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FLIGHT SIMULATOR FOR SERIOUS GAMING

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ABSTRACT: *Providing entertainment is the primary concern of the gaming. Once this primary objective alters to provide learning and training materials it calls simulators or the serious gaming. Learning through experiencing or facing the actual scenario is considered as an effective learning technique. The limitations of the experiential learning and how the simulations are going to address those limitations are also reviewed in this paper. Aviation field is one of the most critical and potentially high risk areas where one has to spend lots of money and resources in training scenario. Hence the serious gaming concepts have being playing as an effective cost cutting solution in aviation training. In this paper it is intended to discuss the seriousness of a selected flight simulator and how they adopted the teaching learning concepts. How the simulator can be used in the learning curve is also discussed separately*

KEYWORDS: Serious Gaming, Flight Simulator, Flightgear, Experiential Learning

INTRODUCTION

Computer games are basically focused on providing entertainment and fun. When games are designed with different intensions like teaching, learning and training, then it is called serious gaming applications or simulators (Michael & Chen, 2005). Serious gaming concept copes with solving real world problems more than providing entertainment. In several fields, training is a risky, costly and demanding process. Pilot, astronaut, military, fire rescue training and medical surgery training can be pointed out as such domains. In order to reduce the potential risk and training cost serious gaming concept can also be adapted to various fields such as health, security, inland defense, communication as well as in education fields (Djaouti, Damien, Alvarez, & Pierre J, 2011).

"Serious Gaming" is a combination of the aspect of "seriousness" and the "gaming". The seriousness refers to the contents of the application which is used in teaching and learning process. Federal Aviation Administration (FAA) has proclaimed that human factors, both mental and physical, significantly affect to the aviation safety. Practically this is a common fact to all fields. Most of the time worker injuries, wasting time and accidents are caused by those factors (Aviation Maintenance Technician Handbook – General- Chapter 14, 2013). Training will provide a basic platform to stand in critical situations and experience it. That will improve both mental and physical fitness which will directly affect in reducing the human error factors.

As the technology grows rapidly during the past decades hardware and electronic device cost has being reduced. There is free and open source software available for physics integrations and virtual environment rendering. Some free and open source software provides the

framework to implement the projects on top of that. Flightgear (Flightgear, 2015), GiPSi (GiPSi), spring (Montgomery, 2002) and OpenSurgSim (OpenSurgSim, 2013) are some frameworks where developer can integrate his solution without building it from the scratch. With those available resources real experiential training has been replaced by the low cost virtual immersive environment training in numerous fields. Albeit the serious gaming concept is widely spread, the discussion is going to be bounded to the aviation domain.

EXPERIENTIAL LEARNING

Experiential learning is a different paradigm other than the traditional reading writing education. This concept has the proper combination among learning, training and other life activities and extracting the knowledge itself. Acting and experimenting are identified as teach enhancers (Winett, 1972). According to the Kolb, experience creates a concrete basis of learning through experiencing (Kolb, 1984). It enhances the observation and decision making power. Lewinian Model present a common characteristics of experiential learning with four stages proceeding in spiral way.

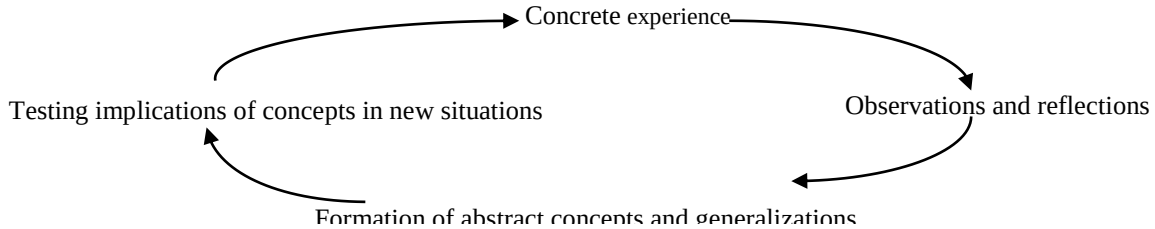

Figure 1. The Lewinian Experiential Learning Model (Kolb, 1984).

