Illustrating how hydraulic machinery works

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Summary

In this research proposal we present a method for automatic depiction of how it works illustrations of hydraulic machinery.

Chapter 1

Introduction

How things work visualizations have been used as an efficient method to explain how a wide range of systems work. This technique usually involves displaying where each part is in relation to the system, showing how force is transmitted from one piece to the next and animating motion. In order to perform this task a range of visual transformations are used. Such as viewing the system from different angles, zoom degrees, transparency levels, as well as displaying only a subset of the parts. Generating material of this sort typically involves manual methods, usually in the form of an expert drawing each illustration by hand or composing a fixed animation using specific software.

Hydraulic machinery is commonly used in our everyday lives. Such as jacks used to lift cars, rams on excavators or gerotors to control fuel intake. Their popularity is based on their faculty to transmit a force or torque multiplication independently of the distance between input and output. A typical hydraulic equipment has a contained liquid fluid that becomes pressurised when a force is applied to it. Then that force is transmitted to the other end of the fluid. Understanding how the pressure is directed and how it interacts with other parts in the machinery is essential in order to grasp how the whole system works. Therefore, to illustrate the general process, the spatial configuration of each part in the system must be unveiled. As well as the chain of motions that takes place within the gears and the liquid fluids.

There are some common visualisation and illustration techniques used for hydraulic machinery. **Motion arrows** are used to point out how the solid parts move and also to indicate fluid flow movement. **Frame sequences** display complex motions key frames and they can highlight temporal interactions between the parts. **Animations** are an useful tool for highly dynamic systems, for example when an excessive number of frame sequences are needed.

Generating visualisations and illustrations for hydraulic machinery is challenging for designers. They must understand in detail how the force is applied and what kind of flow movements are entailed. Furthermore, with 2D illustrations it is impossible to change the viewpoint to explore the object from different angle. Moreover, hydraulic visualizations are usually costly animated by hand, which in addition leads to infrequent updates.

Simulations can be used to illustrate how hydraulic machinery works. This research proposal aims to introduce a method for generating *How things work* illustrations for hydraulic machinery. This illustrations would help users understanding how this kind of equipment works.

In summary, the main contributions would be:

- An application for creating how things works illustration for hydraulic machinery 3D models.
- A method for detecting motion and interaction of fluid inside 3D model parts.
- Algorithms to automatically generate illustrations with motion arrows and frame sequences

1.1 The Problem

Given a 3D CAD model of some hydraulic machinery we want to generate how things work visualizations. Namely, adding arrows depicting the fluid movement.

The problem can be subdivided into:

1. Part analysis: Detecting fluid containers and fluid handling parts.
2. Fluid simulation: Simulate how the fluid behaves in the previously detected parts.
3. Fluid visualization: Generate arrows to show the results of the simulation.

1.2 Previous Work

This proposal is based on the following three main areas of previous work.

1.2.1 Explanatory illustration

Explanatory illustration has been effectively used to show complex and/or copious amounts of scientific and technical data. Researchers have have look into generate automatic illustrations for mechanical assemblies [MYY*10].

1.2.2 Fluid simulation

Fluid simulation is a well known research area. One of the firsts papers in this area introduced a Grid method [FM96] to solve Navier-Stokes equations by applying forward Euler time integration. Stam [Sta99] extended this method in order to overcome stability issues. More recent simulations introduced the Smooth Particle Hydrodynamics (SPH) technique [Des96]. However the previous techniques assumed the fluid to have no interplay with any rigid body (solid-coupling). Carlson [CMT04] proposed solid-fluid coupling algorithm for grids models using distributed Lagrange multipliers. On the other hand, Muller [MST*04] presented his own method for SPH simulations, which Akinci [AIA12] further improveded with the inclusion of friction and dragging. Shao [SZMTW14] also solved stability issues in the previous SPH solid-fluid coupling techniques.

1.2.3 Flow visualization

Streamlines are the standard approach to produce flow visualization. Extensive work has been done in this area as visualizing fluid movement has a broad range of applications. This includes visualizing 2D flow in images using an image-guided algorithm [TB96] and using the fewest number of streamlines [LHS08]. Seeding techniques for curves on 3D surfaces were explored by Wicke [WST09], who developed a technique to combine model reduction with with grid based methods. And Spencer [SLCZ09] whose method generates streamlines only for visible parts of the surface, thus providing a significant gain in efficiency.

1.3 Related Work

Chapter 2

Data Structures Used in this research

2.1 The 4D-Stack - A Revolutionary Data Structure

The 4D-Stack turned out to be a complete disaster as traversal time approached $O(n^9)$. It is best illustrated by the following equation: $F(x) = \prod_{0 \leq i < k} d_i(x)$ but the following may not be true:

$$-f(x) = -\log \prod_{0 \leq i < k} d_i(x) = -\sum_{0 \leq i < k} \log d_i(x)$$

2.2 More Irrelevant Stuff

If you want to put numbers on equations use this form:

$$f(x) = \int_0^L h(\langle x - p(t), n(t) \rangle) dt \, . \tag{2.1}$$

Chapter 3

Results

Due to a time quake during the research, the results were catapulted into the future. They will appear in about 20 years. In the meantime to demonstrate the use of tables, please see table 3.1 for a list of students who took more than 30 years to graduate.

Name	Dates	Degree	Title	Present Position
Rudolphe Neyrouge	1953 -	PhD	Non-linear Fictional Analysis	co-tutelle with NPole University, Arctic
Rip van Winkle	1754 -	PhD	Modelling 4D Harmonic Maps	University of Old People
Graduated				
Johnny Depp	1967 - 2009	MSc	How to Act an MSc	Actor
Valentina Lsitsa	1992 - 2013	MSc	Hitting the right notes	Pianist
Johann S. Bach	1567 - 1953	MSc	Interactive Piano	Composer

Table 3.1: Graduate Students, last seven years.

Chapter 4

Conclusions and Future Work

No conclusions can be drawn until the results appear and no future work is recommended.

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