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# ARE VISUALLY APPEALING SIMULATION MODELS PREFERABLE?

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## ABSTRACT

In the early days of computer simulation, models were mostly developed in Fortran, and there was no graphical animation. Due mainly to increasing graphical capabilities of operational systems, simulation was integrated with animation, setting a new standard in simulation software. The objective of this article is to explore this issue, first making a literature review and then trying to answer the question depicted in the title. It first demonstrates a methodology to evaluate whether a simulation model can be considered "attractive"; then, in a practical study, we try to correlate this "attractiveness" factor to the model's preference. The conclusions were very promising, showing that "attractiveness" is one factor that does interfere in model's preference.

## 1 INTRODUCTION

In the early days of computer simulation (1960's), models were mostly developed in Fortran and ran for hours, maybe days on mainframes; the most important thing was the results generated from the model, so the analyst could decide what was the best system configuration or predict the impact of a change. There was no computer animation and the only graphics available were the ones generated by the analyst, converting a great amount of output data into graphics (bar charts, pie charts, etc) for better understanding and interpretation.

The concept of Visual Interactive Simulation (VIS) was first credited to Hurrion (1976) but, at that time, due to the nongraphic nature of operational systems like DOS, a little development took place. This scenario has changed a lot since then. The turning point was the Windows™ operating system, which in the 80s, allowed to incorporate visualization and animation massively into practically every simulation software (there were also some simulation software that had animation in DOS, but as said, the graphics were very basic). Nowadays, we have an enormous possibility of generating fancy graphics and animation including 2-D and 3-D graphics. Some simulation software uses a web 3-D library like Google Sketch Pad (sketchup.google.com) for importing 3-D icons. In fact a more detailed classification is provided by Robinson et. al (2012) defining also 2 ½ D. According to these authors "2 $^{1/2}$ D representation consists of 3D icons displayed on a 2D background with no perspective projection or photo-realism".

It is important to note that, despite the importance of visualization and animation, they are no substitute for simulation results. According to Law (2007): "Animation's expanding use is primarily due to its ability to increase model credibility and thereby influence decision-makers".

The objective of this paper is to address how good-looking models seems to attract more attention of the audience. It is organized in 5 sections: Section 2 provides a brief literature review, since as will be seen, not much was written regarding this subject. Section 3 proposes a set of characteristics of a good-looking model. Section 4 correlates visual characteristics and preferences for a sample of web distributed simulation models. Section 5 provides the conclusions of this work.

## 2 LITERATURE REVIEW

Based on interviews, Robinson and Pidd (1998) investigated which are the factors that lead to a successful simulation study. They created 10 dimensions based on 338 identified factors, and the first dimension is the model. The model dimension includes components such as velocity, ease of use and aesthetics. Other dimensions are: credibility of the model, availability and precision of input data, software and so on. So it seems that aesthetics must not be neglected. Furthermore credibility of the model relies mainly on its output data, but fancier graphics seems to address initial credibility at the outset.

According to Rohrer (2000), animation can help simulation in the following areas:

- Verification and validation;
- Understanding of results;
- Communication of results;
- Getting buy-in from nonbelievers;
- Achieving credibility for the simulation.

Swider et al. (1994), attempted to correlate animation and visualization with verification, conducting several experiments to investigate how animation can show that a computerized model diverges from its original specification. The author concluded that “viewing animation to discover invalid operation is a complicated task”. It can’t be denied that, although not 100% efficient, model bugs can be detected through animation. In fact, according to Robinson (1997): “The visual display of the model proves to be a powerful aid for V&V”. What is not possible is to substitute simulation results by the animation as confirmed by Law (2007) (“Animation is not a substitute for a careful statistical analysis of the simulation output”) and Clark and Krahl (2011).

Akpan and Brooks (2014) goes beyond Rohrer’s list second’s point stating that animation can even help clients, decision makers, system operators to better understand both system and simulation methodology. Another advantage cited by this author is that animation enable the involvement of non-technical personnel in simulation projects.

Regarding Rohrer’s third point (communication of results), Sneddon (2011) addressed the same question raised in this paper (on the importance of simulation model’s visual aspects). The conclusion was quite direct: numerical results are not the only important thing - animation is also very important. As the author states, “simulation is about communication”.