Even though this experiential learning is significant with knowledge gaining, real life scenarios has limitation in following this process. As briefed in introduction phase cost of experiment, ethical and social reasons and the safety issues has affected in this process. Furthermore the impossibility of creating natural conditions (storm, snowing, forest fire etc.) has again condemned the concept, learning through the experience.While concerning the importance of learning through experiencing and its limitations, Simulation environments would be the best educational environment where almost all the limitations were addressed in proper manner.

DEVELOPMENT STRATEGY

As discussed above simulations are used in training with practically difficult scenarios. The experience gained from simulation would be impossible in real world due to the cost, risk, time and safety. For the military training of bombing scenario it is not applicable to practice in real environment. It will risk lots of properties and even the life of the pilot. Same goes with the medical surgery training process. Normally surgeons have to practice using corpse or small animals such as rats. Both scenarios don't give the proper education for a surgeon. Here the simulation plays as a great rescuer. With the prevailing technologies it is possible to integrate physics to simulate the real time pressure, bleeding and beating to replicate a real patient-doctor contact.

In pilot training there are difficult scenarios such as engine fire, stormy or snowing weather, night landing, and landing on a mother ship where it is impossible to get the real experience without a proper training. These scenarios can be successfully replicated on the virtual environment and give the real feeling to the trainee. But the training process cannot be 100% substitute from the simulation training. This simulation environment will only cover the practical section where they have to use the real equipment or flights. Even with the simulators

there are impossible scenarios where it cannot be simulated to get the real feeling and apply the real time motion or physics. These activities which are within the simulation boundary should be identified in feasibility study.

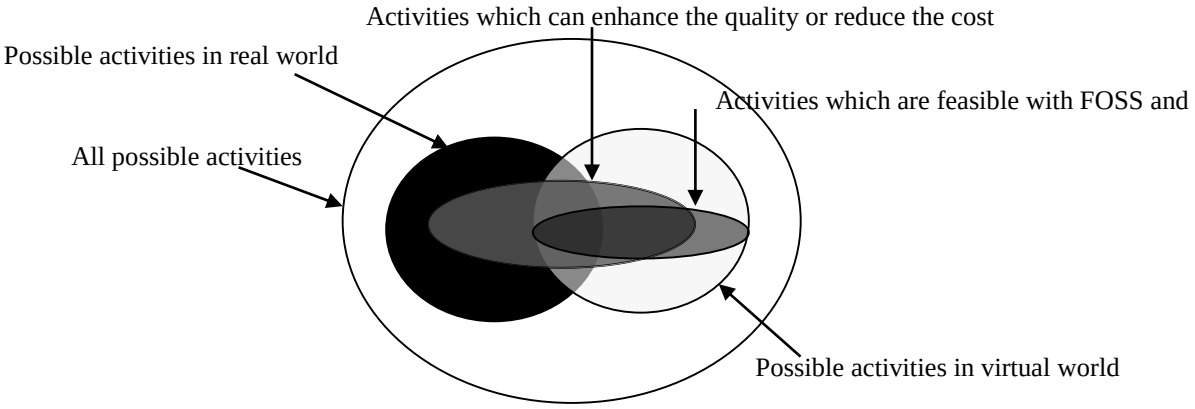

Figure 2. Activities identified in first stage (Sandaruwan, Keppitiyagama, Dias, Kodikara, Rosa, & Senadheera, 2012)**.**

Behavioral realism can be improved with higher accuracy of motion prediction and visualization (Yin, 2010). High polygon count could increase the mesh qualities with better realism. Due to the limitations of computational power there will be implementation and rendering issues with those meshes. Physical realism can be increased by interfacing the solution with real equipment. As the opening section reveals this interfacing has become a low cost procedure with the COTS hardware. In the fighter jet simulation it is used those COST hardware in interfacing process. Only the right and left consoles were interfaced with throttle. The front meter gauges and integrated warning panels were displayed in wide screen. Physical, Semi-physical and digital simulation technology is generally used in astronaut training. When considering this the fighter jet simulation can be considered as a man-in-loop emulation system where applied semi-physics and simulation method (Jian-gang, Jun-yi, & Ning, 2010). Further the fighter jet simulator can be enhanced using the motion system to increase the physical and behavioral realism

