Visualization Contest 2006 - California Streaming

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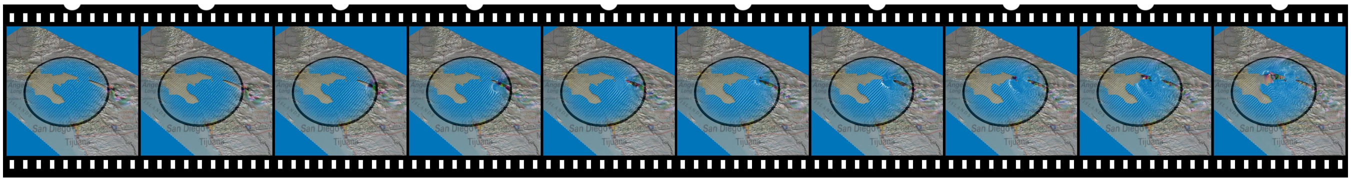

ClearView for streamed, interactive flow in action. Three data layers are blended together (focus+context, particles). The lens is an intuitive and user-friendly means to see through the context layer while maintaining positional cues. The velocity magnitude at the surface was color-coded and displayed as well. The velocities x,y,z components map to r,g,b respectively. As can be seen, there is a strong phase shift perpendicular to the St. Andreas Fault (upper right in each image). For a larger view, see Image 1 included on the DVD.

1 Introduction

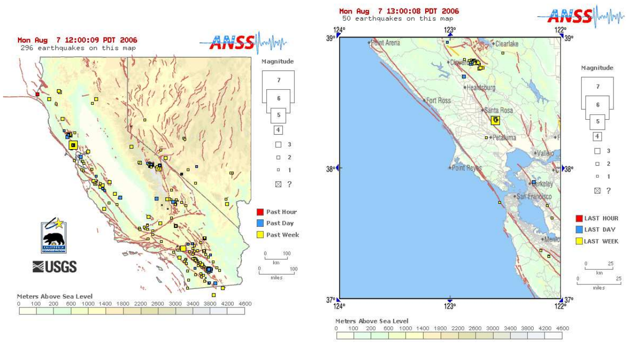

Figure 1: *Left: USGS-maintained map of recent earthquakes in California, from http://quake.usgs.gov. Right: Zoom on a magnitude 4.4 earthquake and several smaller aftershocks.*

As can be seen in Figure 1 (left), earthquakes are a rather frequent phenomenon in the state of California. Though gladly most of the recorded events are of minor strength, computer simulation can help to predict stronger earthquakes. In order to take pre-emptive measures saving human lives, a concise understanding is necessary. By far the most promising means to gain that understanding is a fast, high-quality, and intuitive visualization of measured real-world or simulated **large** data. Figure 1 (right) demonstrates the need for a high-speed visualization framework. A zoom on a magnitude 4.4 earthquake shows several smaller aftershocks. For larger earthquakes, these aftershocks can still be considerably devastating, making it highly advantageous to perform a visualization in the usually short period between the strong phase and the first aftershock. High-quality visualization is needed to allow precise predictions in earthquake hazard reduction. Interactive and intuitive visualization enables the expert to quickly explore unknown grounds efficiently, and thus to gain insight into the earthquake's behaviour in the least possible time.

2 Visualization System

In this contribution we addressed the aforementioned issues, presenting a rapid visualization system that runs at interactive frame rates on commodity PC hardware. To achieve the best possible performance, we have modified our GPU-based particle engine [Krüger et al. 2005] that runs on consumer class graphics hardware. To deal with large real-world or simulated data sets, we are able to stream huge datasets from hard disk. This allows us to present all of the time steps publicly available at the San Diego Super Computing site. User-friendly and interactive control over these time steps is provided by an interface similar to those used in traditional media players. We achieve high quality by application of well-established flow visualization modes, such as particle tracing, stream-lines, stream ribbons etc. The necessary integration for these primitives is performed using higher order numerical schemes and in full float precision on latest nVidia graphics hardware. To provide an intuitive visualization, we build on the experience gained with our *ClearView*[1] focus+context approach [Krüger et al. 2006] and applied it to the visualization of unsteady vector fields. Additional data layers can be visualized together with the time-resolved wave propagation field in order to give better positional cues. To demonstrate the capabilities of our system, we obtained a heightfield of southern California from the USGS, we reconstructed the basins as described in the meta-data description, and we obtained an additional topographic texture map. The user can toggle these data layers interactively to co-locate features in the wave propagation data with precise geographic features. ClearView automatically blends the selected layers based on only a few user-selected parameters. To further increase flexibility, for each layer a custom-taylored high-level fragment shader can be used that has full access to the multi-modal dataset as well as the state of the visualization system. For instance it is a matter of only a few lines of shader code to obtain a color-coding of the near-surface layers of the velocity data.

