Prof. Chaoqun Liu

Dr. Chaoqun Liu received both BS (1968) and MS (1981) from Tsinghua University, Beijing, China and PhD (1989) from University of Colorado at Denver, USA. He is currently the Tenured and Distinguished Professor and the Director of Center for Numerical Simulation and Modeling at University of Texas at Arlington, Arlington, Texas, USA. He has worked on high order direct numerical simulation (DNS) and large eddy simulation (LES) for flow transition and turbulence for almost 30 years since 1990. He was the Chairman of the First and Third AFOSR International Conference on DNS/LES. As PI, he has been awarded by NASA, US Air Force and US Navy with 50 federal research grants of over 5.7 million US dollars in the United States. He has published 14 professional books, 128 journal papers and 152 conference papers. He is the founder and major contributor of Liutex and the third generation of vortex definition and identification methods including the Omega, Liutex/Rortex, Modified Liutex-Omega, Liutex-Core-Line methods, RS vorticity decomposition and UTA R-NR decomposition, Principal Coordinate, and Principal Decomposition of velocity gradient tensor. He is also the founder of new fluid kinematics.

Plenary Lecture 1:
Liutex-Based New Fluid Kinematics and New Fluid Dynamics

Liutex is a physical quantity like velocity, vorticity, pressure, temperature, etc. describing local fluid rotation or vortex, which was ignored for centuries. Liutex was defined by the UTA Team in 2018 as a vector for vortex. Its direction is local rotation axis and magnitude is twice local angular rotation speed. As the third generation of vortex definition and identification, Liutex has been widely applied for visualization of vortex structure to replace the first generation or vorticity which cannot distinguish shear from rotation and the second generation such as Q, Δ, $\lambda 2$ and λci methods, which are all scalar without rotation axis, dependent on threshold and contaminated by shear and stretching. A number of new vortex identification methods have been developed especially Modified Liutex-Omega method which is threshold insensitive and Liutex-Core-Line method which is unique and threshold-free. According to Liutex vector, a unique coordinate system called Principal Coordinate can be set up and consequent Principal Decomposition of velocity gradient tensor can be made. Being different from classical fluid kinematics, the Liutex-based new fluid kinematics decomposes the fluid motion to a rotational part and non-rotational part (UTA R-NR decomposition). The non-rotational part can be further decomposed to stretching and shear including symmetric shear and anti-symmetric shear in contrast with the classical fluid kinematics which decomposes fluid motion to deformation and vorticity which was misunderstood as rotation. As fluid stress is determined by fluid strain, the new fluid kinematics will determine the viscous force. Traditional Navier-Stokes (NS) equations

define the stress based on Stokes's assumptions that the stress is supposed proportional to strain, and both strain and stress tensors are symmetric. There are several questions with NS, which include: 1. Both symmetric shear terms and stretching terms in strain and stress are coordinate-dependent and thus not Galilean invariant; 2. The physical meaning of both diagonal and off-diagonal elements are not clear, which is coordinate-dependent; 3. It is hard to measure the strain and stress quantitatively, and viscosity is really measured by vorticity not by symmetric strain; 4. There is no vorticity terms in NS, which plays important role in fluid flow especially for turbulent flow. The new proposed governing equations for fluid dynamics use vorticity tensor only, which is anti-symmetric. The advantages include: 1. Both shear and stress are anti-symmetric, which are Galilean invariant and independent of coordinate rotation; 2. The physical meaning of off diagonal elements is clear, which is anti-symmetric shear stress, 3. Viscosity coefficients are obtained by experiment which uses vorticity, 4. The vorticity term can be further decomposed to rigid rotation and anti-symmetric shear, which are important to turbulence research, 5. The computation cost for viscous term is reduced to half as the diagonal terms are all zero as six elements are reduced to three. Several computational results are made, which clearly demonstrate both NS and new governing equations have exactly same results. In fact, the new governing equation is identical to NS in mathematics, but its physical assumptions are just the opposite of NS. It is recommended to use the new governing equations to replace Navier-Stokes equations. New fluid dynamics by considering high order terms for turbulent flow is still under development.