Banks and Chwif (2010) also addressed the importance of animation in three major areas: Validation, understanding and acceptance, and ultimately selling simulation results. Nevertheless, they make the warning: “Do not get overly impressed by fancy graphics,” citing military examples, where sometimes, smoke, dust, and muzzle flashes are displayed in simulation. It is appropriate to use the “very close to reality aspect” within military simulation because the model is for training. However, using too much realistic graphics is questionable when used in models whose primary object is to act as a decision support tool. This is confirmed by Robinson et al (2012), that found that “2-D visual display provides the most effective and efficient means of eliciting knowledge, when compared to $2^{1/2}$ D and 3D representations that were used”. Clark and Krahl (2011) also points that “ironically a more realistic animation can be detrimental as the audience will sometimes focus on inconsequential details”.

From literature review, animation can improve understanding of the model and credibility. But at what cost? How much ideally must be spent on animation? Though this question is far from being addressed directly, Chwif et al. (2010) gave a hint of how the cost of animation can be. The authors were worried in estimating the implementation time of a discrete-event simulation and identified 3 components that contribute more to this time. One component is the number of simulation objects, other is the number of logic lines of code and the last component is graphical complexity. They defined three levels of graphical complexity:

- Basic level (1), when standard graphics provided by the software are enough. There is no change of the basic icons.
- Medium level (2), when using customized icons (either built or from the Icon Library) and changing the background by adding layouts and writing messages to the screen and legends. There could be also the addition of dynamic tables and special purpose graphs.
- Complex level (3), when animation is obtained by using nonstandard graphic objects to mimic the behavior. An instance is given by a bridge crane (generally an additional piece of logic is necessary to handle the animation)."

The authors developed an equation that correlates the three components with the time spent in developing a simulation model. Although it is quite specific for one simulation software (in this case, SIMUL8) and the graphics were evaluated in 2-D, some insights can be gained for the correlation equation presented. Let's consider a small and a medium sized model (cases A and B respectively). In the former case (A) let the number of objects be around 50 and 100 lines of code, and the second case (B) be 100 objects and 500 lines of code (since this methodology proves to be weaker in large models we are eliminating them from the analysis). Let's vary graphical complexity between 1 (low level to 3 complex level) and apply the regression equation. Results are depicted in Table 1. So, varying graphical complexity between 1 to 3, the average rise of development time is around 25% (31% in case A and 20% in case B). So improving graphics can be costly.

Table 1: Development time of a model varying graphical complexity.

| Case A - Small sized model | | | |
|---|---|---|---|
| O | G | L | Time (hours) |
| 50 | 1 | 100 | 13 |
| 50 | 2 | 100 | 15 |
| 50 | 3 | 100 | 17 |
| | | | |
| Case B - Medium sized model | | | |
| O | G | L | Time (hours) |
| 100 | 1 | 500 | 41 |
| 100 | 2 | 500 | 45 |
| 100 | 3 | 500 | 50 |

As a final remark to this section, we'd like to point that the literature in this area (simulation models aesthetics) is very scarce. As Akpan and Brooks (2012) affirms "It is easy to overlook the role of the animation in simulations as it does not affect the behavior of the model, and it often receives little attention in simulation textbooks".

## 3 METHODOLOGY

This section addresses the question: "What makes a simulation model visually appealing?" First of all, we have to define a classification here. Basically, simulation animation can be 2-D (the focus of this paper), $2^{1/2}$ D or 3-D. Bijl and Boer (2011) compared the visualization of some 3-D COTS simulation packages and evaluated them according to some graphic properties used in game technology, aiming on how realistic aspects of 3-D visualization can be improved. However, there are practically no reference regarding 2-D graphics. We will try to address the initial question by looking at two articles. One is already cited (Swider et al., 1994) and other is from Chwif et al. (2010).

We should state basic prerequisites of a "good looking model". According to Swider et al. (1994) and with some insights from Chwif et al. (2010), there are some elements that a good-looking model should have:

1. **Objects with contrast and easily identified**. Avoid objects with no contrast: objects or icons should be different in contrast and also between icons and the screen which they are layered. Use colors and cross-hatching to separate different function or areas: a good looking model makes use of colors and hatchings to separate objects and this enhances understanding. Figure 1 shows a model that exhibits the problem being discussed. Note that the identification of the single objects tends to be difficult.
2. **Short connections**. Make connections as short as possible and connect processes with as few crossing lines as possible. Excessive connections can confound the observer. Figure 2 shows a model that has too many (and too long) connections.
3. **Excessive information**. Avoid overloading the user with too much visual information.
4. **Organize the flow**. The objects must be organized to show a notion of process.
5. **Closer to reality**. The objects must have an identity to assist the observer in making a translation between the model world and the real word. If a model has an icon similar to a forklift truck and it is meant to represent a forklift truck that will be acceptable. But, if a model has a hamburger to represent a forklift truck, this will be difficult to understand.

