e.g., optimization of the control properties of the hardware, improvement of structure dynamics by means of control algorithms),
- adaptronic systems (e.g., general, integrated design guideline for adaptronic systems enabling an efficient development and assessment of adaptronic systems, system analysis and assessment, adapted power electronics, signal processing, control systems, system integration),
- structure health monitoring / structure health control (e.g., state monitoring of mechanical systems, load monitoring, local and global damage detection, monitoring of active systems),
- rapid prototyping / rapid manufacturing methods (e.g., inexpensive manufacturing techniques for the production of function-integrated structures and parts, integration of sensors and actuators in layered structures),
- production and manufacturing (e.g., machining techniques for miniaturized adaptive systems, printing of sensors and actuators on sheet metal parts, machining processes for sheet metal structures printed with sensors and actuators,

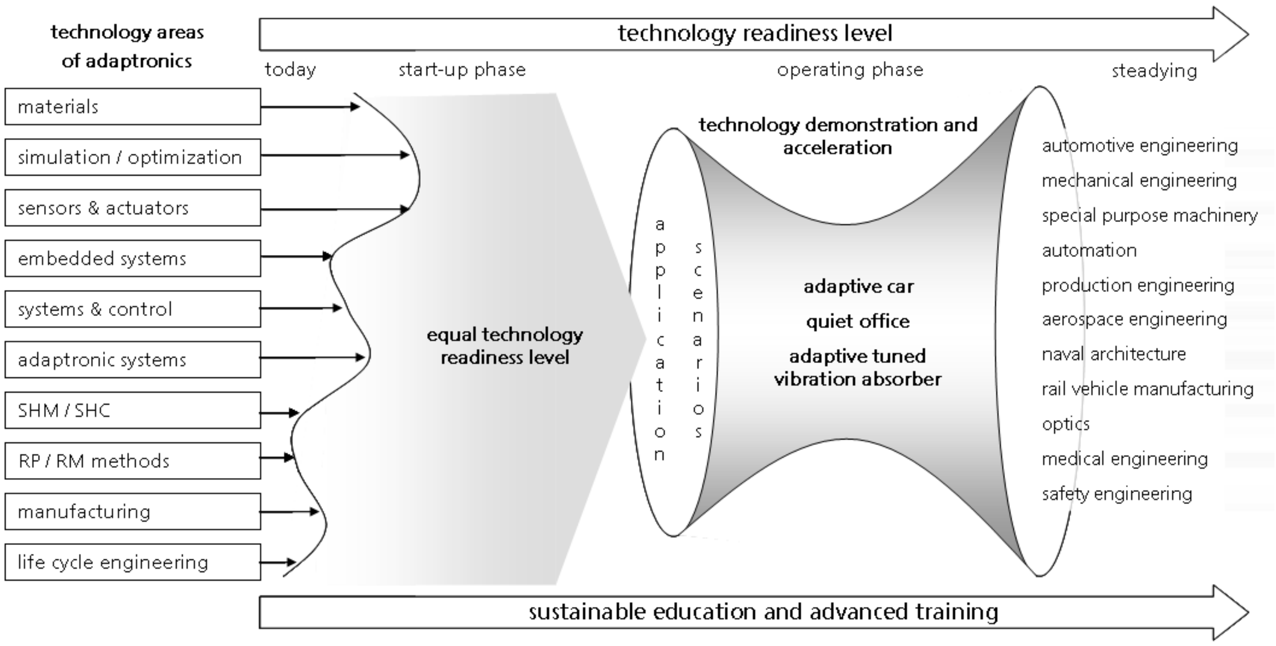

Figure 2: Structure of the LOEWE-AdRIA project.

manufacturing technologies for structural components with integrated sensors), and

- life cycle engineering and reliability of adaptronic systems (e.g., development of experimental and virtual methods, supply of reliability data of better quality and higher quantity, strategies for monitoring and error analysis in electronics).

These ten technology areas supply the necessary technologies for the three application scenarios (see Fig. 2), namely,

- adaptive car (e.g., noise and vibration reduction, monitoring of structural properties, optimization of passive car safety, improvements with respect to temperature range and environmental properties, integration into the electrical system),
- quiet office (e.g. planar structural elements such as windows, facades, or office walls, ducts of air-conditioning systems, office appliances such as printers or projectors, reduction of structural vibrations, of the structure-borne and air-borne sound transmission, and of the sound radiation of planar components, adaption of the connection impedance of bearing elements, increase of the sound absorption, minimization of flow-induced noise, cost-efficient simulation tools, development of transparent piezoelectric sensors and actuators), and
- adaptive tuned vibration absorber (adaption of the parameters of each of several distributed vibration absorbers, network consisting of several communicating tuned vibration absorbers, integration of sensors, signal analysis, and control into the system, decentralized control).

Research demonstrators

In order to get the project running, the coordinators decided to start with the definition, design, and manufacturing of three demonstration structures, i.e., an "acoustic aquarium", a three-dimensional truss structure, and an active engine mount.

The "acoustic aquarium" consists of a cavity made of rigid or elastic walls covered by a thin rectangular plate made of steel, aluminum, or glass (see Fig. 3). The rectangular plate represents all kinds of planar structural elements. Various approaches for active vibration control and active structural acoustic control can be applied to this plate in order to decrease its sound radiation or transmission or to increase its sound absorption. The plate can be excited by loudspeakers inside or outside the box or by an electrodynamic shaker. Piezoelectric patch or stack actuators or active tuned vibration absorbers can be used to reduce the vibrations and the sound radiation of the plate. Various control strategies and various sensor and actuator types and materials will be tested.

