A Classification of Visual Style for 3D Mobile Games

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Abstract—Graphic styles for 3D games can be designed in any direction as the designer desires. Graphic styles range from an abstract composing with a degree of independence from visual references to a realistic rendition of the real world. Cel shaded, voxel graphics, and photo-realism are terms that widely used to characterize the graphic style. Nevertheless, these designates are not systematically set and well prescribed since development techniques change rapidly due to hardware and software innovations. In order to visualize a chosen graphic style, numerous compositions, materials, and execution are required. The purpose of a game, as defined by developers, can be game experience goal, player enjoyment, market capitalization, or specific objectives such as cognitive improvement. Different graphic styles can be used to reach the same goal, but some of graphic styles may have longer production time than others. In this study, we survey a hundred and forty of popular 3D games in the mobile platform with a focus on their basic construction including forms, proportions, texture, and lighting, to propose an alternative classification of graphic styles for today’s technology.

Keywords—3D Games, 3D Graphic, Model, Visual style

I. INTRODUCTION

Graphics have an important role in terms of communication and create the aesthetics to the players with the purpose of making a game experience goal in the form of the game development team has designed [1]. In order to designs various game objects by game designers’ perspective such as the environmental in the game must clearly define the characteristics of the visual style. The characteristic defining can make graphic designers produce the work that contains the exact characteristic throughout the game for determining perspectives and images in the game [2] including the providing a graphical format to support the purpose of playing games such as educational games or practice skills game beyond the entertainment [3].

Visual styles, known as graphic style, range from abstract composing with a degree of independence from visual references to a realistic rendition of the real world including Cell shaded, Voxel graphics and Photo-realism, which is the term that widely used to characterize the graphic style. However, these designates are not systematically set and well prescribed since development techniques change rapidly due to hardware and software innovations [1]. According to the literature review of work [4, 5, 6] have defined the graphic style and some graphic style limitations, for example, some game graphics give more than one graphic style definition that cannot make a clear decision of the graphic mean. In this case, the graphic styles can lead to be the problem for the communication in the game graphic designers.

In this research has proposed the conceptual framework of 3D graphics and 3D games graphic clustering by applying the art theory. In addiction the application of 3D graphics creation techniques can be used in determining the graphic style in order to have a clear decision with the sample study in this work. The sample of this study have gained from the survey of 140 famous 3D game on smartphone template was applied in this research. The results showed the factors that produce each type of graphic style and could be used to make a conceptual framework for categorizing 3D graphics regarding to create a guideline of graphic style for game graphic developers.

The result of this study can help the graphic development team for designing the graphics style more clearly and easy to understand. In addition, the result can also present the characteristics of each graphic style that allows the developers to evaluate the steps and the overall production time of the graphic model creation. This result can help the graphic development team to determine the appropriate graphic style for the target group and match the objectives.

II. LITERATURE REVIEW

A. Visual Style in 3D game

3D games graphics in the game industry was developed in order to have specific characteristics for making the game more interesting and consistent with the objectives to the game players which lead to various type of 3D game graphics. With reference to this reason, the research in this field have divided the graphic into three types: (i) Abstract graphic is the kind of graphic that was shown in geometric form in order to replace of characters, objects and places; (ii) Stylized graphic is a kind of graphic similar to cartoon that uses for personal or thing representation by expanding the most important feature, this graphic is the most flexible and versatile that can be customized to get the most benefit; and (iii) Realistic graphic is the graphic that illustrates the characters, the form that the characters, objects and environment in the game look like the more realistic as possible[1]. However, with the graphic type division, in this case, seems divided into a wide range. This division can lead the confusion to the game development team because of the stylized graphic is highly flexible which can be designed in many forms of graphics. In the real work of stylized graphic, the development team members may be able to see in different graphics meaning that causes the graphics designing team cannot produce a consistent graphic to the overall graphics game.

