Introduction to SU$^2$

OpenMDAO-SU2 Joint Workshop
Stanford University
Monday, Sept. 30 2013
Prerequisites

- C++ compiler
  - GNU gcc
  - Intel icpc
- GNU Autoconf/Automake tools
  - http://www.gnu.org/software/autoconf/
  - http://www.gnu.org/software/automake/
- Git
  - http://github.com
- Numpy/Scipy
What is SU²?

The Stanford University Unstructured (SU²) is a software package for:

- Fluid Simulation
- and Engineering Design

SU² is distributed as Open-source software

SU² is under active development at Stanford University in the Aerospace Design Lab (ADL) of the Department of Aeronautics and Astronautics.

http://su2.stanford.edu/

SU² v3.0 (Eagle) will be released on Jan 11th, 2014
Motivation

Advanced design environment
• Enable analysis and design of complex engineering systems
• Multi-physics simulation

Leading-edge solver technology
• Tool for CFD research
• Global accessibility
Why SU$^2$?

1. **An open-source model**: basic formulation with a reasonable set of initial capabilities, we would like to see contributions from the community!

2. **Portability**: SU$^2$ has been developed using ANSI C++ and only relies on widely-available, well-supported, open-source software.

3. **Reusability and encapsulation**: SU$^2$ is built so that the main concepts (geometry, sol. algorithms, num. algorithms, etc) are abstracted to a very high-level. This abstraction promotes reusability of the code and enables modifications without incorrectly affecting other portions of the suite.

4. **Flexibility** required to re-purpose existing software for new and different uses. Enabling a common interface for all the necessary components.

5. **Performance**: we have attempted to develop numerical solution algorithms that result in high-performance convergence of the solver in SU$^2$.

6. **Gradient availability**: for many applications it is important to obtain grad. of the responses computed by SU$^2$ to variations of design parameters.
Why SU$^2$?

Shape Optimization
- Self-contained optimization env.
- Gradient availability (adjoint method)
- Built-in:
  - Design var. definitions
  - Surface deformation
  - Mesh deformation

Multi-Physics Simulations
- Simultaneous analysis of different equation sets w/ tight coupling
- Aero-structural, aero-acoustic, free-surface, reacting gas mixtures, etc.
SU² Modules

- SU2_CFD: Computational Fluid Dynamics
- SU2_DDC: Domain Decomposition Code
- SU2_MAC: Mesh Adaptation Code
- SU2_MDC: Mesh Deformation Code
- SU2_PY: Python drivers
- SU2_SOL: Solution file processing
- + More
The main idea is to **embed the physical object into a 3D grid, and then modify it as a whole**. The object inherits the deformation of the auxiliary grid.

**Capabilities: Geometry Deformation**

- Engineering-like design variables
- Fine control of the design surfaces
- Nested FFD strategy (local and global control)
The Mesh Adaptation Code in the SU$^2$ suite facilitates **strategic mesh adaptation** based on several common schemes, including gradient and goal-oriented methods.

1. Goal-oriented mesh adaptation.
2. Engine propulsion effect adaptation.
Capabilities: Optimal Shape Design

- Magnitude of surface sensitivity is related to changes in cost function caused by changes in geometry.
- Designers can use this sensitivity information to determine appropriate parameterizations of the configuration prior to optimization.

Mach number = 1.7
AoA = 2.1
Free-stream pressure = 11665.9 Pa
Free-stream temperature = 216.65 K

Fan face Mach 0.515
Total nozzle temp 569.7 K
Total nozzle pressure 109764.5 Pa
Computational analysis tools have revolutionized the way we design aerospace systems, but most established codes are proprietary, unavailable, or prohibitively expensive for many users.

The SU² team is changing this, making computational analysis and design freely available as open-source software and involving everyone in its creation and development.

Why?

- Worldwide accessibility.
- Encourage contributions from everyone.
- Enables CFD research everywhere… the complexity of today’s problems requires tools to start from in order to make a technological impact.
Open-source Community
The first 20 months...

- 49,000 website visits from 136 countries
- 6,000 code downloads
- Many top universities and aerospace companies

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A Student-led Initiative

- “Learning through building”
- Two-way information exchange
  - Students equipped with expertise
  - Research & Industry interest
The SU^2 Team

• Aniket C. Aranake, Alejandro Campos, Sean R. Copeland, Thomas D. Economon, Kedar R. Naik, Amrita K. Lonkar, Trent W. Lukaczyk, Santiago Padrón, Brendan D. Tracey
  – Ph.D. Candidates in the Aero/Astro department.

• Francisco Palacios
  – Engineering Research Associate in the Aero/Astro department.
  – Lead Developer.

• Michael R. Colonno
  – Engineering Research Associate in the Aero/Astro department.

• Juan J. Alonso
  – Associate Professor in the Aero/Astro department.
  – Aerospace Design Laboratory (ADL) Director.
Why is SU$^2$ important?

- Cutting-edge research from Stanford available in real-time.
- Enables advanced Computational Fluid Dynamics research in places that don’t have the resources or expertise.
- Making the state-of-the-art in computational fluid dynamics freely availability will help companies create faster and greener aircraft, cars, boats, etc.
- Perfect tool for facing some of the future challenges for aviation: achieving supersonic flight over land, and reducing fuel burn, emissions, and noise.