Resumen

En esta tesis se investigaron modelos de simulación en tiempo real para animaciones de superficies líquidas, basados en un modelo de Lattice Boltzmann de la física de aguas superficiales. La implementación de dichos modelos permitió implementar un motor físico capaz de producir escenas de estanques o aguas abiertas, cuya superficie reacciona a las perturbaciones introducidas interactivamente por el usuario. Estas perturbaciones pueden ser por ejemplo la agitación provocada por un objeto movible (hélice, barco u otro objeto definido mediante una triangulación arbitraria), u otro tipo de perturbaciones externas, como por ejemplo efectos de lluvia.

Un aspecto significativo del modelo investigado fue el tratamiento de bordes y obstáculos internos móviles, que intervienen como condiciones de contorno en el esquema numérico. Se implementó para ello un modelo completo de interacción fluido-objeto que simula en forma flexible escenarios de ondas producidas por embarcaciones, reflejos del frente de onda en puentes, y otras situaciones de interés en animación, tanto para la animación de efectos especiales como para simuladores de entrenamiento náutico. En particular, se propuso una estrategia novedosa para el cálculo de la fuerza de flotabilidad basada en la integral de la presión del fluido sobre la superficie sumergida del objeto. El método propuesto es más versátil y exacto que otros esquemas que estiman el volumen y aproximan el centro de carena, y es muy fácil de incorporar a cualquier implementación de simulación de fluidos basada en grillas.

Los tiempos de cálculo obtenidos son razonables y permiten utilizar el método en aplicaciones de computación gráfica interactivas con una adecuada tasa de cuadros por segundo en equipos de cómputo convencionales. La validación se realizó con escenarios

tridimensionales, mostrando muy buena concordancia con otras simulaciones y métodos numéricos más sofisticados y que consumen muchos más recursos.

El modelo completo de simulación está disponible en Internet[1] para ser utilizado como biblioteca y ha sido descargado más de 4.000 veces con visitas de Croacia, EEUU, Rusia y Turquía. Adicionalmente, los videos generados a partir de esta tesis, han conseguido más de 21.000 visitas en el sitio Youtube. La facilidad de uso del módulo ha hecho que se utilice en aplicaciones de campos tan variados como el arte escénico, la domótica o los videojuegos.

Clasificación (ACM CSS 1998): I.3.5 Computer Graphics - *Computational Geometry and Object Modeling*, Physically based modeling. I.3.7 Computer Graphics - *Three-Dimensional Graphics and Realism*, Animation.

Palabras clave: LBM, Animación basada en física, Computación Gráfica, Simulación de superficies de fluido

[1] http://www.plademа.net/~cgarcia/projects

Abstract

This thesis presents the research results of real-time algorithms for interactive liquid surfaces animation, based on a Lattice Boltzmann model which represents the surface-water interface equations. These results are developed and thoroughly tested, resulting in a physical engine able to produce dynamic scenes of ponds or open waters, with surfaces that react to the perturbations introduced interactively by the users. Examples of these perturbations are the agitation induced by moving objects (ships, propellers, or any specific object defined by an arbitrary triangulation), or other type of external perturbation, like rain drops.

A major topic developed in this work was the treatment of fixed and dynamic borders, like bridges' columns or boats, which are represented as dynamic boundary conditions or external forces that interact with the numeric simulation. The solution led to a complete model for fluid-structure interaction (i.e., fluid-to-structure and structure-to fluid) that provides flexible representations of waves produced by boats, wave reflections in bridges, and other situations of interest in computer animation, either for the creation of special effects or in the graphic support of nautical training simulators. In particular, a novel strategy for the calculation of the buoyancy force was introduced, based in the integration of the hydrostatic pressure over the solid immersed surfaces. The proposed method is more versatile and accurate than other schemes based on the tracking of the center of buoyancy, and it is very easy to implement in grid based representations.

Even though the main purpose of this work was aimed to produce physically and visually accurate simulations, the resulting implementation achieves reasonable calculation times. Thus, the application of this model in interactive computer graphics achieves an adequate frame rate using conventional desktop computers without losing accuracy, using more efficiently the computational resources than other more sophisticated numerical methods.

The engine is freely available on the Internet[2] as a library, which was downloaded more than 4,000 times including visits from Croacia, USA , Russia and Turkey. Additionally, the videos generated using the product of the present thesis have been viewed by more than 21,000 visits in YouTube. The flexibility of the engine was demonstrated in the variety of applications generated from it, like scenic art, domotics and videogames.

Clasification (ACM CSS 1998): I.3.5 Computer Graphics - *Computational Geometry and Object Modeling*, Physically based modeling. I.3.7 Computer Graphics - *Three-Dimensional Graphics and Realism*, Animation.

Keywords: LBM, Physics based animation, Computer Graphics, Surface waters.

[2] http://www.plademа.net/~cgarcia/projects

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