In the previous works, game graphic styles were classified and explained [4, 5, 6, 7]. However, the diversity of graphic styles are not covered since the technology of the computer

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1 978-1-7281-2544-2/19/$31.00 ©2019 IEEE
hardware and software are rapidly improved then better technique of 3D creation caused more variety of graphic styles. In some research works [8, 9, 10] have explored the graphics styles from video games in order to find specific terms for describing graphics patterns to use in communication. In work [11] have proposed the categories of the game graphic structure by divided into graphic formats, techniques used in the graphic formats production, colors and lighting in the game that has a limitation because of the work does not refer to the various characteristics of the elements that produce the graphic model.

B. Art theory with visual in games

The graphic that game players can see in the game was judged from the overall display graphic in the game, it was called “graphic style”. Graphic Style is considered an art which consists of (i) Form is the shape that has the volume, (ii) Light and Shadow are the brightness of the area was affected by the light that causes to make image or graphic dimension, in the 3D graphics productioncall this technique “Lighting” and (iii) Color and Texture; Color refers to the object’s color and texture is the surface details of the object. In the 3D graphics production technique, color and texture are in the same process that call is “Texturing”. In addition, proportion is another factor that can produce a graphic style. Proportion is the relationship between the element size of each object and the element size of all objects, for example, people have a proportion 1 to 7 means that one person has the size to 7 pieces. The graphic that has a proportion of cartoon is totally different from the actual graphics proportion. Thus, there are four basic factors that produce the graphic style: (i) Form, (ii) Proportion, (iii) Lighting and (iv) Texturing. These four factors lead the game designers to understand what they see and can produce a better game graphic style [12].

C. 3D Production in Game Development

3D graphics production process is the important factor for game development because this process illustrates the image details in the game to create aesthetics to the players. According to the game designer have divided the 3D graphics production process into 5 steps:

1. Modelling is the step of 3D shapes creation by using specific software that is used for creation only.
2. Textured is the providing of specific details to the object by defining characteristics from 2-dimensional images (Bit map) to illustrate the surface from the shader calculation. In this case, the surface consists of (i) Diffuse/Color map, (ii) Specular map, (iii) Occlusion map, (iv) Normal map and (v) Emission map.
3. Rigging is the art of transforming the static 3D into something that can be animated.
4. Animation is a set of gestures or actions that are continuous until the character or object can move.
5. Lighting is one of the most important parts in 3D games that use for creating the game atmosphere and making the game look more realistic by using the good light can make the game more attracting.

From the five steps were mentioned above, three of five steps that are important for game visualizing: (i) modeling, (ii) texturing and (iii) lighting. These three steps can produce a specific 3D graphic and make the graphic is interesting.

D. Consider the visual style in game

In the game visual style considering, there are four factors that use for considering to the overall game graphic include: (i) Terrain refers to the surrounding landscape that is used for architecture or objects located; such as forests, grasslands, desert, ocean beaches; (ii) Architecture consists of houses, buildings and monuments that appear in the game; (iii) various game objects are the objects of the game which are divided into two groups 1) the objects that characters can interact with and 2) the objects that the characters cannot interact with; and (iv) Character refers to the game character which consists of characters that player can control and the character that player cannot control (Non-person character, NPC) [11].

III. OUR MODEL FOR 3D VISUAL STYLE CLASSIFICATION

A. Clustering 3D visual style

The objective of the research is mainly focused on the 3D graphics style classification and propose the conceptual framework for graphics style clustering. In order to make the clustering has more accuracy and better performance, the authors have studied the literature review and related techniques. In addition, the authors had been surfing the information of graphic from the game market by selecting the 3D games from Apps Store Thailand in the date of 12th January 2018. In order to get the variety games, the authors have selected 400 games from 200 Top paid games and 200 Top free games. There are 140 3D games were appeared from 400 selected games, with these 140 games, the authors have analyzed the graphic of each game from the game players’ videos that were uploaded in Youtube. After watching the game players’ videos, the authors collected images from each video to analyze and cluster the graphics game. The process of 3D graphics clustering is illustrated in Figure 1:

Fig. 1. 3D Graphic Clustering Proceses.

