Expository animations

Can Instructional 3D Animated Visualization Enhance Users' Comprehension of Aquaculture Process Plant?

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ABSTRACT

Modern aquaculture industry starts to face inventions of the fourth industrial revolution where the machines communicate, share and transform information into the actions earlier done by humans. The shift concerns mostly industries operating in open seas with the main focus on fish welfare operated by autonomous technology. Land–based aquaculture still endures trend of automatization and bets on operators' eyes culturing the species. At the same time, products and components designed for land–based process plant goes through continual change. Prioritizing product development is in many cases followed by neglecting appropriate instructional material of final product crucial for the user. This paper suggests conceptual purposes of possible instructional animation outcomes, applicable in fast developing aquaculture industry. Going through general principles of aquaculture process plant in order to distinguish characteristics of land–based facility from broad field of aquaculture industry. Continuing with principles of expository animations enclosing it with its nature of convenient design and usability. Concluding the findings with a concept suggesting directions for design of three-dimensional expository animation in context of dynamical processes.

KEYWORDS: instructional animation, 3D visualization, aquaculture process plant, users' comprehension

1. INTRODUCTION

Product and service development driven by designers requires accurate consideration of users' interaction and understanding users' experience with the product through whole process, from the scratch to the final (Press & Cooper, 2016). Even if the product or service is designed properly the novice users could struggle with its functional features. This attitude especially regards products' usability in terms of its dynamical and mechanical processes. Recently, the term of Industry 4.0 appeared in context of aquaculture industry. It may invoke associations with machines overtaking humans' jobs or with internet of things and its own anatomy of autonomy (Hukkelås, 2018). Product development boost the implementation of sensors, actuators and cyber physical systems into the products of aquaculture industry sector (Norsk Fiskerinæring, 2018). Concepts such as internet of fish supplying internal data communication between underwater sensors and applications connected to these giving users broad range of information about cultured fishes are in common use. When looked at land–based aquaculture, human maintenance still keeps its stabile position by side of digital automatization (Soltveit, 2018). It is followed by easier control of the facility based on land and lower amount of cultured fish compared to cages located in open seas.

But which type of instructional material supports late industrial products and processes in the land–based aquaculture facility? Particularly, the core interest in this paper are the issues of users' comprehension of products in the field of aquaculture process plant. Also, to examine the possibilities for implementing 3D visualization and expository animations into this industry sector.

Expansive implementation of instructional animations has founded its place in different spheres of manufacturing and production industry. Beneficial features of instructional animations can simplify complex information demonstrated to the novice users of any product or service through its dynamical effects and continuous variability (ThePro3DStudio, 2018). In addition to positive results regarding appliance of animations into the improvement of understanding complex dynamical systems or visualizing information of three-dimensional artefacts, some research outcomes suggest that animations seem to be particularly challenging (Boucheix & Schneider, 2009).

The aim of this review is to link together theoretical base for qualitative animation design approach with appropriate focus field in broad spectrum of aquaculture structures, processes and principles. The answer on the questions stated above may built on reasonable argumentations gathered with help of literature study together with design project conducted in parallel with this article. The paper will firstly step into general principles of land–based aquaculture plant. It will continue within cognitive processing in instructional design together with three-dimensional visualization as the solid backgrounds for forthcoming design of the animation. It will inspect efficiency of the instructional animation relating to users' controllability besides its interactive features. Furthermore, it will serve more detailed study of instructional functions of animation together with its advantages and disadvantages. After all, alternative design approach involving sequencing of the animation will be also considered.

2. METHODS

This article is built upon literature review, with sources primarily from articles, books, researches and web-sites. Theory related to aquaculture process plant are withdrawn from the book Aquaculture Farming Aquatic Animals and Plants and from authors' design research project. Articles related to animation scoped to instructional animation were found under fields Learning & Instruction or Computers & Education. Articles referred to this paper has aimed to review on how and if the expository animated graphics enhance users' comprehension of displayed subject matter. Especially, one of the criteria for this review lies in examining animations conveying dynamical systems or its internal processes, mostly in the industrial context. Articles related to tutoring practical composition of the animation in a certain software were therefore not included in this paper.