The three-dimensional truss structure demonstrator (see Fig. 4) represents general truss structures such as cranes, bridges, or automobile, aircraft, or ship structures and substructures. Sensors and actuators can be applied at the connection points of the truss bars or integrated into the truss bars. Likewise it is possible to apply actively tuned vibration

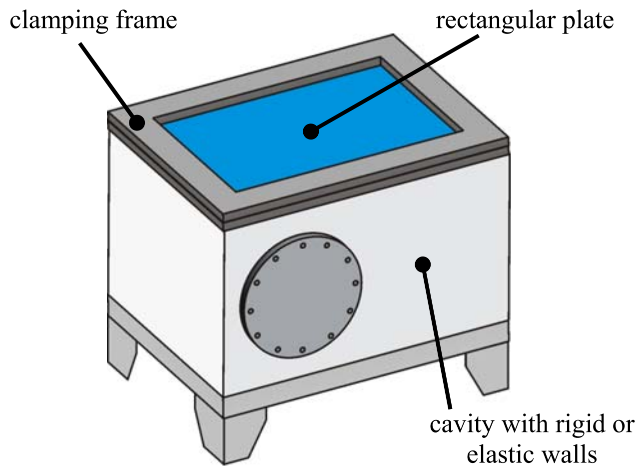

Figure 3: Demonstrator "acoustic aquarium".

absorbers to the nodal points of the structure. Truss structures are widely used benchmark structures and can be extended step by step to create increasingly complex truss structures.

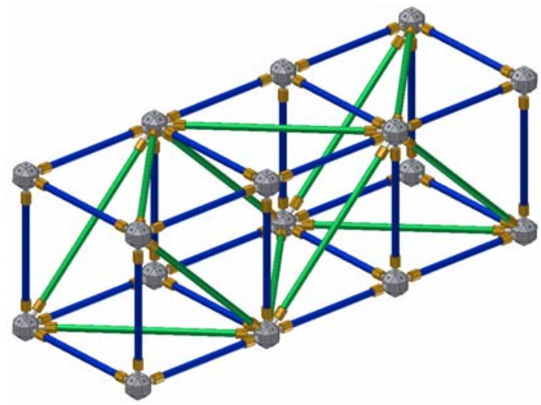

Figure 4: Demonstrator "3-D truss structure".

The third demonstrator is an active engine mount (see Fig. 5). It allows the testing of active mounts under realistic conditions. As a first step, only the vertical direction is considered. Later on, the complexity will be increased stepwise, which requires a modular design. Actuators can be positioned in the flux of force (active interface) or outside the flux of force (adaptive tuned vibration absorber, neutralizer). Both vibration (acceleration, displacement, strain) and force sensors will be used and adapted to this specific application. Also, various control concepts such as feedback, feedforward, model-based, adaptive, and digital control approaches will be tested. Engine run-ups can be simulated by increasing the rotational speed of the unbalanced mass on top of the active mount. Not only the active mount but also the excitation and the behavior of the base structure will be simulated numerically.

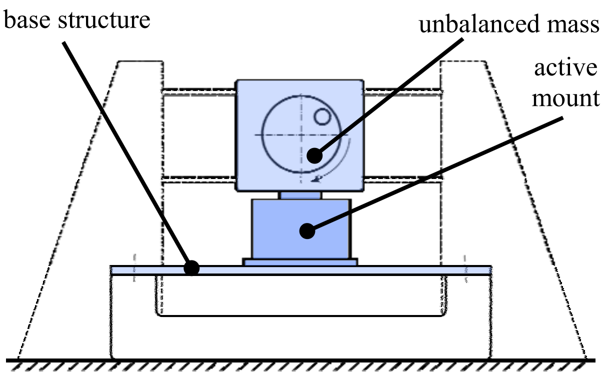

Figure 5: Demonstrator “active engine mount”.

Summary

The LOEWE-Zentrum AdRIA is a large interdisciplinary research project aiming at the advancement of adaptronics and smart structures technology in Darmstadt, Germany. Its projected total duration is six years, the total budget is approximately 48 million Euros. The project is organized in a matrix structure consisting of ten technology areas and three application scenarios. The scientific work starts with the design and manufacturing of three demonstration structures. The project logo is depicted in Fig. 6.

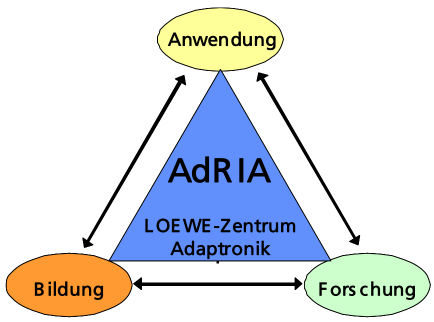

Figure 6: Logo of the LOEWE-Zentrum AdRIA: research, application, education.

Acknowledgments

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References

[1] Reference to the LOEWE-Zentrum AdRIA homepage: URL: `http://www.loewe-adria.de`

[2] Reference to the homepage of the LOEWE initiative: URL: `http://www.hmwk.hessen.de/` → Forschung → Forschungsförderung → Landesprogramm LOEWE