This article highlights two of the main areas of teaching and research at the chair of Computing in Civil Engineering. These two major areas, (i) structural health monitoring (SHM) and (ii) building information modeling (BIM), are fields of teaching and research that are of utmost importance for solving today’s and future economic and societal problems. Last but not least, this article elucidates the integration of software tools and technologies into the courses taught at the CCE as well as the implementation of modern teaching elements, such as computer-supported collaborative work, e-learning, blended learning, and practical experiments in the laboratory ("project-based learning").

**Key words**: research-oriented teaching, Project-based learning, E-learning, Computer-supported collaborative work, Blended learning, Building information modeling, Structural health monitoring.

**Introduction**

This article illustrates the research-oriented teaching at the Chair of Computing in Civil Engineering (CCE) at Bauhaus University Weimar, Germany. Exemplarily, two main areas of research as well as their practical implementation into several courses taught at the CCE are shown. These two major areas are structural health monitoring and building information modeling, which are fields of teaching and research that are of outmost importance for solving today's and future economic and societal problems.

Structural health monitoring systems, consisting of sensors, data acquisition units, computer systems and connecting cables, are designed to detect structural changes before they reach critical states. By analyzing the sensor data recorded from the structures, SHM systems provide the opportunities to enhance the safety and reliability of engineering structures and to reduce the costs for management, maintenance and repair throughout the structures' life cycles [2, 3]. However, in conventional SHM systems the installation of cables can be expensive, time-consuming and labor-intensive, entailing high maintenance costs for the SHM systems. Therefore, the Chair of Computing in Civil Engineering focuses on the development of wireless sensor networks for SHM. Eliminating the need for connecting cables, wireless sensor networks have emerged as a cost-effective and reliable alternative to conventional, cable-based SHM systems [4, 6, 7].

The second major research area focuses on building information modeling (BIM). Building models exist in several forms, designed for partial problems in the planning, execution and utilization phase. A well-known difficulty is the smooth interaction of these models. The Industry Foundation Classes (IFC) represent a considerable step in the direction of building information modeling for an integrated digital planning of buildings as well as for easy data exchange. The IFC provides an open model for the exchange of data in the building industry. Meanwhile, the IFC moves more and more into the industry. Especially the Scandinavian countries are in the forefront of their application. Building information modeling does not yet play the role as it should – in the authors opinion – within the university education of civil engineers and architects. However, there is success, especially in Germany, on the initiatives of the buildingSMART association and the “inpro” project in Europe. There are promis-
ing approaches for the creation of building models on the basis of the IFC and, although the basic idea to create building models is not new, there are promising opportunities to renew the discussion of this question [1, 9, 10].

In the following subsections, this contribution describes, by means of two examples, the integration of two major research areas into the teaching at the Chair of Computing in Civil Engineering.

Implementation in the courses
The Chair of Computing in Civil Engineering aims to teach the students a basic understanding of software tools and technologies to be applied for solving problems in civil engineering. As a result, students are capable of exploiting, adapting and even developing software tools based on the acquired knowledge.

The students of civil engineering at Bauhaus University Weimar get in touch with computing in civil engineering at the beginning of their first term while participating in the project “Geometric Modeling and Technical Representations”. This project is a cross-chair course, where students are confronted with questions of descriptive geometry, of technical drawing, and of computer-aided modeling (CAD). The course “Engineering Informatics”, taught subsequent to the aforementioned course, communicates the basics of programming technology as well as algorithms and data structures. Object-oriented programming techniques and database technologies represent key aspects of this course. The students learn programming paradigms using civil engineering examples, such as heat transition calculations or structural analysis. Both courses are mandatory, i.e. all civil engineering students are required to attend these courses. These courses consist of a lecture and tutorial part. Tutorials take place predominantly as a practical part in the computer lab guided by tutors. To strengthen the introduced knowledge and the practical skills, a complementary assignment must be produced and presented to the tutor by each student.

The two mentioned courses serve as a basis for further studies in the field of computing in civil engineering. To synergistically bring practice, theoretical knowledge, and research activities together, the Chair of Computing in Civil Engineering provides advanced courses that are closely connected to the chair’s research activities.

Course Structural Health Monitoring
Since 2013, the Chair of Computing in Civil Engineering provides a course that has a unique project character for Master students of Civil Engineering and for students of the degree program Natural Hazards and Risks in Structural Engineering (NHRE). Students become familiar with the principles and practices of structural health monitoring and smart structural systems; they are able to design decentralized systems to be applied for continuous (remote) monitoring of civil infrastructure. In addition, the students learn to design and to implement intelligent sensor systems using state-of-the-art data analysis techniques, modern software design concepts and embedded computing methodologies.

In the course, students first take part in a lecture and a tutorial on the subject. In the second part of the course, the practical implementation of SHM systems is of interest. Interdisciplinary student groups are implementing SHM systems using wireless sensors that collect data from a structure and analyze the structural response autonomously. The type of analysis the student groups want to realize is free of choice. Laboratory tests in the context of a project-internal competition conclude the course. Each group presents their implemented algorithms, which will be evaluated according to specific criteria: “How well do the sensors analyze the structure?”, “How complex are they?”, “How properly have the students coded?”, and “What is the quality of the transmitted data?”