From the Figure 1, there are three main processes of 3D graphics clustering:
1) Visual style classification: in this process, the authors have separated the visual style into three groups: (i) Abstract, (ii) Stylize and (iii) Realistic. This separation can lead to the overall view and easy to cluster for the next process (the second process).
2) Visual style clustering: when the process classification the visual style into 3 groups was finished, in this process have analyzed the visual style of each group and cluster each visual style group into subgroups including shape, proportion, texture, and lighting of each group: shape, proportion, texture and lighting of each group.
3) Review visual style and analyzing: in this process, the analyzing of subgroups from the second process is presented. The purpose of this process is to find the specific characteristics by considering the shape, proportion, texture,
and lighting of each visual style. In addition, the group of each visual style also were analyzed in order to analyze that each visual style in the group has the consistency to each other or not because in this process can identify of some groups that can be considered as the same group or some group have different visual style inside the group. This process works continuously until the visual style is clearly set to each type of characteristic.

B. Our fine

From the study found that the characteristic of four factors: Form, Proportion, Lighting, and Texture can use as the criteria for visual style clustering. For each factor have the following characteristic:

![Fig. 2. The Visual Style clustering framework](image)

**Form**, was divided into two groups: (i) Geometric is the shapes with clear edges and corners such as cylindrical spheres, conical pyramids, rectangular or rectangular boxes and (ii) Organic is the form which is no certain shapes or edges, was created by nature such as tree shapes, shapes of living things or objects.

**Proportion** is separated into four types including (i) Pictorial is a proportion that cannot be identified and have no clear pattern, (ii) Irregular is the proportion that retrenches of the detail from the actual proportion, for example, the character proportion have the proportion of head to body from 1 to 3 that cause the model's appearance to have various style based on the designer's idea. This proportion type can be found in cartoons. (iii) Approximately is the proportion that looks realistic. This proportion is slightly retrenching the detail from the actual proportion, for example, the proportion of the face character that can be retraced in order to have a specific characteristic. This kind of proportion was found in only the game character. (iv) Realistic is the real proportion that refers to the real proportions can create things which look realistic.

**Lighting** is divided into three types: (i) Low light refers to the light in the game that is a little light, in another word, the art of giving the light revert to object in order to make the object shadow, (ii) Natural refer to the light in the game that looks like the natural light (look like realistic light), and (iii) Extraordinary refers to the light in the game that is a light looks more attraction and more realistic than real light such as light effects, special effects make the light look more realistic than natural light.

**Texture** or surface have divided into four types: (i) Solid is the surface of the monotone object that does not show specific details of the object surface; (ii) Elementary is the surface with each elementary surface is detailed with various colors and weight values. In determining the specific object surface characteristics of each object causing the dimension of the surface or the light of the deceived eye which is not caused by the dimension of the surface and the true light. (iii) Influence is the surface with each surface object consist of the detail of surface object and have the light reflection in a different characteristic such as glossy surface, glass surface, and plastic surface, all these reflections are the reflection from real light with real-time in the game. Finally, (iv) Exquisite is the surface with each surface object has the clear surface details, for example, scratches, wrinkles and cracks that are expressed as dimensions, depth, and shallowness. The reflection with this surface has the reflection much more detail to the object surface, for instance, in the same type of surface or texture, in the uneven areas, the reflections will spread more than smooth areas.

From the characteristics of the four factors (Form, Proportion, Lighting and Texture) mentioned above, it can be used to define the framework (illustrated in Figure 2) for clustering the graphic style with the following steps: **Step 1**: Analyzing the object shape in the game that the Geometric shape was represented by G and Organic shape was represented by O. **Step 2**: proportion analysis of the game object in order to know that the overall proportion object was grouped in which type of proportion. The Pictorial proportion was defined by 1, Irregular was defined by 2, Approximately was defined by 3 and Realistic was defined by 4. **Step 3**: Light characteristic analysis in the game by defining the Low light with L, Natural light with N and Extraordinary light with E. **Step 4**: Texture analysis of all object texture in the game by considering most of the object texture cluster in which type of texture. 1 represents solid texture, 2 represents elementary texture, 3 represents the Influence texture and exquisite texture was represented by 4.

