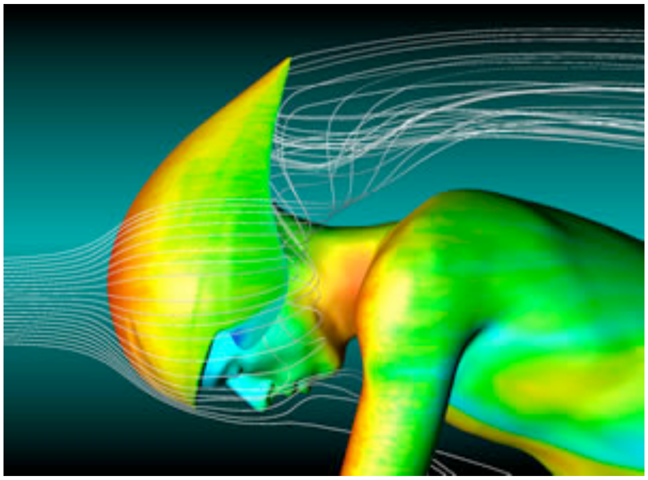
CFD analysis from scanned models help
British Cycling Team sprint to Olympic medals

by Erin Hatfield



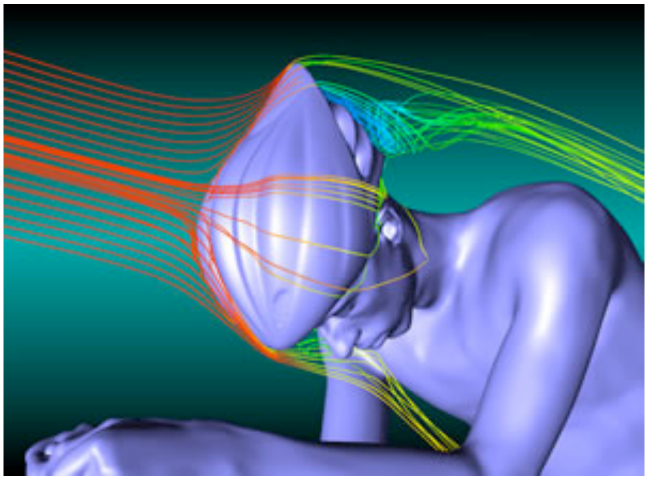
Tenths of a second can mean the difference between a gold medal and fourth place in Olympic track cycling.

Before the 2004 Olympics in Athens, the British Cycling Team found a unique way to help save those precious fractions of a second: The team commissioned computational fluid dynamics (CFD) studies from the Sports Engineering Research Group (SERG) at the University of Sheffield to improve the overall aerodynamics of their equipment. A combination of 3D scanning technology, Geomagic Studio reverse-engineering software, CFD programs from Fluent, and EnSight visualization software produced results that helped the team earn four medals.

Last-minute CFD analysis

In June 2004, just weeks before the Summer Olympics, the cycling governing body enacted a rule change stating that only helmets passing a formal safety test in an accredited laboratory could be used in Olympic track competition. The British Cycling Team had four helmet designs that fit the specifications, each with different aerodynamic stylings.

To help determine which helmet was best for competition, the team turned to SERG for a quick CFD analysis. The British Cycling Team had worked with SERG months before to optimize the aerodynamics of the handlebar and wheel/fork designs on the team bikes in preparation for the Olympics.



SERG’s Dr. John Hart ruled out CAD as an option for creating the digital models needed for CFD analysis: There was not enough time to model from scratch, and CAD is not well-suited to create the organic shapes required for accurate modeling and CFD analysis of the helmets and athletes. Hart decided that the best solution was to capture the geometry of the athletes and helmets with 3D Scanners’ ModelMaker X70 non-contact 3D laser fitted on a Faro Gold arm, then merge the scans and create a NURBS model of the data in Geomagic Studio.

“CAD engineers work at different tolerances than those required for CFD analysis,” Hart says. “Even if we had the CAD files for the helmets, we would have had to spend a great deal of time cleaning up the model to make it watertight. Reverse engineering the helmets and surfacing them in Geomagic Studio guaranteed a highly detailed, watertight model in less time.”

