画像ベースレンダリングによる高速道路サグ区間における運転シミュレーション映像の生成（計画概要）

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我々は「複合現実交通実験空間」（産官学共同研究による交通・運転シミュレータの拡張形）において、模擬運転映像の生成処理を行うシステムの開発を行ってきた。本システムでは、実写画像を利用した画像ベースの描画方法と旧来の運転シミュレータを利用した幾何ベースの描画方法の両方を適切に利用することで高い現実感と汎用性を同時に実現できる。我々は本システムを東名高速道路のサグ区間に適用し、現実感の高い運転映像を生成して運転者の心理解析などに役立てたいと考えている。本稿ではその際の運転映像生成における技術的課題と解決方法に焦点をあてながら計画の概要を示す。

A proposal to simulate driving scene of sag zones in highway by using image-based rendering

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We have been developing an efficient and effective image generation system for “Mixed-Reality Traffic Experiment Space”, an enhanced traffic/driving simulation system. Unlike conventional simulators, our system represents the view through image/geometry-based hybrid method to realize high photo-reality. The view is created by synthesizing image dataset captured from real world and conventional polygon-based simulator. We are planning to apply this system to a sag zone in Tomei Expressway. Using our system, we can re-create the situation with rich photo-reality and expected to help human/psychological analysis of a driver. This paper describes the outline of our plan mainly targeting some technical problems and representing our proposing rendering method.

Keyword: Driving simulation, Image-based rendering, Omni-directional image, Free-point view image

1. Introduction

We have been developing a novel simulation system called “Mixed-Reality Traffic Experiment Space”, which is an extended framework of conventional driving/traffic simulator and its view from the user is produced by synthesizing geometric model and real video images, unlike conventional driving simulators.

In general, geometric models are suited for dealing with versatile operation such as embedding other objects, however, have relatively poor photo-reality and require some human work for construction. Image-based model can produce photo-realistic view, however, are poor at such versatile use. We properly use both approaches according to their roles and synthesize them into a single view taking advantage of each merit and compensating each defect.

The richness of photo-reality in our simulation system will just be suitable for reconstruction of “subtle” driving scene such as sag zones, where small changes of road gradient often causes traffic congestions. We are planning to apply this system to a sag zone in Tomei Expressway in Japan. Using our system, we can re-create the situation with rich photo-reality and also expected to help human/psychological analysis of a driver.

However, our current system has to be more improved in several technical points. One problem is the projection principle of real image in image-based approach. Relatively long distance of the sag zone in Tomei Expressway compared to the region of Tokyo Metropolitan Expressway which our current system targets also becomes an issue. This paper discusses these problems and representing our proposing improved approach for rendering.

This paper is composed of four sections. After introduction, overview of our current system “Mixed-Reality Traffic Experiment Space” and especially “IMG module” is described in the second section. In the third section, we clarify technical problems, propose new approach, and describe our future plan. Finally we conclude our argument in the fourth section.

2. Overview of our current system

2-1 Whole system

Overall picture of the system can be represented as Figure 1. TS: Traffic Simulator [3] simulates macroscopic traffic flows, and DS: Driving Simulator [4] recreates microscopic behavior of self vehicle according to user's operation. KAKUMO [3][4] simulates microscopic position of each vehicles from macroscopic traffic flow. Users can experience a driving situation in-side the network of TS. The system virtually deals with existing public roads as a simulation scene, currently a part of Tokyo Metropolitan Expressway.

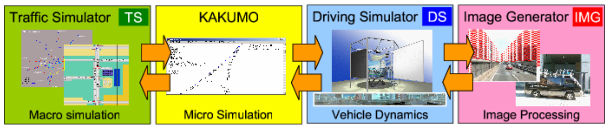

Figure 1 : Overall system of “Mixed-Reality Traffic Experiment Space”

IMG: Image Generator is the module of which we were in charge to develop and described in detail in this paper. Figure 2 shows the detail of the IMG module. It generates user's view in real-time with high reality according to the position of self vehicle given from DS (60Hz in frame rate). We properly use both geometry- and image-based approach and synthesize them at displaying phase. In concrete, near part including roads, traffic signs, and other vehicles etc. is rendered by geometry-base using conventional product of Mitsubishi Precision Co. Ltd., and far part including buildings, sky, etc. is rendered by image-base using our technique to process video image captured along the model course.

The reason why we employ such hybrid approach is derived by considering the aptitude of geometry- and image-based method. Geometry-based rendering is superior from the perspective of computing cost and versatile use such as interactions with other vehicles, changing the contents of traffic signboards, etc. On the other hand, image-based rendering is superior from the perspective of photo-reality provided to the users. By our proposed method in IMG module, a view exploiting each advantage can be created. Additionally, construction process of geometric model, usually with huge manpower, is required only in near-view part, which would lead to less developing cost.