After describing all steps of the framework, the code from each step is arranged as the sequences such as O1N1 refer to the code that considers as one of the graphic style or visual style. By using Figure 2 in the graphic style was identified by considering the four criteria: shape (Form), Proportion, Light and Texture respectively, it can be illustrated that the code O1N1 is in the Abstract graphic style.

The table of graphic style was developed from the previous research study (A Classification of Visual Style for 3D Games) by using the framework which was proposed by the authors to define a group of visual style. The authors have combined visuals or graphics with similar characteristics put to the same group. As a result, there are 12 graphic styles in total that have distinct characteristics of (i) form, (ii) light, (iii) proportion and (iv) texture as illustrated in Figure 3.

The obtained results of this work the authors gave it to three people who expert in the 3D graphics production with more than eight years’ experience of work to evaluate the validity of the visual style classification framework by looking at the consistency theory, 3D graphics creation techniques and the clustering of visual style found in this work. From the evaluation of the proposed framework show that the framework has consistency theory and can be used to consider for a graphic style that can lead the designers to communicate more easily and more clearly in their teamwork.

### IV. Evaluation our model

a) The evaluation of the proposed framework is presented in this section. To evaluate the framework more accuracy and easy to use, the authors have divided the evaluator into 2 groups (i) group of 26 computer graphic students and (ii) group of 16 expertise people who have
experience in work more than 8 years. The explanation of the proposed framework was explained by 3 minutes video. After the evaluators finish watching the video explanation, they all are requested to demonstrate the 10 graphic/visual styles testing include Abstract, Simplified, Simple Stylized, Stylized, Simple Silhouette, Silhouette, Semi Realistic, Photo Realistic, Semi Exaggerated, and Photo Exaggerated. All the 10 visual styles experiments testing were obtained from the random visual styles in 10 different games as illustrated in Table 1.

<table>
<thead>
<tr>
<th>No.</th>
<th>Visual style</th>
<th>Games</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Abstract</td>
<td>Splashy!</td>
</tr>
<tr>
<td>2</td>
<td>Simplified</td>
<td>Minecraft</td>
</tr>
<tr>
<td>3</td>
<td>Simple Stylized</td>
<td>Fling Fighters</td>
</tr>
<tr>
<td>4</td>
<td>Stylized</td>
<td>Oceanhorn ™</td>
</tr>
<tr>
<td>5</td>
<td>Simple Silhouette</td>
<td>Limbo</td>
</tr>
<tr>
<td>6</td>
<td>Silhouette</td>
<td>Playdead’s INSIDE</td>
</tr>
<tr>
<td>7</td>
<td>Semi Realistic</td>
<td>Life Is Strange</td>
</tr>
<tr>
<td>8</td>
<td>Photo Realistic</td>
<td>Assassin’s Creed Identity</td>
</tr>
<tr>
<td>9</td>
<td>Semi Exaggerated</td>
<td>Lineage2 Revolution</td>
</tr>
<tr>
<td>10</td>
<td>Photo Exaggerated</td>
<td>Injustice 2</td>
</tr>
</tbody>
</table>

All 10 experiments were pictured by the overall the game graphics within 3 to 5 graphic images and the video games in order to make the evaluators can see and understand the overall game graphic of each game clearly. After understanding of each game, the evaluators requested to specify each game’s graphic style from the 4 options. In addition, the authors have divided the tests into three levels: (i) difficult level have 2 test, (ii) medium level consists of 3 tests and (iii) easy level with 5 tests. The difficulty level comes from the options that the authors have determined. The tests in difficulty level have the features that strongly close to each other, for example, Abstract, Simplified, Simple Stylized, and Stylized. For the medium level, there are four features/options that close to each other: (i) Semi Realistic, (ii) Photo Realistic, (iii) Abstract and (iv) Stylized. In this case, the Semi Realistic and Photo Realistic are similar to each other. The easy level is the level that each option is totally different from each other, for instants, Abstract, Stylized, Silhouette, and Photo Realistic. While doing the evaluation process, the evaluator groups will receive a manual for determining the graphic styles includes (i) the visual style clustering framework, (ii) Images illustrate the characteristics of shapes, proportions, light, and surface and (iii) The table of 12 graphic styles, due to the evaluators cannot remember all the content of graphic styles in the 3 minutes VDO explanation. The results of the test will be collected to analyze and summarize in the next section.