So it seems that an attractive model is simple and provides a organization and identification of objects. Based on these findings we will state a "model appealing scale" by attributing a binary number (0 if the model does not attend the stated point and 1 if the model attends the point) to each point addressed above and computing the sum of the grades. So, if the model does not obey any of these points, its appealing scale will be 0; furthermore ,if it observes all of these elements, it will receive the maximum note, i.e. 5. We can also divide per 5 the score and multiply by 100 to have a "appealing percentage".

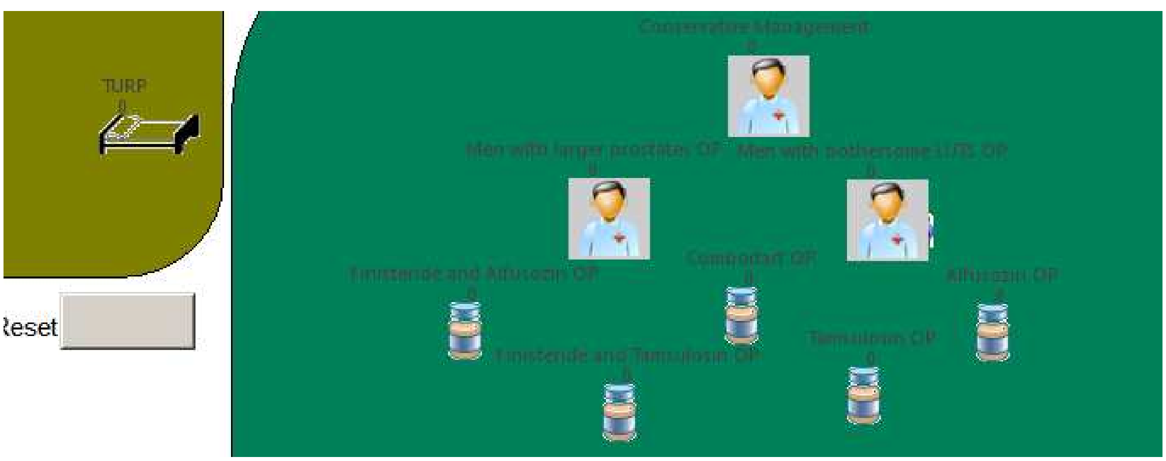


Figure 1: Low contrast - difficult to identify objects (source: www.YouSimul8.com).

In order to better show how this methodology can be applied, we will exemplify by evaluating some models. These evaluations should be done with a running model since entities are objects too, but in this paper, we will analyze only static images of the model.

The objects and background in the model depicted in Figure 1 have low contrast, making it difficult to identify the objects (item 1). Furthermore, there is no organization of flow since the objects are placed onto the screen without any logic (item 4). It shows few or no connections, which is acceptable to the criteria stated in item 2. Item 3 is OK too, because it is not overloaded. Finally, regarding item 5, it is OK too, because it presents a good correspondence of the icons with reality. Thus, the model's appealing score is 3/5 = 60%.

Regarding the model depicted in Figure 2, we have the following:

- Item 1: OK. The white screen with the objects provides a lot of contrast.
- Item 2: Not OK. Too many connections.
- Item 3: Not OK. Too much visual information.
- Item 4: Not OK. There is no clear notion of process.
- Item 5: Not OK. There is no strong matching between icons and reality.

Thus, the model has an appealing score of 1/5 = 20%.

