Predicting 3D fluid flow over design drawings

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Context and goal

Line drawing is a fundamental tool for designers to quickly visualize 3D concepts. A long-term goal of our research group is to develop algorithms capable of understanding design drawings to provide designers with immediate feedback on the feasibility of their concepts.

Figure 1 illustrates a potential usage scenario where a designer quickly draws the body of a car, and would like to evaluate the aerodynamism of that car. Given existing tools, the designer would first have to model the shape of the car using 3D modelling software, then run a 3D fluid flow simulation, and eventually re-draw the car and repeat this process if not satisfied with the outcome. Unfortunately, creating a 3D model takes much more time than drawing, which makes this iterative workflow long and tedious.

Our ambition is to sidestep 3D modeling by predicting the outcome of a fluid simulation directly over the design drawing. We plan to build on recent machine learning algorithms to achieve this goal, as described next.

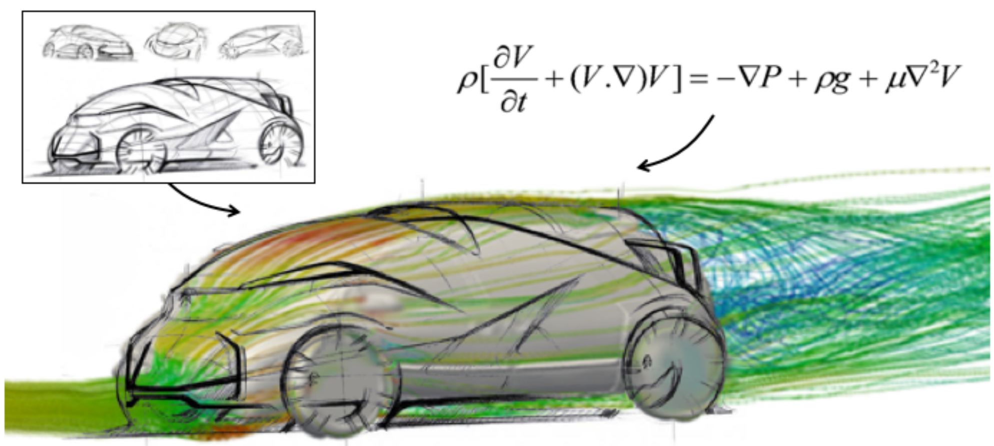

Figure 1. Our long-term goal is to predict the physical behavior of an object as soon as it is drawn, such as aerodynamism of a concept car.

Approach

The flow of a fluid around an obstacle is a complex physical phenomenon that requires costly computation to be simulated. In addition, the simulator needs knowledge of the complete 3D shape of the obstacle to account for how the fluid interacts with its surface.

Recent work has demonstrated that a machine learning algorithm can learn the typical behavior of a fluid flow when trained with a large number of pre-computed simulations on a restricted class of object, like cars [1]. The main intuition behind this approach is that while each car has its unique characteristics, all cars share common aspects and as such tend to have similar impacts on fluid flow. Given many examples of existing cars, the machine learning algorithm makes a good guess of how a new car would behave by analogy to similar cars.

The first part of the internship will study how well the above method works when applied on line drawings rather than 3D shapes. A key challenge is to develop a representation of the input drawing and the output fuild flow that is suitable to machine learning. In the method of Umetani and Bickel [1], the car is represented with a canonical shape that is deformed to best fit the different cars, which provides a consistent representation to the machine learning algorithm. We will start with a similar representation, except that we will focus on the most salient curves that define cars rather than their complete surface to form a line-drawing representation of the shape. Algorithms that analyze collections of similar shapes will be considered to extract this consistent set of curves [2] and align it with each car in the dataset. Similarly, we will also analyze the output flow field to identify salient streamlines, which could be used as a more compact representation of the flow that is well suited to real-time visualization applications. We will generate this training data by running a fluid simulator [3] on the “car” category of the ShapeNet dataset of 3D models [4].

This first experiment will give us novel insights on the ability of the machine learning algorithm to extrapolate information in-between the curves. The second part of the internship will study how well the method generalizes to line drawings that do not perfectly conform to a canonical set of curves. Several solutions will be considered, such as training the machine learning algorithm on incomplete or noisy data, or pre-processing the input drawing to transform it into a canonical representation [5].

Work environment and requirement

The internship will take place at Inria Sophia Antipolis. Inria will provide a monthly stipend of around 1100 euros for EU citizen in their final year of master, and 400 euros for other candidates. This internship could form the basis for a Ph.D. thesis where we would explore applications of this methodology to other design tasks where physical behavior matters.

Candidates should have strong programming and mathematical skills as well as knowledge in computer graphics, geometry processing and machine learning. Experience with physical simulation is a plus.

References

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