V. RESULT

From the result of the evaluation process, the authors got the test score and the recommendation for the visual style clustering framework. In addition, the authors got the graphic styles of each game that are selected by the evaluator groups. These selected visual styles were used in order to make sure that the corresponding answer from the evaluators is consistency to the graphic that the authors have proposed or not.

From the Boxplot, which is illustrated in Figure 4, presented the score from both evaluator groups that gain from the 10 tests (was presented in the previous section). From the evaluation of 10 tests, the computer graphic expertise people gave the highest score was 10 and the lowest score was 3 with the average score of 6.93. For the computer graphic students
group, the highest score is 8 and the lowest score is 2 with an average score of 5.85. From this result, it can be seen that the level of the score indicates the ability to understand the proposed.

From both groups, scores are at the level that the authors expected, especially in the student group who have less experience than expertise.

TABLE II. RATIO OF CORRECT FOR EACH VIDEO GAME (EXPERT)

<table>
<thead>
<tr>
<th>Games</th>
<th>Visual style</th>
<th>Ratio of correct</th>
<th>The most chosen visual style</th>
</tr>
</thead>
<tbody>
<tr>
<td>Splashy!</td>
<td>Abstract</td>
<td>0.43</td>
<td>Abstract (0.43)</td>
</tr>
<tr>
<td>Minecraft</td>
<td>Simplified</td>
<td>0.625</td>
<td>Simplified (0.625)</td>
</tr>
<tr>
<td>Fling Fighters</td>
<td>Simple Stylized</td>
<td>0.875</td>
<td>Simple Stylized (0.875)</td>
</tr>
<tr>
<td>Oceanhorn</td>
<td>Stylized</td>
<td>0.813</td>
<td>Stylized (0.813)</td>
</tr>
<tr>
<td>Limbo</td>
<td>Simple Silhouette</td>
<td>0.75</td>
<td>Simple Silhouette (0.75)</td>
</tr>
<tr>
<td>Playdead's INSIDE</td>
<td>Silhouette</td>
<td>0.125</td>
<td>Stylized (0.688)</td>
</tr>
<tr>
<td>Life Is Strange</td>
<td>Semi Realistic</td>
<td>0.5</td>
<td>Semi Realistic (0.5)</td>
</tr>
<tr>
<td>Assassin's Creed Id</td>
<td>Photo Realistic</td>
<td>0.875</td>
<td>Photo Realistic (0.875)</td>
</tr>
<tr>
<td>Lineage 2 Revolution</td>
<td>Semi Exaggerated</td>
<td>0.75</td>
<td>Semi Exaggerated (0.75)</td>
</tr>
<tr>
<td>Injustice 2</td>
<td>Photo Exaggerated</td>
<td>0.563</td>
<td>Photo Exaggerated (0.563)</td>
</tr>
</tbody>
</table>

In addition, the authors have received each game graphic style form the expertise group that was used as the further work for making a clear view of the consistent answers between the expertise group and the graphic styles that the authors have presented. Table 2 illustrated the proportion of the answer from the expertise group and the graphics style selected by the authors. From Table 2, it can be observed that the visual styles that have the proportion with the answer value of greater than 0.80 have 3 visual styles, proportion value from 0.70 to 0.80 have 2 visual styles, proportion value from 0.60 to 0.70 have 1 visual styles, proportion value from 0.50 to 0.60 have 2 visual styles, proportion value from 0.40 to 0.50 have 1 game and a proportion value of 0.125 have 1 game.

