The summary of "SIMULATION AND VISUALTIZATION OF AIR FLOW AROUND THE BAT WINGS DURING FLIGHT"

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SUMMARY:

The bats have some unique features like specialized skeletal anatomy, high muscular control over wing conformation, and highly deformable wing membrane skin. So, their wings not only flaps but also undergoes large shape changes with every wind-beat cycle. These unique features have been raising various questions in researcher's mind, who have started incorporating, in their research, various sophisticated methodologies drawn from the physical and mathematical sciences. The simulation and visualization of the air flow around the bat wings during the flight, poses significant technical challenges. So, this paper is describing an interdisciplinary approach to build the tools for the simulation and visualization. The main tools and techniques described here are data acquisition, data processing, numerical simulation and visualization of preliminary simulation results.

So, to start with, the infrared markers are attached to the bat wings. Then more then 20 species are made to fly though the wind tunnel. Wind tunnel is the main part of this whole experiment, and makes this project DDDAS. Two high speed digital cameras track these infrared markers. A bat species, known as Pteropus Policephalus, is chosen for experiment because of its large size wings and relatively slow flight. Motion of bat in one complete wing beat is equivalent to about 160 video frames. So, after 160 video frames are selected, the Peak motion capture system is used to extract the 3D coordinates of the markers. This whole bunch of data is used to animate a simple 3D polygonal model of the surface of the bat's wings. But due to high wing deformations during flight, the 3D coordinates of few markers cannot be determined in some frames. *At the heart of generating polygonal bat wing model is the ability to reconstruct accurately the positions of these markers* [1]. So, this missing data is reconstructed using the approach based on proper orthogonal decomposition (POD) combined with least-square approach.

To show the bat motion cyclic, which is required for this simulation, periodicity is enforced on the POD mode coefficient.

The animated polygonal model is the basis for the sequence of tetrahedral meshes of the volume 10 by 10 by 20 around the bat geometry, which has a wing span of approximately two non-dimensional units at its widest [1]. Wings are represented by infinitely thin tessellation of triangles. An arbitrary Lagrangian-Eulerian (ALE) formulation of the incompressible Navier-Strokes equations is used to solve flow fluid. This allow to run simulation for changing geometry without remashing at each step i.e, a single tetrahedral mesh can be deformed to fit number of frames, approximately 7 to 15, depending upon the rate of deformation. If deformation become too extreme, then the elements degenerate and new tetrahedral mesh must be created. So, multiple meshes are necessary and all these meshes must be interpolated so as to simulate the entire wing beat. *The mesh generator Gridgen is used to generate up to 15 meshes for one wing-beat. Each mesh has approximately 6000 spectral tetrahedral elements. Governing equations are solved by hybrid spectral/hp element solver Nektar. Preliminary simulation were performed using*

third-order polynomial expansion in each element [1]. Reynolds numbers play a major role in this experiment and use of highly maneuverable instead of simple oscillating wings have made this Reynolds number simulation challenging. Here Reynolds number is set to 100, which is greatly reducing the computational effort and time. This simulation results in the time varying fields that are unfit for the real time visualization due to their size and complexity. So, the sets of pathlines and streamlines are precomputed and stored, so that they can be visualized later interactively. CAVE is used for visualization as it is considered more engaging then less sophisticated desktop displays. *The user has interactive control over the number of lines displayed, how randomly they are distributed in space, and the mapping of opacity to flow quantities* [1].

ANALYSIS:

The main objective of this project is to understand the mechanism that is responsible for bat's special flight capabilities and exquisite aerodynamic control. This can be studied by simulating the air flow, pressure and other conditions around the bat wings so as to imitate the real conditions. Wind tunnel, as described in [2], is the apparatus used for studying this interaction between the bat's body and an airstream. It simulates the conditions of bat in flight by causing a high speed stream of air to flow past its body (and wings). Forces exerted on the bat may be determined from measurement of the airflow upstream and downstream of the bat. So, this shows that wind tunnel is apparatus that actually makes this whole project DDDAS, where we can vary the various conditions and hence see the effects. And in this simulation, the wind tunnels are also fitted with two high speed cameras that trace the infrared markers that are attached to the bat wings. And these infrared markers then helps to create the 3D polygonal model of the bat wings.
This application can yield insights of the use in future technical applications, such as the development of unmanned micro-air vehicles.

[1].I.V.Pivkin, E. Hueso, R. Weinstein, D.H. Laidlaw, S.Swartz, and G.E. Karniadakis, **Simulation and Visualization of Air Flow around Bat Wings During Flight**, pg 689-694
[2] http://education.yahoo.com/reference/encyclopedia/entry/windtunn