FLIGHT DYNAMICS

The study of the execution, stability and control of the flying objects is considered as the flight dynamics (Stengel). In flight dynamics it is studied how the forces are affecting or influenced the flying objects with their speed and orientation along with the time. These mobile objects are measured with an external frame which is defined as static. Earth frame, body frame and wind frame is used as referential frame for a flight. Earth frame is fixed relative to the earth while the other two frames are defined relative to the airplane center of gravity. Except defining the relative frames it can define relative orientation of the reference frame and can be expressed through various forms. Direction of cosine or rotation matrices, Euler angles and Quaternions are some of such techniques (Wikipedia, 2014).

To create the environment more familiar to the real world environment flight simulators has adopted many modules to their physics model. Flights, ships and vehicles are rigid bodies with complicated motions as they have both translation motion and rotation modes. The shape of

the rigid body affect in the motion producing. Mathematical formulation was used in calculating the friction and rotation caused by the shape. The fixed and unchanging space of the rigid body is defined as the body shape. Rigid body forms six degrees of freedom complex motions and roll, pitch and yaw are the most critical flight dynamics parameters. These can be defined as the angles of rotation in three dimensions.

The lift generated by the wings of a fixed wing aircraft is depending on the pitching of the nose and relatively increase or decrease the Angle of Attack (AoA). The roll angle is to change the horizontal direction of the flight (Wikipedia, 2014). In the flight simulation movements, behaviors of the air and the flight are studied. How the forces react with each party are identified and mathematically fed to the simulator. In flight dynamics there are three basic flight dynamic models which were adopted in flight simulations. With this flight dynamic models it was ease to implement the real time physics with the simulations.

LRCSIM

NASA originally developed this FDM. Flight gear used this FDM up until 2000. But no longer supports this. Engineering flight simulation facility at NASA developed LaRCsim. This is used to debug aircraft flight control laws. Flight controls written in C or FORTRAN. This is basically a set of C routines that implements a full set of equations of motion for a rigid-body aircraft in atmospheric and low-earth orbital flights. This used additional subroutines that describe the aerodynamics, propulsion system and other flight dynamic elements of a specific air vehicle. After combined with specific routine of vehicles LaRCsim provides a simulation of vehicle for engineering analysis and control law development. This can be seen in both desktop and cockpit based near real time simulation. Current version is lack of following features (Jackson, 1995.)

- Measures are in English Units.
- Rotating oblate spheroidal earth model, with aircraft C.G.coordinates.
- Vehicle X-Z symmetry is assumed

Version 1.4 had following features.

- Six degree of freedom
- LaRCsim is able to remember the previous settings.
- Initial conditions specified at by a flag on the command line.
- Time step and initialization flags are now passes to model routines.
- LaRCsim is self-contained so it does not need any supporting files to run.

JSBSIM

JSBSim was launched in 1996 aiming at modeling fight dynamics for aircrafts. Flightgear adopted JSBSim instead of LaRCsim in 1998 (Berndt J. S., 2004). JSBSim is developing under the GNU General public license, so it is available for any simulation. It's simply a collection of programing codes. JSBSim has basic Object Oriented Concepts such as Encapsulation, Inheritance, Abstraction and polymorphism. The Standard Template Library which contains algorithms and containers such as vector class is available with JSBSim. The class structure of the JSBSim represent "family tree" framework. Aerodynamics, propulsion and flight control are the set of models which comprehend the JSBSim framework. Most of the programming code is written in C++ while C language is used minimally. JSBSim supports multi-platform

environment such as Windows, Linux, Apple Macintosh, and even the IRIX operating system from Silicon Graphics. JSBSim is proven its value in market by being a pioneer in larger, full features flight simulation applications (Berndt J. S., 2011). JSBSim supports both English and metric units while LaRCsim only support English units. This unit casting is done with changing the unit parameter. Following example shows the definition of wingspan in feet and meters (Berndt J. S., 2004).

```
<wingspan unit="M"> 10.91 </wingspan>
```