3. GENERAL PRINCIPLES OF AQUACULTURE PROCESS PLANT

Following section will serve elementary insight of contemporary land–based aquaculture system, its structure, water exchange and intensity. This part of article may aid the reader to understand and thus imagine an aquaculture process plant. The core in this part is land–based aquaculture plant together with fish tank solutions. Complex aquaculture system has a great diversity in way the plant is operated and may seem challenging to very novices. Land–based aquaculture facility has its established structure principles, with great variations in forms the plant is built up. Among the pipe solutions characterized for land–based facility may the inlet water, outlet water and fish transportation cover usual processual principles. In generall, tanks are located on the land above ground and may be constructed in interior or exterior environments. As a great advantage of tanks is the ability to build it in environments usually inappropriate for aquaculture, since the water inlet is transmitted through the process plant (pipes) and does not come in direct contact with local soils, see fig.1 (Southgate & Lucas, 2012).

Figure 1: Land–based indoor facility using tank solution as the aquaculture structure. Sisomar AS aquaculture plant, Norway. (Photo by AKVA group, 2018)

Overall, most common materials are synthetics such as fiberglass, polyethylene reinforced with steel or concrete. Design of the tank system solution should keep optimal water flow characteristics and thus achieve exact water exchange rate for the actual cultured species. This supports good quality of water which further prevents creation of 'dead places' inside the fish tank(Southgate & Lucas, 2012). Inlets and outlets have its primer function in regulating water exchange inside the tank system. Control and adjustment of the inlets into the tank systems is managed by using valves. At the same time, inlets driven into tanks needs to provide water movement in order to transform the water through the system structure and to retain quality of water. Water movement uses also to transport the fish between tanks, to vaccination facility or to final point e.g. boat or car. Water is delivered through pipes into tanks and may be also supplied by addition of pure oxygen to the process water(Southgate & Lucas, 2012). Outlets has its function in "maintaining water level, retaining cultured animals, allowing drainage of the system structure and removal of wastes" (Southgate & Lucas, 2012, p. 23) e.g. dead fish and feces.

Beside the technology, human maintenance of the land–based facility is a crucial element of keeping fish environment healthy and thus avoid fatal loses. In semi–closed system, where the water is continuously brought into the facility and do not provide any recirculation, it causes need of control over the water quality. The control involves oxygen rate inside the tank and water flow which can be expanded, reduced or stopped (Southgate & Lucas, 2012). For instance, optimal water flow conducted through the pipe streaming water into the tank gives the operators ability to train the fish and keep forage level low. The operators provide this manually through the components where the water flow blended with right amount of oxygen is maintained automatically. Owing to healthy production of fish, operators demand great comprehension of the products and components conducting the water through the aquaculture plant. Human operation of the aquaculture process plant shows real importance in understanding the components in order to sustain the maximum of cultured species alive. As the operation of the products outcomes in dynamical processes e.g. water mass combined with water flow, may these be depicted via dynamical medium. Thus, the concept of instructional animation as learning tool for the operators might convey dynamical results of operations provided through the products and components.

Figure 2: Operator at land–based indoor facility. Sisomar AS aquaculture plant, Norway. (Photo by Sisomar AS, 2018)

4. BACKGROUND

4.1 Cognitive processing in designing instructional material

To design, develop and implement any instructional material requires authors' understanding of humans' mental possibilities (Kirschner, 2002). This part of the paper will introduce the reader into the cognitive load theory (CLT) also known as cognitive processing what may offer important key to design any instructional animation. Cognitive processing architecture builds upon two types of memory: short–term memory also called working memory, is the memory in current use, your consciousness and activities related to continuous present. An issue, especially crucial for instructional designs, "is that it is limited to about seven items or elements of information at any one time (Baddeley, 1992; Miller & Newcomb, 1956; in Kirschner, 2002). Further, working memory needs to systematize in order, differ and correlate presented information and thus the human mind cannot accelerate more than two or three elements of information at the same time. Permanent knowledge is stored via long–term memory, it also gives meaning to our current existence. Due to most scientists' implications is the volume which can be stored in long-term memory unlimited (Kirschner, 2002). Thus, human brain has the ability to save large scale of complex data in long-term memory. Cognitive processing links restricted working memory together with unlimited long-term memory. Therefore, instructions which requires larger cognitive demand of individuals' working memory may cause problematic challenges. Thus, the designed instruction needs to consider processing limitations of individuals' working memory. Nevertheless, consider how the presented information has been stored in the individuals' long-term memory, and if the acquired information is ready for re-use (Kirschner, 2002). Further, the ability to gain understanding of mechanical systems from static figures associates with act of creating mental animation (Boucheix & Schneider, 2009; Svartdal, 2018). Several research studies imply that mental animation is equal with spatial abilities. It proposes higher differences between low and high personal spatial abilities, especially for more advanced mechanical components which requires greater effort of conducting the mental animation. Moreover, individuals with high spatial ability may surpass others with low spatial ability in comprehension of mechanical systems presented by static figures followed with text guidelines (Boucheix & Schneider, 2009).