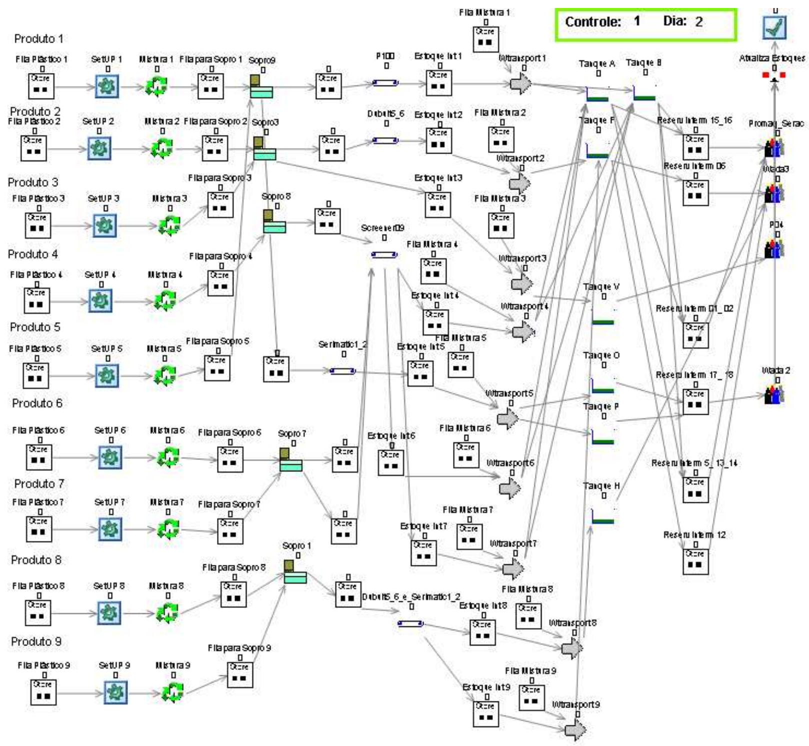


Figure 2: Model with too many connections (source: author´s model).

Observe now Figure 3. Let’s again evaluate it according the proposed methodology.

- Point 1: OK. Despite the grey background, there is still contrast between objects.
- Point 2: OK. There are practically no connections overlapped.
- Point 3: OK. There is not too much visual information.
- Point 4: OK. Although not shown explicitly in figure 3, there is a notion of process that can be verified dynamically, since entities moves from point A to point B.
- Point 5: OK. There is a strong match between icons and reality. We can see the machines, the product (chair) and transportation equipment (forklift trucks).

Therefore, this model has the maximum appealing score: 100%.

## 4 PRACTICAL STUDY

The objective of this section is to answer to the question: “Are visually appealing simulation models preferable?”. This answer will be obtained by:

1. Accessing **YouSimul8** (www.YouSimul8.com) and evaluating a sample model regarding the appealing score defined in the previous section.
2. Check the number of access, which will measure a "preference" to that model. The number of access should be corrected, having in mind the time that was posted.
3. Relate the appealing factor with number of access.

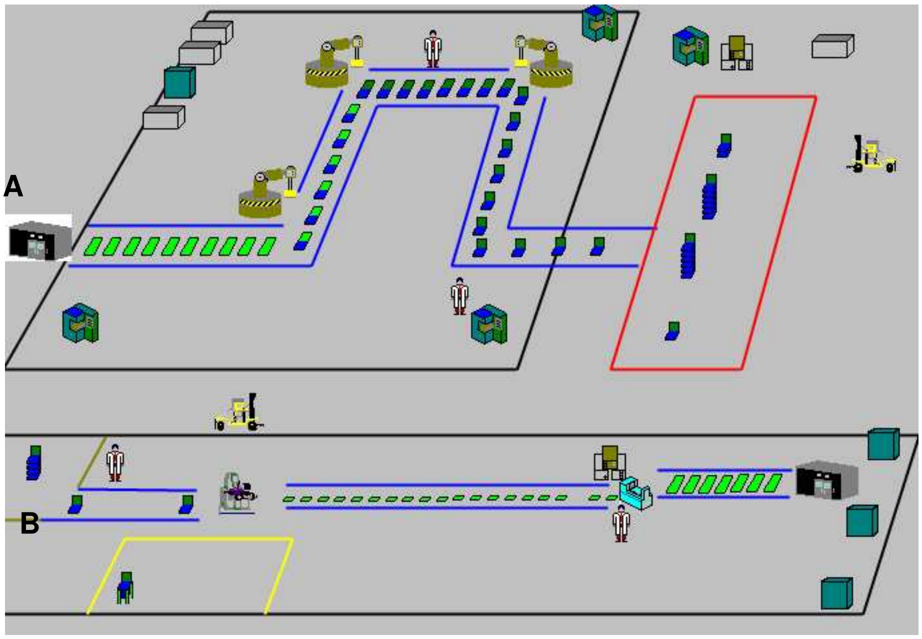


Figure 3: Example of a model (source: SIMUL8´s Standard Demo Model).

YouSimul8 is a web site where people can post their simulation model, as long as it has been created in SIMUL8 simulation software. The site can also run the model using Ajax technology, so we can, even not having the original file, evaluate models results and rate their "appealing factor".