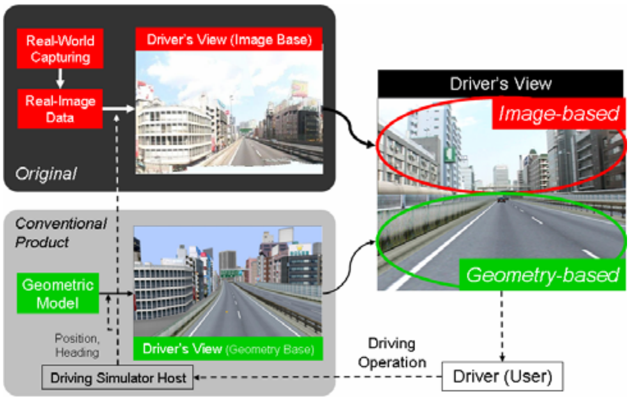

Figure 2: The detail of the IMG module

2-2 Related works

There are some works related to our system. One is the reconstruction of urban scenes. [7][8][9] reconstructed scenes by geometry-base, and [10] by image-base. Also, both approaches are used for rendering in [11][12] if not limiting the target to urban scenes. In any case, none of these studies are designed for driving simulation.

On the other hand, driving simulators are actively developed by private enterprises and academic fields [15][16][17][18]. Almost all of conventional simulators are designed using geometry-based rendering. Some works can deal with real image [13][14], however, they assume that users drive along designated curve and make no lane changing.

2-3 Strategy to reconstruct photorealistic view from user viewpoint

Image data source for far part is captured from real world. We equip nine video cameras on the roof of our capturing vehicle and run along the targeting road. Mosaicing nine camera images by using [5], omni-directional video image stream can be created along the road (Figure 3). Once omni-directional images viewed from running path are accumulated, a view from outside the path can be created by processing following image. Therefore, capturing travel is carried out only once.

Figure 3: Omni-directional image

Geometric models assumed in the image part are just simple two walls along the roadside (Figure 4(left)), which is also a boundary of near (geometry) part and far (image) part. These walls are split into slits whose widths are defined by sampling points of omni-directional image on the running path. When rendering the image part, the slits are rotated towards the user's visual-line direction. If the user's viewpoint is located upon the capturing path, a part of omni-directional image from to in direction is mapped to the k-th slit as a texture (Figure 4(right)), where is a direction to the end edge of the n-th slit.

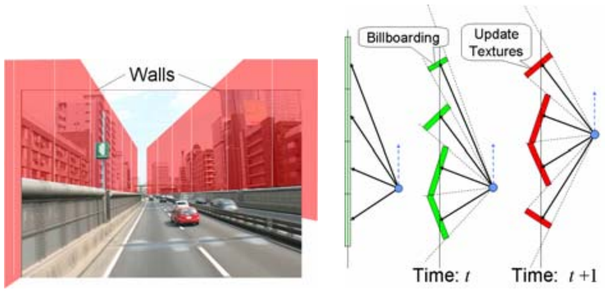

Figure 4: Virtual walls used for texture mapping of real image.

If the user's viewpoint is located out of the capturing path, we first create virtual omni-directional image by improved method of [6], and map it to the slits. In Figure 5 for example, left view from a star-signed point can be composed of forward-left, left, and backward-left part of omni-directional image captured at time t1, t2, t3 respectively. In this method, view of plumb-front direction becomes singular, i.e. required ray is not sampled at any point in advance. In such case, the ray captured from nearest sampling point is substituted instead.

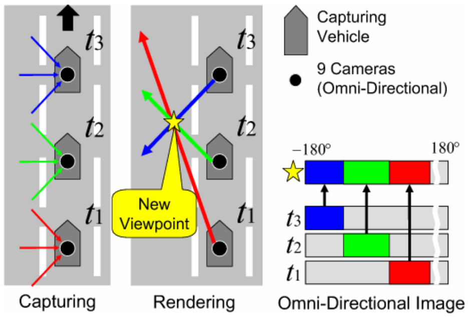

Figure 5: Creation of driving view seen from the point out of capturing path.

Image part and geometry part are independently rendered by each computer. As for geometry part, it is a conventional product of DS. Both RGB values and depth value of each pixel are output through DVI terminals of them. To integrate each view, a hardware called VizCluster is used. It receives those outputs and determines RGB values of each pixel according to the depth value, and passes them to multiple projectors.

2-4 Rendering examples

Figure 6 shows the rendering examples of conventional simulation system(a) and our synthesizing result of image and geometry part (b)(c). The dashed line in the Figure 6(b) represents the boundary of both parts. Sky, buildings, advertising displays are rendered with realty and vehicles can dynamically change their location.

(a) Conventional view

(b) Our method

(c) Our method

Figure 6: Rendering examples.

There exist some distortions in image part as seen in Figure 6(c). This is caused by several reasons. The dominant one is that we assume just two flat walls for projection along the roadside, which especially becomes unreasonable when elevated bridge etc. intrudes.

3. Application to a sag zone in Tomei Expressway

3-1 Tomei Expressway

Tomei Expressway is a highway running the middle region of Japan from Tokyo to Nagoya via Kanagawa and Shizuoka. It is one of the artery road connecting Tokyo, Nagoya, and Osaka together with Chuo and Meishin Expressway. In 2002, the gross number of traffic reached 151,416,468. More than 76,000 vehicles on the average of whole region per one day ran. Especially, more than 126,000 vehicles ran between Yokohama-Machida and Atsugi.