4.2 Three-dimensional scientific visualization

Scientific visualization with help of computer graphics, such as 3D, creates visual representation of images which gives the user easier comprehension of complex scientific concepts or outcomes. The main difference between 3D visualization and 3D scientific visualization lies in its feature of users' virtual research in real time, e.g. exploring or modifying the environment through VR or controllable animation (Popovski, Nedelkovski, Mijakovska, & Popovska Nalevska, 2016). Scientific visualization builds up from processes involving simulation, data extraction, visualization and rendering (Popovski et al., 2016). Transforming artificial 3D models, scenes or environments to 2D picture describes the process of rendering and stands for one of the most crucial activities typical for visualization development (Muller et al., 2017). Rendering engine can be built into modelling software or offered as a separate rendering computer program. Interfaces designed for intuitive exploring of 3D volumes in artificial environment allows the user more detailed inspection of the space, objects and its relations (Popovski et al., 2016). This artificially displayed environment, e.g. through render, animation or VR could represent a setting or a vision based on reality. But scientific visualization is aimed to visualize descriptive or informative abstract data, rather than sharing real object in the real world. In terms of animated graphics, to reach the ultimate result, the animation can be converted to controllable user interface, a virtual workshop, where the participant can modify the data and maintain the simulation of artefacts and environment on their own. "Scientific visualization is essential in interpreting data for many scientific problems. It transforms numerical data into a visual representation which is much easier to understand for humans" (Popovski et al., 2016, p. 439)"

4.3 Animation

"One particular instance of multimedia instruction is animation, in which objects appear to move continuously" (Berney & Bétrancourt, 2016, p. 150). More specified description could refer to Bétrancourt & Tversky (2000) whose supposed that animation conveys sequences of frames which are appearing continually; one after another and are driven by the designer or the user. Animated graphics can be categorized into 3D and 2D computer animation, where 2D animation is built from two-dimensional geometry and do not depict the depth. The 3D animation may seem more realistic; indeed, it is built from 3D geometry and depict the depth thus offer feasible opportunity for spatial perception (Muller et al., 2017). As it transmits alteration with continuous use of time, the animation could bring advantages into the comprehension of dynamic systems in the fields of complex industrial or mechanical processes. Although few research studies inquired into beneficial effect of the animation in learning purposes, there are literature reviews which support advantageous assumptions of instructional animations. On the other hand, many literature studies focused on comparing animated and static visualizations offer contradictory and uncertain results concerning instructional or educative purposes of the animations. Furthermore, some studies report that the animation did not aid to more effective comprehension compared with static visualizations (Berney & Bétrancourt, 2016).

4.4 Are animations efficient?

One reason why the animations could fail may cause their tendency of breaking down the principle of comprehension. Mental limitations of some individuals could constrain understanding of the modifying visual situation and could result in misunderstanding. Furthermore, changes may concern the parts of elements of a dynamic system while the movement of others or of the whole mechanical system may be simultaneous. Besides, involved users need to keep attention to external resources, such as text or audio. In this manner could animations seem challenging to perceive and require perceptual and conceptual mind (Boucheix & Schneider, 2009).

4.5 Increasing value of the animation through interactivity

In terms of controllable and uncontrollable animations can some dynamical processes visualized in a controlled animation give the user better understanding whilst other works better with uncontrollable animation. This provides interactive approach of the animation and the features such as slow-motion, replay or perspective modification could enhance controllability. Boucheix & Schneider (2009) imply that user controllability of the animation may lead to lower mental demand and thus benefit users' comprehension of the subject matter. On the other hand, allowing controllability of the animation has also its disadvantages. Individuals who are novices to the animation tool may struggle with interactive features and turn their attention upon individual perceptual interests rather than pieces of information related to subject matter (Boucheix & Schneider, 2009). Interactivity as an added function in the animation can strength users' perception and comprehension when inferring complex visualizations. To give the opportunity to start, stop and replay offers the user deeper examination of details conveyed in the animation. Furthermore, zooming in and out or allowing alternative three-dimensional sights can serve even greater chance for understanding (Tversky, Morrison, & Betrancourt, 2002). In addition, functions embedded in animations offers even more than interactive features, detailed effects could enhance usefulness and advance user experience by making it fun and engaging (Audi, 2018).

