Miniature Urban Farming Plant: A Complex Educational "Toy" for Engineering Students

Lina Schulze-Buxloh [1]
Rolf Groß [2]

FH Aachen University of Applied Sciences, Germany[1, 2]

Abstract
Urban farming is an innovative and sustainable way of food production and is becoming more and more important in smart city and quarter concepts. It also enables the production of certain foods in places where they usually are not produced, such as production of fish or shrimps in large cities far away from the coast. Unfortunately, it is not always possible to show students such concepts and systems in real life as part of courses: visits of such industry plants are sometimes not possible because of distance or are not permitted by the operator for hygienic reasons. In order to give the students an opportunity of getting into contact with such an urban farming system and its complex operation, an industrial urban farming plant was set up on a significantly smaller scale. Therefore, all necessary technical components like water aeration, biological and mechanical filtration or water circulation have been replaced either by aquarium components or by self-designed parts also using a 3D-printer. Students from different courses like mechanical engineering, smart building engineering, biology, electrical engineering, automation technology and civil engineering were involved in this project. This "miniature industrial plant" was also able to start operation and has now been running for two years successfully. Due to Corona pandemic, home office and remote online lectures, the automation of this miniature plant should be brought to a higher level in future for providing a good control over the system and water quality remotely. The aim of giving the student a chance to get to know the operation of an urban farming plant was very well achieved and the students had lots of fun in "playing" and learning with it in a realistic way.

Keywords: *Urban farming, food production, smart engineering, 3D printing, sustainability.*

1. Aim of the project
Urban farming is an innovative and sustainable way of food production and is becoming more and more important in smart city and quarter concepts. It also enables the production of certain foods in places where they usually are not produced, such as production of fish or shrimps in large cities far away from the coast. Especially in the course of "Smart Building Engineering", the students should get to know such innovative and technically demanding concepts as practically as possible in the courses. Excursions and plant tours at industrial partners certainly contribute greatly to such an understanding, but unfortunately, it is not always possible to show students such concepts and systems in real life: visits of such industry plants are sometimes not possible because of distance or are not permitted by the operator for hygienic reasons. In order to give the students the opportunity of getting into contact with such an urban farming system and its complex operation, a smaller version of such a plant for demonstration and teaching purposes is necessary at university. Therefore, an industrial urban farming plant was set up on a significantly smaller scale.

2. Concept
In order to be able to work on the complex question with all aspects, an interdisciplinary team was formed consisting of students and individual academic staff from various disciplines like mechanical engineering, smart building engineering, biology, electrical engineering, automation technology and civil engineering. Starting from a first simple variant, which was developed as part of a thesis [1], the system was further developed and thus reached a higher level of complexity step-by-step.

3. First implementation
All needed technical components like water aeration, biological and mechanical filtration or water circulation have been replaced either by aquarium components or also by using a 3D-printer [2] for printing self-designed parts like clamps for attaching hoses or spare parts for the filter system.

Figure 1: First set up of the aquarium as a test tank. You can see the skimmer in the technical chamber (far left), the mechanical internal filter (center), the thermometer (center), the pump for aeration (top center) and the circulation pump (top right), own representation.

During the first set-up, a commercially available circulation pump [3] from the aquarium trade was used to generate the water flow. In addition, a mechanical filter [4] and a skimmer [5] have been integrated to remove suspended matter and small dirt particles from the water. The aeration of the water for maintaining a sufficiently high oxygen concentration for living beings was ensured by a small membrane pump [6]. A water heating system [7] was integrated, but only used rarely and removed quickly.
For the production of artificial salty seawater for the aquarium, fully demineralized water from the fully demineralized water system of the chemical laboratories and workshops of the Aachen University of Applied Sciences is used and 30 g / L sea salt mixture [8] from the seawater aquarium trade has been added. After a short time, the added salt has dissolved well in the water. The artificially added seawater was adjusted to a salt content of 25 ‰. To keep this range of salt content it was necessary to add demineralized water regularly, as the air conditioning let the water evaporate from the aquarium and the salt content would otherwise increase significantly as a result.
The cold water shrimp (*Palaemon elegans*) was put in the system and feeding and monitoring of the most important water parameters were initially carried out manually with test strips [9] and food for crustaceans [10] from the aquarium trade. All determined values such as pH value, water temperature, nitrate and nitrite content and salt content were documented, in order to learn more about the system and its reactions to changes.
This simple “miniature industrial plant” was also able to start operation and has now been running for two years successfully. Due to Corona pandemic, home office and remote online lectures, the automation of this miniature plant should be brought to a higher level in future for providing a good control over the system and water quality remotely.

Water Temperature	
Water Parameters/Quality	Salinity Alkalinity Nitrite Nitrate Ammonia Phosphate Calcium Magnesium pH-Value
Oxygen Content of the water	
Water level of the aquarium and the tank providing additional water	
Water circulation	
Automatic Feeding	
Monitoring of Equipment	Pumps Filters Dosing

Table 1: Overview of important parameters of the system, which should be controlled automatically and (as far as possible) with remote access.

4. Further development

Due to the corona pandemic and the associated home office regulations, it was not always possible to monitor the aquarium on site. Therefore, in the next step, better remote maintenance and monitoring should be integrated so that it can be better estimate whether and when an intervention is necessary without causing damage. In order to automate the feeding, which is necessary every 2-3 days at the latest, an automatic feeder from the aquarium trade was put into operation, which only needs to be filled every 14 days and independently dispenses food into the aquarium at fixed intervals.
A biological filter system with pellets was integrated in order to solve the problems with the water quality that initially occurred after a few days in operation with shrimps due to sharply increasing nitrite concentrations: The pellets in the bioreactor serve as a settlement area and carbon source for anaerobic bacteria. In this way, these bacteria can live in the bioreactor and, through their metabolism, biologically break down the resulting nitrite into molecular nitrogen, which can then escape from the water as a gas. After a running-in phase, the problems no longer occurred and the water quality remained consistently good enough to provide good conditions for the shrimps.
In the next step an additional tank for demineralized water was added to the system, so that a small pump can add demineralized water at regular intervals to compensate evaporation and to keep the salinity stable.

5. Conclusion and outlook

The ability to observe and control the consequences of a change in a system in real time was a very instructive experience for the students: the complexity of biological systems, which sometimes show unforeseen changes, could not have been realistically represented with a model or a simulation of such a system. The aim of giving the student a chance to get to know the operation of an urban farming plant was very well achieved and the students had lots of fun in “playing” and learning with it in a realistic way. With increasing level of complexity the system became more and more realistic. The idea to make students from different courses work together was very effective: The cooperation between these students was very effective and gave everyone involved a better and more comprehensive insight into the solution of a complex interdisciplinary problem. The project promoted interdisciplinary teamwork and communication very well, so it was a good training for the students’ future business life. Therefore, such interdisciplinary projects should also be offered and supported in the future, especially for students in the higher semesters, as part of their final theses. Developing an existing project further and bringing it to a technically higher level was very motivating for all the students involved. Some students said it was more like an exciting game than a thesis.

References

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[4] Eheim pick up 60
[5] Fluval Sea PS 1 Abschäumer
[6] Tetra APS Aquarium Luftpumpe 10-600 l
[7] Tetra HT Regelheizer
[8] Tetra Marine SeaSalt
[9] JBL Aquarienwasser-Teststreifen, 50 Stück, PROAQUATEST EASY 7in1
[10] Tetra Crusta Menu