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## Innovative tools for engineering creativity development

Solving problems and searching for new effective ways and tools are considered to be engineer's main goals nowadays. An engineering activity is getting more innovative, requiring strong abilities and well developed skills of coming up with new ideas and bringing them to life rather than having definite and limited amount of professional knowledge. In this regard analysis, convergent and divergent thinking, inventing, creating are vitally important qualities for an engineering expert. In his job today, an engineer works in a multidisciplinary environment which significantly influences his approaches, methods and tools. For example, a mechanical engineer does not deal only with mechanisms, as the main advances come from IT and electronics. This means the designing approaches are changing according to the needs of the modern market and together with emerging technologies.

As for machines and mechanisms, engineering is performed towards the expanding tendency to automation which allows a system to work without human making decisions. Designs in different industries are provided by the collaboration of experts from different fields: mechanical, electrical, software and hardware engineers, economists, ecologists, etc. Any participant of a project has to understand how all the mechanical or structural parts are merged in one machine, how they influence each other and environment and how the control is performed. It is necessary for an engineer to realise all the design aspects, because neither the machine (the system) nor its separate part or unit will never be isolated. In this respect the understanding of the process, cause and effect is crucial, so the skills and tools which enable to analyse and predict machine's operation and its environmental influence have to be developed along with fundamental professional knowledge while engineers are being trained at university.

Innovative engineering tools are mostly based on modeling in the orthographic drawing or built from predictive equations. Mechanical engineers widely use CAD software to visualise concepts and simulate its operation in real conditions. A physical prototype is great for presenting the look of the design, its shape, material etc. At the same time, to build a drawing can be not enough to realise and solve the problem. Engineers often have to make decisions when the system cannot be described by an equation. In this case, methods of descriptive modeling are applied. They are based on the Unified Modeling Language (UML), which allows to present the behavior of the system, to study and explain the deeper interactions between its components and account for all the effects that could be caused by the design[1].

Application of UML models to engineering students' projects could help them to practise innovative engineering methods and tools as well as to develop their creativity. One group of UML models enables to perform a structural analysis of the system (design). To explain what happens inside the system, show all the operational steps, decision making process, interactions with the users and environment, there are *behavioral diagrams* (Use Case Diagrams, Sequence Diagrams, Activity Diagrams, etc.), which are also UML models. Developing a project solution, students complete UML diagrams in order to present an idea or a concept, show the progress and identify the failures as well as the ways for improvement. They study to analyse evidences and predict different situations: those which develop according to the plan and unexpected ones, for instance, a mistaken misuse of the system[1]. While developing their designing skills,

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[1] UML Overview. *Introduction to Engineering: Imagine. Design. Engineer! EdX courses*. URL: https://courses.edx.org/courses/course-v1:ASUx+FSE100x+2177C/courseware/c2bd0ab3c10d4ac08d963fe8991df8af/5c8e2d61be254b508b41758951dfb3e1/3?activate_block_id=block-v1%3AASUx%2BFSE100x%2B2177C%2Btype%40vertical%2Bblock%408f5ffc00dcc94b6494f1f9f7b553811f

engineering students are taught to be focused on the end user and his needs. UML models development engages students into a productive research activity when they are trained to consider all the details and circumstances, all possible interactions as well to be able to predict what will happen with the system, which is being designed, under specific conditions. Such a practice requires divergent thinking skills, abilities to analise, predict, search for better solutions etc. All these help to organise specific educational environment which influences the student's creative potential positively, appealing to student's intelligence, invention, reflection, motivation and responsibility[1].

One of the UML models, which is used to study and present the connections and interactions inside the system as well as between the system and the environment, is a Case Use Diagram (UCD). The process focuses students on the end user's needs and his expectations as well as on all the possible interactions and effects caused by different situations and conditions rather than technical details of the design operation. In a Use Case Diagram, the designed system is considered to be a black box with anything inside. The diagram includes four elements, the system, the actors (actual humans, animals, plants, processes or other machines that deal the solution), the services (connected with actors), and the relationships. While developing the model, an engineering student analyses all the actions performed by the solution (machine). The number of the actions (cases) is not limited, so the student is free to predict and create all the possible options and, after that, to explain the relationships between the cases.

When the student is working with the diagram, he is focused on reasons and causes. His creativity appears when he needs to assess the situation as well as analyse input and output parameters or establish 'forward' and 'backward' relations. Students need to consider as many variants of their system operation as it is possible. When the process of a UCD building is a part of a group or team work,

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[1] Тітова О.А. Підготовка майбутніх агроінженерів у творчому освітньому середовищі. *Освіта і наука у мінливому світі: проблеми та перспективи розвитку*: матеріали міжнар. наук. конф. м. Дніпро, 29-30 бер. 2019 р. Част. І. / наук. ред. О.Ю.Висоцький. Дніпро: СПД «Охотнік», 2019. С. 30-31.

students can apply any creative brainstorming technique. Having defined the actors, students analise and show the relationships between the actors. This process effectively develops such skills as analysis, synthesis and prediction as well as abilities to establish cause-and-effect relation or causative errors, etc. Students think of two types of relations, included and extended. Establishment of an included relationship requires a student to realise and think carefully about the initial function of his system (design or solution) as the diagram is considered to be incomplete without all the included relationships' arrows. The extended relationship is dependent and optional. To reveal it a student needs to think of some triggering situations which can cause or require additional functions of the system. The process of Use Case Diagram building often leads students to a wider view on their design or solution, when they start considering of how the concept could influence other machines, plants, people, animals and environment in whole. That activates and develops students' reflective skills, makes them think about priorities, ask questions and search for answers about values improving students' consciousness and fostering their responsibility.