Boucheix & Schneider (2009) developed four hypotheses based on different approaches when composing an animation including both sequential static frames, fully animated system process combined with levels of user controllability. These levels were divided to non-controllability, partial controllability and fully user-controlled animation of mechanical system. The final outcome of their research experiment comparison showed that visual presentation of static graphics was equal as fully animated dynamic mechanical system concerning users' creation of mental model. In addition to this, experiment towards user controllability of the animation has shown ineffective impact on learners' comprehension. Contrarily, B&S (2009) also imply that user controllability could increase efficiency in other animation contexts or in distinctive subject matter.

4.6 Instructional functions and cognitive processing of animation

In a certain condition may animations turn users' attention to a specific area displayed through instructional data, such as dynamic arrows or visual cues. Further, the animation may be used as a tutorial of an operation to be understood, kept in mind and carried out by the spectator. Moreover, an animation could help the user to understand dynamic functions of the mechanical steps conveyed simultaneously, such as flush technology systems (Berney & Bétrancourt, 2016). One of three possible functions of expository animation is its ability to transmit composition of a system. This type of animation renders in what way the parts or components of a system are organized in their architecture. Secondly, animations can transmit dynamic movements or behavior of the system and its components. Thirdly, animation can transmit "the causal chain underlying the functioning of dynamic systems" (Berney & Bétrancourt, 2016). In other words, "causal chain" can be understood as many sequences presented in original order and within specific time apparent in the system.

5. DISCUSSION

5.1 Advantages and disadvantages of animation

When looked at beneficial features, an evident advantage of the animation lies in its direct illustration of depth and spatial environment of the elements played and displayed continuously, such a smooth visualization of any dynamic system (Berney & Bétrancourt, 2016). Compared to static graphics, these may require mental spatial creation developed manually in users' mind, which may lead to higher probability for users' misunderstanding. Concerning disadvantages of the animation, there is no opportunity for comparison of the altered information afterwards, but static visual graphic offer action of discussing and re-inspecting different stages of presented dynamical process or a system (Berney & Bétrancourt, 2016; Tversky et al., 2002).

Other disadvantages caused by animation:

- Quite huge amount of information to be processed.
- "Transience" of the animation – its motion and difficulties related to it. Transience could, on the other hand, lead the observer to predict or foresee upcoming information, and thus make visual information easier to endure.
- Retrieved information from visual motion – could end up in cognitive overload or in fail perception of the motion.

Comprehension of the animation is driven by individuals' knowledge and spatial ability. Compared to learning from text and static figures, the research has shown that visualization could outperform text information, but animation was not taken into account. Categorization of the animations proposed by Carney & Levin (2002) divided presentational animation from decorative animation, where decorative functions of the animation does not directly represent instructional information (Carney & Levin, 2002; in Berney & Bétrancourt, 2016). Furthermore, functionality of the animation could be classified in the level of abstraction characters displayed in the animation.

5.2 The content to be animated; Appropriate design of animations

A designer developing an animation need to consider the question: In which time is animation correct medium for use? Bétrancourt & Tversky (2000) suggest that animation is not likely to be useful if the data to be visualized are familiar to the spectator and has already been able to create a mental model of the subject matter, or the subject matter is smoothly imaginable. If the beneficial effect provided by animation seem to be low compared with static visualizations, the problem may lie in visuals' low necessity to be understood by an individual. Lastly, to convey information through animation meets its advantages only if it is adequately designed for certain purpose (Bétrancourt & Tversky, 2000).

The second question designer would deal with is "When would an animated display be more effective than static one?" (Bétrancourt & Tversky, 2000, p. 320). The development of animations may conclude in additional costs for designer creating animation and also result in spectators' higher cognitive load of the subject matter presented in the animation. Animation is likely to enhance understanding of a certain task in the contexts of transferring an idea or a standard principle over time, a dynamical movement in a certain course or conveying relations between time and space. Or, to transmit a mobile process that creates difficulties for spectators to imagine it on their own. Due to Bétrancourt & Tversky (2000) the interactivity during instruction enhance understanding and provide enjoyment.

5.3 Sequencing: alternative approach to designing instructional animation

Lowe & Boucheix (2016) suggest that conventionally-designed animations presenting complicated data to the spectators who are missing background context has confirmed to be problematic. They characterized these problematics causing negative effects by dynamic features of the animation, but at the same time its direct and dynamic presentation of information related to both space and time has proven to be main advantage of the animation (Lowe, 2003, in Lowe & Boucheix, 2016). Among many improvements developed by different researchers, such as controllable interface of animation or allowed modification of animations' speed, Lowe & Boucheix (2016) propose that "problems learners currently have in processing animations could be reduced by a fundamental re-thinking of animation design." Research looked into alternative propositions of designing instructional animations and compared conventional and novel forms of animation with focus on quality of extracted mental model and understanding of dynamics depicted in the animation.