3 Visualization Tasks

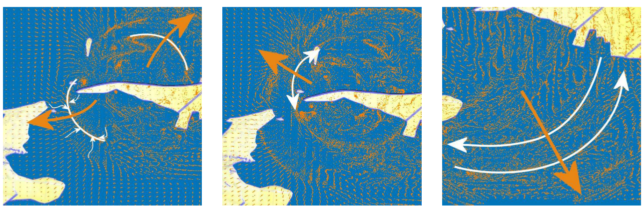

Figure 2: *The particle patterns of several wave types. From left to right: P-waves (longitudinal), S-waves (transversal), and L-waves. These three types can be easily recognized by particles in motion.*

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[1]ClearView will be presented at IEEE Vis 2006

To answer the question more precisely, we designed classification filters that decompose waves into locally longitudinal and transversal components. To do so, the local propagation direction is estimated using the gradient of the velocity magnitude, and two consecutive directions are compared using dot and cross products. Further taking the local rotation (curl) of the velocity field as well as the depth below surface into account allows us to highlight areas that are likely to produce Rayleigh-waves. Love-waves are very hard to classify by localized filters, but they are easily apparent by the moving particle formations in the near-surface layer of the velocity. However, since velocities have to be upscaled for particle integration in order to obtain recognizable motion, regions with both P- and S-components may also be identified as vortices. These vortices do not occur in nature, but are a convenient way to identify interesting regions. Especially Question 5 can easily be answered by inspecting these vortices. In Figure 2 we show the distinct particle patterns associated with the various wave types.

Q1. Waves in the Whittier-Narrows Area ?

This question is very hard to answer, and we think that it might be easier to tell from a subblock of the original high-resolution area. However, we think that there is a pronounced motion in that area, but this only occurs in about the middle of the simulation. At that time, there is a strong velocity component in NS direction. This can be seen in Image 2 on the accompanying DVD. The structure in question is only a transversal component of a slowly evolving wave-front, so it is not directly related to the propagation direction of the wave. Nevertheless, the wave front deforms at this particular region and travels on for several seconds in its deformed state.

Q2. Do Waves focus towards Centers of Basins ?

From our visualization it can be easily seen that basins act as a new source of waves (also see Q5). Additionally, there are very pronounced velocity peaks at lower depths of the Ventura and Los Angeles basins. These locations seem to "store" the kinetic wave energy, probably by reflections off of the holes' walls (see Question 4), making them stable wave emitters for several seconds (see also Q5). This can be observed very well in the movie, where such features stay in the basins for more than 20 seconds. The effect is exceptionally strong in the Salton Sea, the Los Angeles, and the Ventura basin, where wave peaks stay for a long time in one position. In the Salton Sea basin the effect is weaker, here several stable vortices (presumably P/S joints) can be found that clearly follow the outline of the basin.

Q3. Large Conversions between Wave-Types ?

Right after the first shock, P waves will be emitted east and west of the epicenter, while S waves occur at about 30% to the main axis of the St. Andreas Fault. While the shock wave travels further, Love-waves evolve, starting west of the Salton Sea Basin. L-waves can be classified very clearly in the accompanying movie by the "back-and-forth" patterns evolving (see also Figure 2). We also found that later in the simulation (around 190s) the dent that runs in east-west direction in the Salton Sea Basin could be a reason for changing wave types. To the north of this small fault we observe stable vortices, while at the south clearly visible P-waves emerge. These can be clearly classified, since the amplitude maxima (connected lines in the animation) collect material from both perpendicular directions. More precisely, compressions can be visualized in this way (Image 3). Furthermore, the joint between St. Andreas Fault and Salton Sea acts as a strong wave emitter later on in the simulation. The fact that all three x,y,z velocity-components are fairly high in that area could hint towards Rayleigh-waves. Last but not least, the Los Angeles and Ventura basins also act as strong wave emitters later. In the close neighborhood of these basins, a mixture of different wave-types is emitted, but further away, these have been converted to L- or possibly R-waves.

Q4. Wave reflections ?

From the performed visualizations we could not observe a structure that we would identify as a clear reflection. There is, however the phase shift at the St. Andreas Fault. The mapping of near-surface velocity components shows clear interference patterns. Some of these patterns (especially those at the southern end of the St. Andreas Fault) could be indications of reflections. On the other hand they could also just indicate that the end of the Fault near Salton Sea simply acts as an additional wave source. The fact that waves are "caught" at basin centers could also be a reflection effect, not unlike a quantum well, where waves would be reflected from the walls. The result could be a stationary wave with a very slowly decaying amplitude. Examples for such an behaviour can be seen in the movie.

Q5. Basins as wave sources?

This is a clear yes. The entire complex of Basins surrounding Los Angeles is a huge emitter of L-waves If in our system particle positions are reset, typical L-wave patterns quickly form around the basin complex. The center can be found in the middle of the Los Angeles and San Gabriel basins, in the middle of the Witthier-Narrows area. This effect can also be observed in the near-surface velocities, as the color mapping looks exactly like the superposition of two waves, one at the original epicenter and the other one in the described location. The waves that are emitted to the south at Salton Sea for a long time during the simulation are most likely not related to the Basin acting as a wave source, but to the end of St. Andreas Fault acting as a wave source.

4 Additional Material

The movie was sped up by 100% from real-time. It was streamed and rendered on a 2.2GHz AMD Athlon X2 processor with 2GB of RAM and a single IDE harddisk. The graphics adaptor was a GeForce 7900GTX with 512MB of RAM. For more information, please also visit http://wwwcg.in.tum.de/vis-contest06

References

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