Figure 1 presents an example of a Use Case Diagram, which was developed for the Disaster Relief project on the Introduction to Engineering online course at ASU, the USA[1]. The task was to build the diagram which illustrates the process of automatic control of outside temperature in an aircraft for wildfire disaster relief. In the provided example, the outside temperature was defined by a student as an input. A designer (a student) utilized temperature sensors and LED in the automation system, so the system would react according to the outside temperature level. Two scenarios ('Sunny day' and 'Rainy day') were under consideration. That was why the system included additional equipment (alarm and cooling systems). The system could have a number of users. The main users were a pilot and crew members who watched lights and moved the aircraft away from the

[1] Project Memo: UML Automation Models. https://courses.edx.org/courses/course-v1:ASUx+FSE100x+2177C/courseware/c2bd0ab3c10d4ac08d963fe8991df8af/fd73bcfddb2d447a93b841832561c84b/

dangerous area (the pilot in a ‘Sunny day’ scenario, the pilot or the crew member in a ‘Rainy day scenario’). Other users were sensors, which measured the outside temperature, fire, which increased the temperature, aircraft, which overheated and caused the cooling system to be turned on (‘Rainy day’ scenario) and maintenance team, which checked all the sensors and a cooling system.

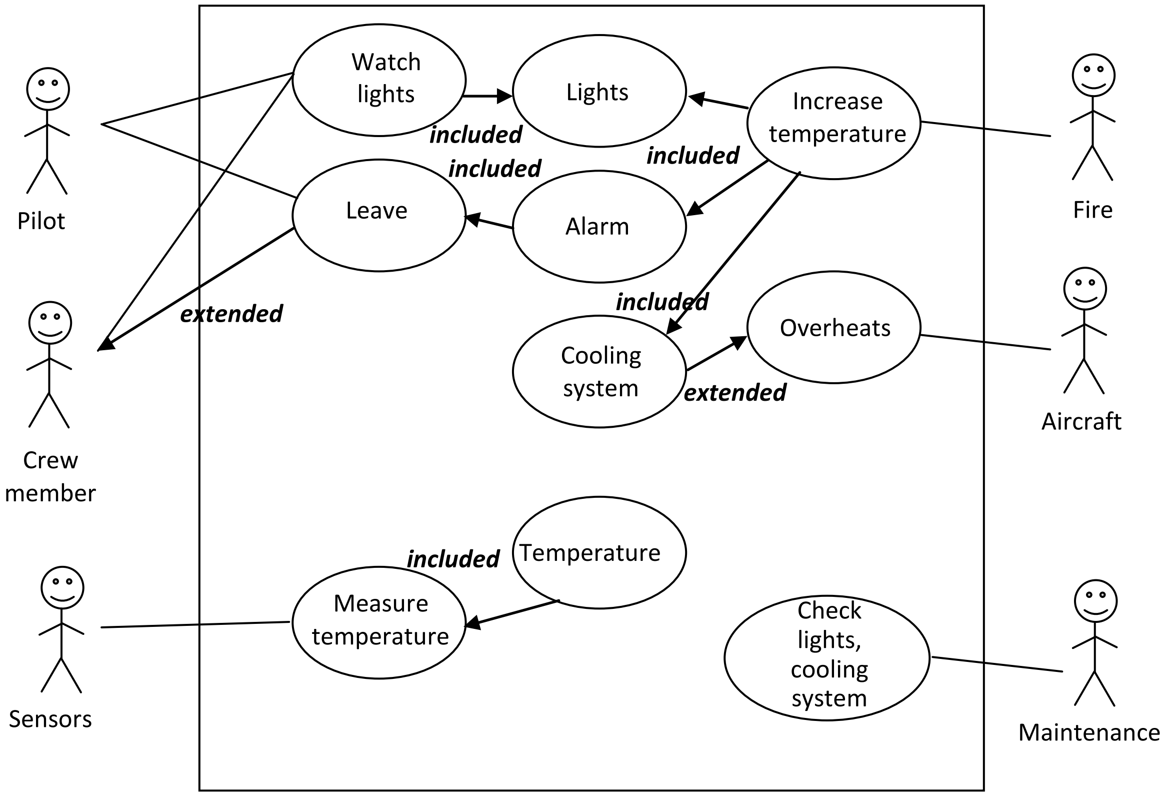


Fig. 1. Use Case Diagram for automatic control of outside temperature in an aircraft for wildfire disaster relief

Development of a Use Case Diagram is usually followed by the building of a Sequence Diagram, which shows all the stages of the operation process, and an Activity Diagram, where all kinds of final behavior are shown. They allow to study the features of the design deeper and realise its advantages and disadvantages.

Such innovative modeling tools allow engineering students to pass typical designing steps and realise the designing process as well as gradually improve their creative skills and abilities to invent functional, manageable and safe solutions. During their work at projects, students activate and develop their reflective and analysis skills, convergent and divergent thinking, inventing and creating. They also establish values, improve professional consciousness, responsibility and team work skills which are crucial for an effective engineering activity focused on the problem solving under current quickly changing conditions.