From Table 2 again, it can be seen that 9 selected game from the expertise group were matched with the graphics style that was proposed by authors. On the other hand, there is one game that has the smallest value of proportion is Playdead's INSIDE, in this game the authors have selected it as the Silhouette graphic style that is the graphic remark with the low light, with the proportion appearance is realistic. But the results from the expertise group was selected the Playdead's INSIDE’s graphic style in the Stylized group with the highest selection proportion of 0.688. The Stylized graphics style is a graphic style that has the proportion reduction from reality and uses the texture to shows the details that lead to producing the specificity of the game object. This conflict is important to the authors for reviewing of both graphic styles in order to make the graphics segmentation more accuracy and better performance.

VI. DISCUSSION

From the experimental results, the authors have found that the Playdead's INSIDE game a different view of game graphic style from the expertise group and the authors. The authors have considered the game graphic style in the Silhouette style, while most of the expertise considered it as the Stylized style. The authors have analyzed these two graphic styles and can find the two major different factors: (i) Lighting and (ii) proportion. While considering the graphics of Playdead's INSIDE game that illustrated in Figure 5, it can be seen that the overall light in the game is the low light which makes the game look dark. But it still shows the details of the surface or texture in the game, for example, the proportion of children characteristics were presented in this game graphic. These reasons make the game difficult to analyze between the cartoon proportion (Irregular) and realistic proportions that lead the expertise considered the graphics style of Playdead's INSIDE as the Stylized more than Silhouette style. With the reference to the 3 minutes VDO that the authors gave to the expertise group for watching, the VDO just explains the framework in just 3 minutes and describing various aspects of the 4 factors in the short time which does not give enough example. Thus, these reasons lead to the results that are different from the authors have expected.

From the case study of the Playdead's INSIDE game, the authors have noticed the low light production, which is a lighting technique that makes the image in the game becomes the shape of a shadow. By using the light with this characteristic, the detail of object texture in the game cannot see the detail or not clear of the object texture. The detail of object texture can be seen clearly or not base on the light providing from developer team, for example, In Figure 6 illustrates the graphic in Limo game. In the Limo graphic, the graphic has the low light characteristic like Playdead's INSIDE game but the Limo’s game graphic have a clear shadow than Playdead's INSIDE game that leads the Limo’s
graphic style was grouped in Silhouette with the proportion value of 0.75.

In the low light analysis, it still consists of some problems for some games, for instance, the Phenomenon which is illustrated in Figure 7. From the Figure 7, the authors have considered the graphic has a low light characteristic but can see the detail of an object that can be considered as Silhouette or Realistic group. On the contrary, when considering the overall picture of the Phenomenon can be in the Realistic group more than the Silhouette. With this case, the authors have an idea of the low light application to applied with Natural light in the game that can create the light look similar to realistic. Thus, Playdead's INSIDE graphic style was grouped in Stylized, while Limo was considered in Simple Stylize group. This concept is consistent with the theory and graphics production processes by applying the light characteristics for further graphic style clustering.

VII. CONCLUSION

The graphics style classification framework was proposed in 2018 that came from studying and exploring of 140 3D graphics game in Apps Store Thailand. In this research, have proposed 12 graphics types. Authors have requested the 3D graphics production expertise to evaluate the accuracy of the framework performance and the groups of graphics style. As the results, the proposed framework is consistent with the theories and can work well for considering the graphic in real work that leads the developer teamwork more easily and more clearly in their communication work. The evaluation result came from the (i) 26 computer graphic students and (ii) 16 3D graphics expertise, to evaluate the proposed framework. As a result, the evaluation score is satisfied with the framework from both groups: student and expertise.

The results of this study can help to communicate in the graphics style defining in the developer team more easily and clearly. In addition, it can help to see the characteristics of each graphic type that allows the developer team to evaluate the process and the overall graphics style production time for determining the appropriate graphic type for the target group in the team purpose. However, in this work have a limitation due to the graphics style have proposed in this study just a part of the graphic style in the graphics world because the authors have explored and selected the graphic style from the mobile platform only. In the future, the authors plan to explore and select the game on other platforms to study to make the proposed framework have a better performance.

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