For further mathematical equations and flight dynamics characteristics JSBSim use the data tables. This provides configured algebraic functions which follow up the mathematical syntax in MathML. If the two variables need to be multiplied then it is enclosed with `<product></product>` clause. There are other functions such as sum, min, max, avg, pow etc.

Flightgear, Outerra and OpenEaagles are few applications which use JSBSim for different perspectives. Flightgear uses JSBSim as the basic flight dynamic model for their simulation (Flightgear-wiki, 2013). Outerra incorporates JSBSim in their world scenery modeling to enhance the effect of viewing ground from an aircraft or rocket (Outerra.) While openEaagle uses JSBSim for enhancing the accuracy of their simulation platform (OpenEaagles)

YASIM

YASim is commonly used in Flightgear simulation. YASim uses basic geometry of the aircraft to generate the primary aircraft characteristics. If the solid flight data is not available and only the flight geometry is available then it is fine to use YASim otherwise JSBSim is the best flight dynamic module to be used for a simulation (Flightgear-Wiki, 2014)

FLIGHT SIMULATOR BASED TRAINING

As the generations are more familiar with the digital media adopting the gaming concept in learning is a successful and timely convenient. However as discussed above as the games are used in learning and training purpose other than the entertainment gaming concept should enclose some qualities to attract the student. The visual realism of the simulation should be one main point where the trainee feels the same real world mentality in the simulation environment. Hence the simulation environment should boost up the visualizing, hearing, feeling and interpreting qualities (R. Batista, 2008).

A game is a structured or semi structured context with goals that players have to obtain, overcoming challenges introduced by the context. In this process the goals and the challenges contained educational purpose then that game can be categorized as an edutainment one. When applying this with flight simulators, it should have goals such as landing to Bucharest airport, taking off a MIG-29 fighter jet. To achieve the goal trainer should be given constraints; weather conditions, abnormal behaviors or normal state.

This educational gaming is effecting than the traditional learning. Games have characteristics such as motivation, cooperativeness, meeting the educational objects; allow applying the concepts in practical scenarios, favor in oral and cultural awareness, respect to others, teamwork (Gouveia, Lopes, & Carvalh, 2011). According to a research survey carried out by Paulo David et.al in military field it has shown motivation for military lifestyles has increased

in military game players (Simões & Ferreira, 2011). Likewise it can be adopted above characteristics to the flight simulations.
Visual realism should be there in order to give the exact experience to the user. Awareness, sensitivity and the visual contrast should be there in order to provide a high visualization. Simulator adaption syndrome is counted as a negative design impact (McCaffrey). In its' sever form dizziness, nausea, sweating and vomiting can be seen. This is a form of motion sickness. With the increased width FOV display system this negative impact could be reduced. In the beginning of the simulator training this was a serious challenge to the designers.

Interaction of the devices has enhanced the quality of simulator based learning. Performance of the hardware and electronic devices has increased rapidly during the past decade and cost has gone down. With the interfacing of the cockpit it can have the real world feeling. Integration of the real time physics and this commodity off the shelf hardware provide accurate scenarios. As the interaction between younger generation and technology grows up rapidly, idea of using augmented and virtual environment in teaching and learning process have proportional advantages (Skill Evolution Report, 2008). Number of research was carried out to identify how the simulation game favors the training process. Whitehall, McDonald (Whitehal & McDonald, 1993) and Ricci (Katrina, Cannon-Bowers, & Janis, 1996)et al showed that integrating game features improves the learning. In 2007 Garris et al. presented some individual attributes that a game should have to be a good educational effective tool (Garris, Ahlers , & Driske, 2002).