Figure 1 shows the setup of the test structure that has been used last year. The structure consists of a plastic tower made of a pipe that is fixed at the bottom. Two wireless sensors are mounted at the top and at the middle of the tower. After forcing the pipe to vibrate (by exciting the structure with a hammer), the wireless sensors start measuring the acceleration, executing the chosen analysis and sending the result to the base station.

The students who won the last competition have implemented a fast Fourier transformation (FFT) to determine the structure’s resonance frequency using the measured data. All the calculations were executed directly on the sensor nodes. The student group has implemented also a graphical representation. The screenshot of their software is shown in Figure 2.
Course Building Information Modeling

Within the course “Building Information Modeling”, the idea of BIM is discussed in depth, and current research approaches are presented [9–11]. The objectives of the course are data integration techniques and methods of building information modeling. Similar to the “Structural Health Monitoring” course, this course is divided into a lecture and a project part.

BIM can generally be seen from two perspectives, from the perspective of building information modeling and from the perspective of the building information model. The course considers both perspectives and is structured correspondingly. In the beginning of the course, the process of information modeling, which is the procedure of creating digital building models, is introduced to the students. Also, a brief summary of software tools available on the market for creating building information models is given. Furthermore, the theoretical background of digital geometric modeling, such as boundary representations (b-rep) or constructive solid geometry (CSG), is taught, and individual stages of the building planning process are analyzed. From the technical point of view, this course is based on the IFC, which is the only non-proprietary model that is currently available. The IFC are standardized as ISO 16739:2013 that specifies a “...conceptual data schema and an exchange file format for Building Information Model (BIM) data”.

The project part of the course offers two different options of practical work to the students. As the first option, the students are requested to implement software algorithms that interpret a given IFC file in terms of data queries. The queries implemented by the students are free of choice, e.g. a listing of all walls that are part of the third story including their material information. The students are provided with Java libraries for reading, writing and accessing IFC files [11], and they are supported by tutors who are joining the class. The implemented algorithms are evaluated according to the utilization of the IFC model structure, to the complexity of the algorithms, and to the quality of coding.
Representing the second option of practical work, the group of students is requested to design a building. Thereby, each student plans a certain part of a building, e.g., different stories for the same building. The students coordinate their work solely by using a BIM collaboration server, which has been developed within a joint research project of the Institute for Applied Computing in Civil Engineering Munich and the IFC TOOLS PROJECT [11]. The BIM collaboration server provides a virtual project room that allows exchanging digital data and building information models based on the IFC. Figure 3 shows the web interface of the BIM collaboration server.

![Fig. 3. Screenshot of the BIM Collaboration Cloud](image)

The collaboration server, besides several other features, provides software tools allowing to check the building model visually, as can be seen from Figure 4. Furthermore, the software tool offers functionalities for clash detection, provision for voids, and it supports the exchange of information between the project partners using the BIM collaboration format (BCF).

At the end of this course, every student writes a paper and gives a presentation expressing his or her personal experience using the collaboration server. Questions such as "Which problems occurred while using the collaboration server?", "Is any functionality missing?" or "Which advantages or disadvantages did you encounter compared to the conventional way of cooperation work?" are to be answered by the students. The feedback that is created by the students is directly used to improve upcoming software versions.

![Fig. 4. Screenshot of the BIM Collaboration Cloud Viewer](image)
ОПТИМИЗАЦИЯ РАЗМЕРА БУФЕРА В КОММУТАТОРАХ СЕТЕЙ ПЕРЕДАЧИ ДАННЫХ

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Традиционным методом борьбы с перегрузкой является выбор оптимального размера буфера, распределение емкости буфера между каналами и источниками трафика, а также в борьбе с переполнением буфера в пиковые режимы работы. Для реализации этого подхода в высокоскоростных коммутаторах сетей передачи данных, где требуются как системы коммутации в магистральных сетях, так и многопортовые коммутаторы [1], ключевым элементом является использование оптических коммутаторов, оптических переключателей. В таких коммутаторах важным является статус оптической буферной памяти. Она включает в себя алгоритм, оптическое буферное устройство, задержки передачи информации в коммутационной системе при использовании объема буферной памяти небольшого размера. Предлагается метод высокоскоростной обработки информации, позволяющий повысить скорость передачи информации в коммутационной системе при использовании объема буферной памяти небольшого размера. Приводятся результаты моделирования алгоритма параллельной настройки. Анализируются требования к производительности коммутационных систем, где требуется учесть скорость передачи данных, а также сказываются требования к быстродействию сети. В магистральных сетях передачи данных, в системах коммутации, в оптико-электронных коммутаторах требуется учесть специфические требования. При этом "узким местом" является выбор оптимального размера буфера в коммутаторах сетей передачи данных.

Ключевые слова:
маршрутизатор, оптический коммутатор, алгоритм, оптическое буферное устройство, имитационное моделирование, оптико-электронный коммутатор.

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