YouSimul8 is divided into 8 sections: BPM, Call Centers, Energy, Government, Healthcare, Manufacturing, Supply Chain and Transport. Healthcare and Manufacturing groups have more models for analysis (more than 20 models) and the other groups have less than 15. Therefore, due to sample size, Healthcare and Manufacturing groups were selected for the analysis. Table 2 and Table 3 presents, respectively, the access ratio (total number of access divided per months since first upload) and the "appealing score" for the selected models, evaluated accordingly to the methodology proposed in the previous section. Both Table 2 and 3 data are divided into two equal sized blocks: Hi access group and Low access block. This was done by ordering the access ratio in descending order. The left hand table represents the Hi access block and the right hand side table represents the Low access block. The bottom line represents the average score for each block.

Now it is necessary to look if the average of each block (Hi and Low access) differs with statistical significance from another. Therefore, it was made a simple ANOVA for one factor with 95% confidence. The results are the following: for Healthcare group we obtained a F value of 6.6 and a F-critic value of 4.3; for manufacturing group we obtained, respectively for, F and F-critic, 19 and 4.22. Since in both cases F is higher than F-critic, the averages between the blocks differs. So we can conclude that, in both cases, higher scores lead to higher number of access.

Table 2: Number of access/month vs. appealing score for Healthcare models.

| Model # | Access ratio | Appealing score |
|---|---|---|
| 23 | 23.5 | 4 |
| 21 | 15.8 | 4 |
| 22 | 15.8 | 4 |
| 7 | 12.4 | 4 |
| 14 | 9.6 | 5 |
| 13 | 9.2 | 4 |
| 17 | 8.8 | 4 |
| 4 | 7.0 | 4 |
| 25 | 7.0 | 2 |
| 5 | 6.4 | 5 |
| 16 | 6.2 | 1 |
| 1 | 6.1 | 4 |
| | **AVG** | **3.7** |

| Model # | Access ratio | Appealing score |
|---|---|---|
| 3 | 6.1 | 3 |
| 2 | 6.0 | 3 |
| 9 | 5.4 | 4 |
| 15 | 4.7 | 3 |
| 8 | 4.3 | 2 |
| 19 | 3.9 | 4 |
| 20 | 2.4 | 1 |
| 11 | 2.3 | 1 |
| 10 | 2.3 | 3 |
| 12 | 1.7 | 1 |
| 6 | 1.4 | 4 |
| 18 | 0.3 | 1 |
| | **AVG** | **2.5** |

Table 3: Number of access/month vs. appealing score for Manufacturing models.

| Model # | Access ratio | Appealing score |
|---|---|---|
| 3 | 82.4 | 5 |
| 13 | 12.1 | 5 |
| 1 | 7.7 | 5 |
| 14 | 6.6 | 3 |
| 2 | 4.9 | 5 |
| 16 | 4.9 | 4 |
| 12 | 4.5 | 4 |
| 8 | 4.0 | 4 |
| 6 | 3.6 | 4 |
| 7 | 3.4 | 5 |
| 5 | 3.3 | 4 |
| 11 | 3.1 | 4 |
| 26 | 2.8 | 1 |
| 29 | 2.8 | 4 |
| | **AVG** | **4.0** |

| Model # | Access ratio | Appealing score |
|---|---|---|
| 19 | 2.5 | 1 |
| 9 | 2.4 | 3 |
| 18 | 2.4 | 3 |
| 22 | 2.3 | 2 |
| 15 | 1.8 | 3 |
| 4 | 1.7 | 1 |
| 10 | 1.4 | 3 |
| 17 | 1.4 | 3 |
| 24 | 1.3 | 3 |
| 20 | 0.8 | 4 |
| 23 | 0.8 | 2 |
| 27 | 0.7 | 1 |
| 21 | 0.6 | 3 |
| 28 | 0.5 | 1 |
| | **AVG** | **2.4** |

## 5 CONCLUSIONS

This article dealt with importance of visuals in simulation models. Literature review about good visuals indicates some advantages, such as aid in Verification and Validation process, facilitating communication, promoting credibility among others. From literature research made so far the relationship between graphics and model preference was never addressed before .

This article provides two contributions: first it settles a methodology to evaluate if the graphics in a simulation model (2-D only) are built accordingly. Although it is a first and rough version, it is the only known tool by the authors to evaluate the appeal of a simulation graphic. In second place, by practical study, we demonstrate that good graphics do correlate with a model's preference.

As further work, since this methodology is still in its early stages, we will try to deepen it by studying more criteria and the inclusion of weights. Furthermore, we can expand the evaluation methodology to deal with 3-D graphics. More practical cases have to be done to reinforce the conclusions.

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