CFD and Realistic Visualization for the Analysis of Fire Scenarios

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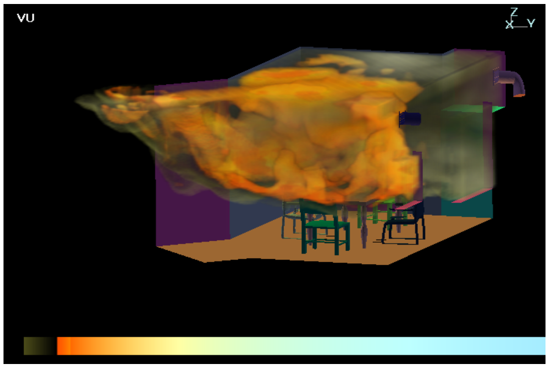

Figure 1: A Fully Developed Backdraft.

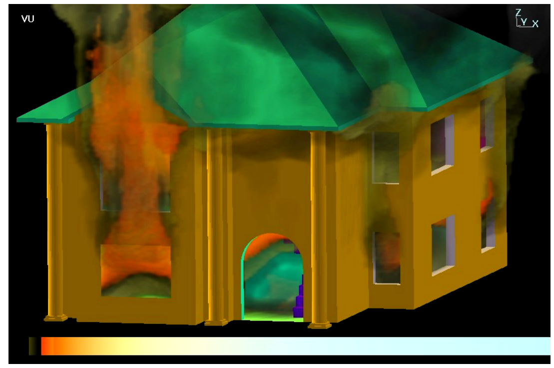

Figure 2: Fire reaching out of a house

1 Introduction

This poster presents the current status of our work on the combination of advanced computational fluid dynamics (CFD) fire simulations and realistic (real time) rendering techniques for the analysis of real-life fire scenarios. Fire representation is a complex issue because it has to deal with a combustion process, a flame front separating fresh and burnt gases, smoke, visibility and illumination. While for the actual simulation of fire scenarios we could use specific CFD fire simulation models [Barrero et al. 2003; Hardy 2004], the use of traditional flow visualization techniques can only give us a limited insight on the behavior of these kinds of phenomena.

The main problem is that on the specific case of real-life fires, a major part of the phenomena is not invisible (flames and smoke). These visible parts not only play a very important role on the combustion process, but also have even greater visible effects on their sorrounding environment (visibility,etc.) that are better understood by using a more realistic representation. We have thus focused our work on the integration of CAD modeling, geometry transfer, flow and fire simulation and enhanced fire and smoke visualization tools to be applied in building simulation. Commercial and research tools were used and studies of backdraft phenomena, fire propagation and visibility have been conducted.

2 Preprocessing

Fire scenarios are modeled by using standard CAD tools. These models are exported as volumes or polygonal meshes that are converted to a suitable CFD cartesian grid representation by our own tools using a fast "dice and merge" discretization technique.

3 Simulation

Accurate fire scenarios are predicted with the fire dynamics simulator [FDS] from NIST. This program uses a finite-volume method to solve the Navier-Stokes set of equations. Turbulence is modeled using the large eddie simulation approach, and fire dynamics is completed by a mixture fraction and pyrolisis combustion model. One of our main interests is to simulate the small explosions due to sudden deflagrations like those produced in a backdraft scenario, as a result a modified version of FDS was used [Hardy 2004].

4 Visualization

The visualization technique is based on a modified version of the fuzzy blobs formulation [Stam and Fiume 1993] that was initially developed for the evaluation of a flamelet based turbulent combustion model [Barrero et al 2003]. A fuzzy blob description of the flame volume is constructed by defining a density distribution for a series of embedded particles on the grid based on the heat release rate per unit volume and mixture fraction parameters. Each blob is converted into a mixture of polygons and micro-3D textures covering the volume of influence for each blob following the density distribution. The velocity field is used as a convolution filter over these textures, which are finally shown using a series of small imposters covering the overall screen area of each blob. OpenGL blending modes are used to integrate the volume illumination function. Fire color is dependant on blackbody emission and the combustion properties of the burning materials on the scene. Smoke is modeled by defining a density distribution based on the mass fraction of burnt gases.

5 Discussion

We have successfully used our techniques for the study of very complex fire situations like backdraft explosions (Figure 1), fire propagation on closed and open buildings (Figure 2), and smoke analysis on tunnel fires [Hardy2004]. We are currently working on the study of more complex fire scenarios like fire in atriums and public places (auditoriums, etc). We are currently studying the possibility of taking advantage of vertex and pixel shaders to improve realism and speed up the blobs evaluation, and also on ways to improve the whole fire simulation process.

6 References

BARRERO, D., OZELL, B., REGGIO, M. 2003, *On CFD and Graphic Animation for Fire Simulation*, CFD2003, Vancouver, May 2003.

HARDY, J.P. 2004. *Simulation numérique et visualisation d'incendies sous-ventilés avec FDSv3.10*, 115p., Master's Thesis, Mechanical Engineering , École Polytechnique de Montréal.

STAM, J., FIUME, E. 1993. Turbulent Wind Fields for Gaseous Phenomena, *In Proceedings of ACM SIGGRAPH 1993*, Computer Graphics Proceedings, Annual Conference Series, ACM, 369-373

FDS, The Fire Dynamics Simulator, http://fire.nist.gov/fds/, National Institute of Standards and Technology, USA