"Capability" is the mental and physical skills that need to be developed in the learner by playing the game. These capabilities lie as cognitive, psychomotor and affective skills (Yusoff, Crowder, & Gilbert, 2010). "Instructional content", "Intended Learning Outcomes", "Serious Game Attributes", "Learning Activities" (challenging and goal driven), "Reflection", "Game Genre" and "Game Achievements" are the attributes which were proposed by Garris et al. Instructional content and Learning outcome are depending on each other. Serious game attributes tied with learning activities extract the knowledge through entertainment. Reflection is measuring progress from one session to another. Game Genre is the category of the game. Open world sandboxes to strategy games or simulation. Game achievements define the training level of the learner. This can be scores, resource amount or collected assets or anything which have a numeric value. This indicates how the trainee has performed within the lesson. This attributes are compare and contrast with a selected flight simulator in a below section.

COMPARISON OF FLIGHT SIMULATORS

Simulation is a less expensive way to have the experience of flying with relative to the real training. A lots of flight simulation applications have been introduced to the market. X Plane (X Plane 10 Ultra realistic Flight Simulation), FSX (Microsoft_Flight_Simulator_X), Flightgear (Flightgear, 2015), YSFlight (YS Flight Simulator), Lock On (Eagle Dynamics) and GL 117 (GL-117 Action Flight Simulator) are some flight simulations with training and entertainment provisions within. Mainly military and pilot training institutes are demanding the real time flying features while the others demanding the entertainment/ gaming features. Hence after analyzing basic features it can be categorized those simulators according to their intended section whether training or the entertainment. So the following briefing is done with the intention of categorizing the simulations and identifying their features. X Plane, FSX, YS Flight and Flightgear were concerned with higher priority as they are the best rating products in market. Hence FSX discontinued in 2012 (Microsoft_Flight_Simulator_X) let it apart from the comparison.

Table 1. Comparison of Existing Flight Simulators

Feature	X-Plane 10	YS Flight	Flightgear
Airports	Facilitate both online downloading and can create own airports	There are default in built airport pack and bundles of community made maps.	Facilitate both online downloading and can create own airports
Aircraft.	Default aircraft bundle is there. Instead of that user can build any new one or download one.	Can model more aircrafts except the default in built pack	Can be populated according to the users wish. Downloadable & inbuilt aircrafts are also there
Controls/ joysticks.	Mouse, keyboard and joystick controls are available.	Keyboard, mouse or joystick assignments are available.	Joystick, mouse and keyboard inputs are allowed.
Processor & GPU support	More GPU support and uses multi processors for background scenery loading.	Not much CPU power needed but GPU must be enough to populate clear visuals.	Does not drain lots of resources. Multi-core processor would be better for threaded tile loader.
Updates.	Updates available with ongoing Q/A forums.	Continuing with an active community.	Continuing. Version 2.0 released in 2013.
Graphics scenery	Lower quality.	Lighter visuals but less realistic.	More realistic.
Settings (Key assigning etc.)	Few control settings available.	Multiplayer, weather changing few settings.	Wider range of setting available with weather, wind and nigh & day settings.
Commercial / Open Source.	Commercial.	Open source.	Open source.
Simulated emergencies	Yes	No	Yes

As the open source project Flightgear has the most realistic virtual environment. It has number of airports available either in default package or online. The ability to design runways and taxiways has encouraged the users to design the non-available airports. Although YS Flight has this extendibility realism is really low with relevant to the Flightgear. In a training realism is a significant fact in order to feel that the user is actually out there in that situation. Accuracy and the real time effect are other aspects that are significant in a training scenario and Flightgear gets more points in those two cases too. Unlike the other open source flight simulators

Flightgear has a large active development community. Abundance of the resources, documentations, forums and the wiki itself boost up the user friendliness of the Flightgear compared to the other open source flight simulators. The feasibility of extending the Flightgear is also a very useful feature with relative to the other flight simulators. The real time physics can be used in the process and Flightgear also supports all three flight dynamics models. Based upon reasons it is selected the Flightgear to be discussed its seriousness or the learning characteristics against the framework that Garris et al. proposed.