Scanning the helmets was relatively straightforward. Each helmet took approximately 25 minutes to scan depending on the complexity of the design. The Faro arm moved around the object, capturing point-cloud data and depth information.

SERG planned to capture data from the athletes by scanning them in different racing positions; one aerodynamic posture and one where the cyclist has his or her head down to test more fully the effect of the helmet shapes.

Because of the time crunch, however, Hart did not have access to a cyclist; he had to scan a colleague for the human geometry. The subject was scanned over the course of two hours, allowing for rest breaks during the scan session. Completed scans were broken into sections that followed closely in succession – upper arm, lower arm, hand – to help eliminate issues from sudden movement during the process.

Refining complex scan data

Point-cloud data collected from the scans of the four different helmets was imported into Geomagic Studio, reverse-engineering software used to generate models for accurate CFD analysis, and to custom manufacture devices fit to an individual's body parts.

Geomagic Studio automatically aligned the scan data and a polygon mesh was applied. The model was cleaned to remove holes and defects in the data. Then patches were created over the polygons, outlining the positions of the NURBS surfaces.

Scan data from the human subject was handled in much the same way, except additional work had to be done to reduce noise and align the data due to subtle movement from Hart's colleague as he was being scanned.

Hart used Geomagic Studio's noise-reduction feature, as well as editing and filter tools, to refine the human model. He then used the software's polygon geometric reconstruction functions to fill in missing data such as body hair and eyebrows that weren't captured due to laser scatter.

"Geomagic Studio's editing tools and ability to handle large, complex data sets made it a great match for this project," says Hart. "We used the tools to refine scan data around the ears and in tight gaps, which enabled us to maintain a high degree of geometric realism on such a challenging human scan with nearly six million raw data points."

Polygons and NURBS patches were applied to the human model and output by Geomagic Studio as a STEP file.

"The STEP file format provides a robust geometric file that's not too large," Hart says. "We can end up with a model with a large number of NURBS patches in order to capture the detail we need. The accuracy of the CFD study was highly dependent upon the geometrical accuracy of the assembled model."

Visualization that proves results

The STEP file containing each helmet design and the human geometry was imported into Fluent's Gambit software, where it was meshed for CFD analysis and a flow domain was generated around each model. The meshes ranged from two to seven million cells, depending on the geometry that was modeled. Wherever possible, prism cells were generated over the surface geometry to capture boundary-layer flow features in detail.

Fluent software was used for CFD analysis, which incorporated data on boundary and physical conditions that SERG had acquired from a previous British Cycling project.

CFD results were imported into CEI's EnSight software, which produced highly detailed flow visualizations showing the aerodynamic properties of the helmets. SERG chose to concentrate on the drag and lift forces in the simulations, using isosurfaces to show wake structures and particle streamlines to visualize swirling, recirculating flow paths.

Based on the wake structures and recirculating flows in the visualizations, SERG was able to quickly identify how different geometric components of the models – such as the helmet and cyclist – interacted and influenced each other. They were also able to pinpoint large wakes that resulted in high drag forces.

Hart colored different aspects of the model within EnSight, and applied properties such as reflective surfaces for the bike and helmet and matte surfaces for fabric and skin. Lighting effects applied to the model helped complete the life-like look, according to Hart, making the results more believable.

“The flow visualizations and images were vital in presenting the physics-based simulation results in an understandable manner to the cycling team,” Hart says. “Being able to clearly show a client what is happening is essential to their understanding of the results.”

Hart and his colleagues used the EnSight images and animations to reinforce the hard data output from the Fluent simulations and help the engineers understand the flow physics that created the lift and drag forces. Based on the results, SERG was able to recommend an optimal helmet style that reduced aerodynamic drag and lift.

“The quality of the model geometry from Geomagic Studio and realistic color renderings and surfaces we applied in EnSight enabled us to incorporate a great deal of realism in the visualization,” says Hart.

The optimized bike design and helmet recommendations SERG made contributed to the team’s medal haul in the Olympic cycling events. SERG is working with the team again through UK Sport for the 2008 Beijing Summer Olympics.

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Erin Hatfield is a writer serving the computer graphics, IT and electronics industries.

CEI Press contact: Amanda Baley, 919-363-0883