Researchers use theoretical framework called Animation Processing Model (APM), see fig. 3, which portray processes related to understanding and further acquiring knowledge from "conventionally designed" instructional animations. The APM can be used for identifying learners' difficulties when altering information from the animation and to propose alleviation of such struggles. APM consist of five main phases, but can be categorized into two wider processing activities:

- Decomposition; including phase 1 where the spectator analyzes and "decompose" the animation into the units which further aid to create a mental model.
- Composition; including phases 2-5 where the spectator converts decomposed units or events into the more durable knowledge constituting a mental model

of the content presented in the animation.

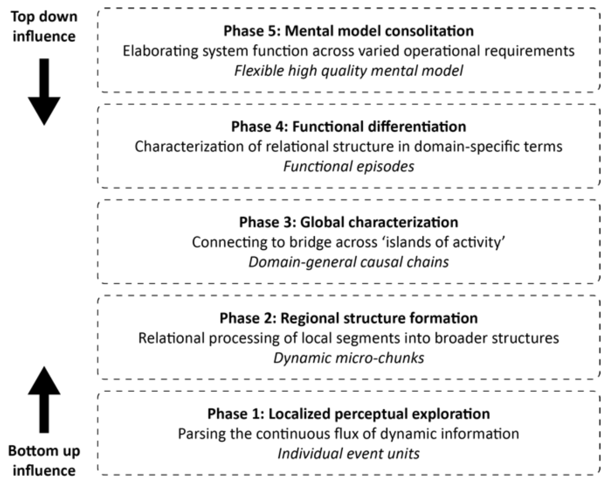

Figure 3: Animation Processing Model (Lowe & Boucheix, 2016)

In some cases, there may be individuals who could struggle with decomposition of a complex animation, especially those who are missing specific background knowledge of the animation subject. In addition to this, others may extract information concerning their personal perceptual interests and thus do not infer appropriate data for mental model creation. Therefore, authors' objective was to ease decomposition processing stage (Phase 1) by serving the spectator already decomposed data through dividing comprehensive animations into the sequences presented in its natural order established in animation as a whole, in terms of *"the contiguous condition"*. Subsequently, the analysis results in authors' expectations that animation built from sequences provided better quality of mental model developed by the spectator (Lowe & Boucheix, 2016).

6. FINDINGS

Expository animations used in research studies reviewed in this article provide poor visual information quality what could be a reason why it often results in doubts regarding the fail of animated graphics compared to static graphics. Animations owing to provide instruction describing complex dynamical systems are often missing design approach and this may lead to its low benefits in contrast with positive research outcomes examining non-animated graphics presented to spectator. This argumentation does support advantages of dynamical animation but looks critically on aspects in which way the animation has been designed. Therefore, the concept of giving the animation as learning tool to the operators of the land–based aquaculture plant, in addition to established learning methods, may enhance their understanding of the certain task if it is built in appropriate way. The content might be provided by an application enabling transmission of the animation, such as PC, virtual reality or even augmented reality. Transmitting medium needs to be accessible to every user maintaining the processes of product or component involved in depicted content. As one of the most essential extraction from this paper is preferability of 3D geometry visualization instead of 2D illustrations. It is mostly based on 3Ds' ability to depict more real and physical representation of actual case. Three-dimensional geometry decreases illustrative level which is common for 2D graphics and provides genuine experience of the artefact presented in the animation since the product is likely similar to the real one. Another aspect to consider is to give the user ability control over the application and thus allow modification of depicted data. The user would be able to simulate in real time and confidently explore the product in very detail. This might be supplied not just with controllability of the animation e.g. to stop, replay or to modify perspective of the artificial environment, rather by stepping into the virtual scene aiming to modify dynamical process. Operators might share decisive commands through the interactive animated graphics with the real product providing actual dynamical function e.g. water inlet.

7. CONCLUSION

In light of findings from this literature review, a set of proposed design approaches for instructional animation have been mentioned in upper part. By following these, designer would be able to capture changes in development phase and adapt recommend methods when designing expository animation. Designer needs to build the animation from elements crucial for conveying the message, thus the spectator is not confused by superfluous components out of the subjects' context. Furthermore, it is possible to conclude that expository animation, despite its different interpretations, may be adapted into the specified field of aquaculture industry, as supplementary instructional tool, in a very short time. If applied as (just) instructional medium there are as far as few challenges to meet when designing the animation. On the other hand, making animation interactive and supported by other responsive systems which may share its features with physical components in real time opens the door to new disciplines.

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