FLIGHTGEAR FOR TRAINING

Among the available flight simulators Flightgear is selected for the discussion due to following concerns. First it is open source and has relatively active community than the other FOSS flight simulation communities. This will ease the customizing process. Airports, Airplanes and sceneries are available online and can be downloaded directly to the package. Editing them is simple and resources, tutorials are available. In that case Flightgear is taken as the base case for comparing the educational capabilities along with model proposed by Garris et al.

Table2. Flightgear Vs. educational characteristics(proposed by Garris et al.)

Feature	Availability in Flightgear	Description
Capability	Yes	➢ Released under GNU license which gives the freedom to create and implement individual contributions ➢ Adopt the sceneries or the environment ➢ Changing the flying conditions ➢ Experience different situations; normal flying scenarios, emergency or critical flying scenarios
Instructional content	Yes	➢ Include the basic instructional content with in the design. Eg: If the engine starting of the being 777 is to be taught then the steps of checking and power on process should be the instructional content.
Intended Learning Outcomes;	Yes	➢ Ability to re-do the trained process under the relevant constraints. E.g. From engine start up training, learner should be capable to re-do the process.
Serious Game Attributes	Yes	➢ A vast number of setting plans: detailed and accurate model, accurate world scenery data, number of various aircrafts, multiplayer model are some features Flightgear ➢ Supports multiplayer feature, voice communication between the players ➢ Practice the formation flight or for tower simulation purposes (Flightgear, 2015)

Learning Activity	Yes	➢ Flightgear has no special missions as in Microsoft Flight Simulator X. ➢ Predefined flying exercises such as flying between selected two destinations following a predefine route in Flightgear. ➢ As Flightgear is free and open source it can integrate learning activities as user wants.
Reflection	Yes	➢ Measure user progressing from one session to the next. ➢ Flightgear has the facility of recording and replaying the flying. ➢ Based on that user or instructor can recognize the previous errors and re-correct them.
Game Achievements	No	➢ Flightgear is an open game platform. It doesn't have levels, individual accounts or achievement counter. ➢ Flightgear loose this attributes of serious gaming application. But since the Flightgear is an open source product this features can be implemented on the framework.

As discussed above Flightgear has the attributes that need to act as an educational platform. Flight simulation is used in training several variation flights such as passenger transportation, military and helicopter flying. Flightgear incorporate almost all this types of aircrafts. Otherwise user can integrate their own designs there. Flightgear can be considered as a real time serious game which serves in educational/training purpose in advanced manner.

Flightgear allows using the multiplayer mode where a group of students can practice simultaneously. This feature allows the students to cooperate with others and share their knowledge. As well as this enhance the oral expressions and their communicational skills. Flightgear facilitates applying the concepts in practical scenarios. With the simulation pilot can train in different day-time conditions, weather conditions and abnormal behaviors. Likewise Flightgear has the basic structure addressing the characteristics which are needed in effective learning process.

CONCLUSIONS

During the past decades simulators have proven that they are an effective and efficient solution in the teaching, learning and training process. Adopting the commodity off the shelf hardware and open source software to upgrade the virtual environments has delivered a great platform for the experiential learning. Flightgear is commonly used open source flight simulator. It has extendable modules which can be used to achieve high realism. When comparing and contrasting the educational characteristics of the Flightgear it has shown its compatibility acquiring almost all the characteristics except one according to the measurements proposed by Garris et al.

As the current generations favor digital media, simulation has enhanced consequence on learners rather than traditional read-write process. Further simulations can be used in the risky and costly training processes to overcome those barriers in training address the safety issue in well-organized manner. Experiencing the difference weather conditions, wind speeds and day-night flying are some natural conditions simulations could generate independent of the real

environment. This won't be possible without the simulations in action. Thus simulators have lift up the prominence of aviation training

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