Welcome and introduction to SU²

SU² Release Version 2.0 Workshop
Stanford University
Tuesday, January 15th, 2013

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Outline

- Motivation
- Why SU$^2$?
- Current capabilities
- Conclusions
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Motivation
Our objective

Develop advanced design environments to enable systems that address the challenge of meeting the demand while minimizing the impact on the environment.

Develop a leading solver in the unstructured CFD community.
Optimization techniques are the **final goal of all practical design project** but they are not used everywhere because:

1. The optimization of a **complete aircraft configuration** implies the interaction of a lot of different SW modules.
2. It is not easy to parameterize appropriately the **geometry modifications** (intersections and geometric constraints).
3. An optimizer is **limited to considering those designs that are described by the selected parameterization**.
4. Important **mathematical difficulties** in the gradients evaluation.
5. Great **time and personnel resources** are typically needed.
To integrate the existing SW packages into coupled multi-physics analysis and design optimization solvers is a challenge.

The variety of approaches chosen for the independent components of the overall problem make it difficult to:

- Expand the range of applicability to situations not originally envisioned.
- Reduce the overall burden of creating integrated applications.
- Exploit fully coupled approaches.
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Why SU²?
Stanford University Unstructured (SU²) suite

The Stanford University Unstructured (SU²) suite is an open-source collection of C++ based software tools to perform PDE analysis and solve PDE-constrained optimization problems.

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

More than 24,000 visits and 3,150 downloads since January 19, 2012
http://su2.stanford.edu/
Why SU²?

Lasting infrastructure for future efforts

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:** SU² has been developed using ANSI C++ and only relies on widely-available, well-supported, open-source software.

3. **Reusability and encapsulation:** SU² 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 SU².

6. **Gradient availability:** for many applications it is important to obtain grad. of the responses computed by SU² to variations of design parameters.
Why SU$^2$?
Multi-physics shape optimization.

Shape Optimization
- Self-contained optimization env.
- Gradient computation using adjoint approach.
- 3D design variable definition and built-in geometry and mesh deformation.

Multi-Physics Simulations
- Simultaneous analysis of different equation sets with tight coupling.
- Free surface simulations, noise, fluid structure, etc.
- Multi-species plasma solver for simulating ionized flows.
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Current capabilities
High fidelity analysis (I/II)

Verification and Validation is critical.

It should address the consistency of the numerical methods, the accuracy assessment for different critical application cases, and sensitivity studies with respect to parameters.

1. Compressible RANS simulation.
2. Rotating frame simulations.
4. Low-Mach simulations.
5. Time-accurate, unsteady simulation.
7. Plasma simulation.
Current capabilities
High fidelity analysis (II/II)

Jan 7th, 2013
Stanford University Unstructured (SU2)
Current capabilities
Optimal shape design and optimization (I/II)

The design optimization of PDE constrained systems is a primary function of SU².

The built-in adjoint solver in the CFD module, in conjunction with GPC, and MDC deliver objective function gradients.

1. Supersonic aircraft design.
2. Airfoil and fixed wing optimization.
3. Viscous (RANS) design.
4. Unsteady design.
5. Nested Free-Form Deformation boxes.
Current capabilities
Optimal shape design and optimization (II/II)

- 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
Current capabilities
Adaptive mesh refinement (I/II)

The Mesh Adaptation Code in the SU² 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.
3. Plasma adaptation.
Current capabilities
Adaptive mesh refinement (II/II)

Goal oriented adaptation

Gradient based adaptation

Grid adaptation
Plasma equations

Two-species Nitrogen gas chemistry model
(M = 25.9, H = 71km, T = 216K, and Re = 6280)

Baseline solution
Goal oriented adaptation
Gradient based adaptation
Outline

• Motivation
• Why SU²?
• Code structure
• Current capabilities
• Conclusions
Conclusions and future work
Analyze, optimize, design!

✓ Thanks to its data structure, SU² is an ideal vehicle for performing multi-physics simulations, including multi-species thermochemical non-equilibrium flow analysis, combustion modeling, two-phase flow simulations, magneto-hydrodynamics simulations, etc.

✓ The optimization of PDE constrained systems is a primary function of the SU² suite.

✓ SU² has been released under an open-source license and it is freely available to the community. Developers around the world can contribute to and improve the suite.

✓ Significant efforts were directed at the development of documentation so that prospective users could get up to speed with a minimum effort.
Conclusions and future work

Workshop agenda

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Tuesday, January 15th, 2013
William F. Durand Building, Rm. 450
496 Lomita Mall
Stanford, CA 94305

11.00 – 11.20: Welcome and Introduction to SU² (Dr. Francisco Palacios & Prof. Juan Alonso)

11.20 – 11.30: Quick Overview of SU² Installation (Dr. Mike Colonno & Aniket Aranake)
*Please come to the workshop with the software downloaded and installed. If you have any problems, we will provide individual support around the room.*

11.30 – 12.00: Introduction to the SU² Code Structure (Amrita Lonkar)
*Have a unique application in mind? Learn the structure of the code so you can expand its capabilities to suit your needs!*

12.00 – 12.30: Running SU² (Sean Copeland & Tom Taylor)

12.30 – 12.45: Break (food provided)

12.45 – 13.15: Problem Workshop I: SU² as a High-fidelity Analysis Tool (Thomas Economon)
*SU² has a multitude of capabilities for performing high-fidelity analysis of complex geometries. Learn about them here.*

13.15 – 13.45: Problem Workshop II: Design and Opt. Using SU² (Dr. Francisco Palacios)
*Learn why SU² is uniquely suited for performing design and optimization of complex aerospace systems.*

13.45 – 14.15: Problem Workshop III: Task-Based Design Eval. with SU² (Trent Lukaczyk)
*Explore the design space with our task-based framework.*

14.45 – 15.00: Adjourn

Thanks for attending, and note that all stated times are Pacific Time (PST).
Please join our community!

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Thank you for your attention!
Your feedback is very important for us!

http://www.cfd-online.com/Forums/su2/

Questions?

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