Between Yokohama-Aoba and Atsugi which just includes the region with the heaviest traffic, there exists a sag zone (Figure 7). A sag zone is composed of a series of subtle changes of road gradient, and often said to cause “agnogenic” traffic congestions.

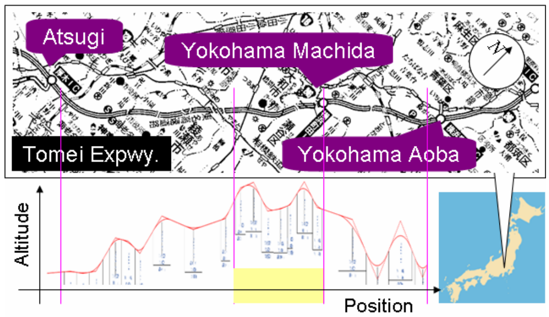

Figure 7: The sag zone in Tomei Expressway.

3-2 Preliminary experiment

As a preliminary experiment, we first ran and capture surrounding view along the sag region by the vehicle, and surveyed rough situation of the region.

3-3 Technical problems

We could clarify two technical problems to realize driving view simulation of this region with reasonable quality.

- Frequent existence of elevated objects
- Long distance

There frequently existed lots of elevated objects on the targeting region of the expressway, as shown in Figure 8. Protruding street lamps, crossing bar, elevated bridges are the examples. These objects are projected with distortion in our current system.

Figure 8: Objects frequently found above the expressway.

Another problem is the long distance of targeting region. The distance is 21.7km (13.6mi), about 1000 seconds in time. It is about 5 times longer than the model course we targeted in our current system: Tokyo Metropolitan Expressway, from Shibuya to Miyakezaka. Image data used for rendering far part should be loaded onto the main memory of rendering machine, however, the amount of image data with reasonable resolution in current configuration is approximately the limit.

3-4 Improved rendering approach

To solve these problems, we are planning to improve our approach by following solutions.

Adding another virtual wall for texture mapping

One is adding another virtual wall above the road other than existing ones along the roadside. Elevated objects will be mapped to the blue wall shown in Figure 9, with less distortion compared to Figure 6(c).

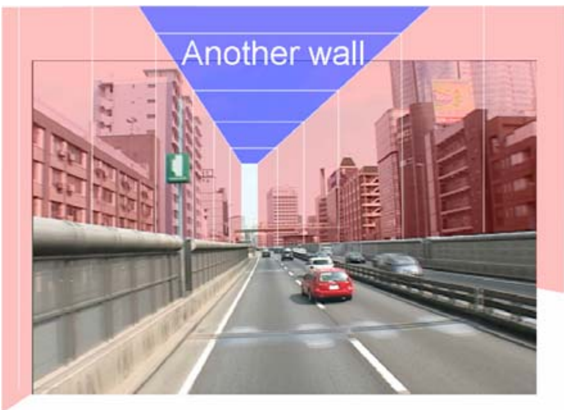

Figure 9: Another virtual wall above the road.

Texture pre-fetch using multiple rendering machines

The other is using multiple rendering machines to temporize loading process of image data to main memory. Image part and geometry part are primarily rendered by independent computers, meanwhile, we are planning to use several computers only for image part. Texture generation task is allocated to each machine per some short, partial regions of the running road. A machine which finished rendering its allocated region is allocated a new short region and pre-fetches the image data for there.

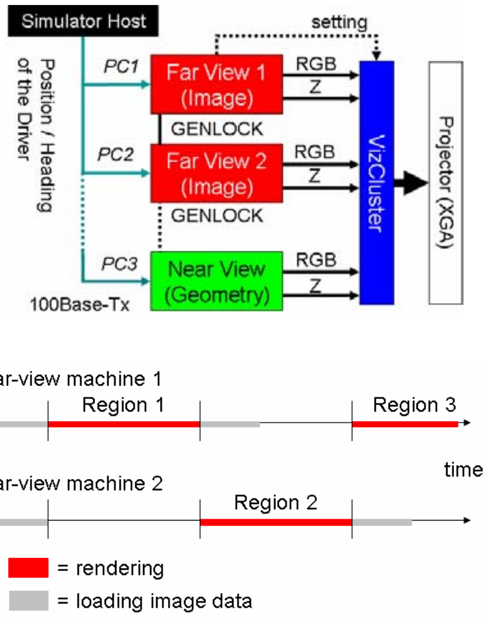

Figure 10: Use of multiple rendering machines for image part.

4. Conclusion

4-1 Summary

This paper described our plan to simulate driving scene of the sag zone in Tomei Expressway using our image generating module in "Mixed-Reality Traffic Experiment Space" on which our image/geometry hybrid rendering method is implemented. The richness of photo-reality in our simulation system will just be suitable for reconstruction of "subtle" driving scene.

However, our current system has to be more improved in projection principle and image data retention on main memory to apply to Tomei. We proposed improved approach for rendering to solve each problem.

4-2 Future works

For the future, we implement improved rendering method and evaluate the effectiveness of proposed approach. We expect that our new system will help human/psychological analysis of a driver.

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