

GPU Accelerated Topology Optimization with Plato/Alexa

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Motivation

- Additive manufacturing (AM) technology has unique limitations and advantages relative to conventional approaches.
- The Plato Team is developing optimization-based design tools that are tailored to leverage AM.

Objective

Create a fast, extensible, and lightweight Partial Differential Equation (PDE) solver to enable optimization-based design.

Given an optimization problem:

$$\begin{aligned} \text{Objective:} & \quad \min_{\mathbf{z}, \mathbf{x}} f(\mathbf{u}, \mathbf{z}, \mathbf{x}) \\ \text{PDE Constraint:} & \quad g(\mathbf{u}, \mathbf{z}, \mathbf{x}) = 0 \\ \text{Inequality Constraint:} & \quad h(\mathbf{u}, \mathbf{z}, \mathbf{x}) \leq 0 \end{aligned}$$

It's necessary to solve the PDE constraint and compute total derivatives. To do so, we need:

$$\frac{\partial f}{\partial u_i}, \frac{\partial f}{\partial z_i}, \frac{\partial f}{\partial x_i}, \frac{\partial g_I}{\partial u_j}, \frac{\partial g_I}{\partial z_j}, \frac{\partial g_I}{\partial x_j}, \text{ etc.}$$

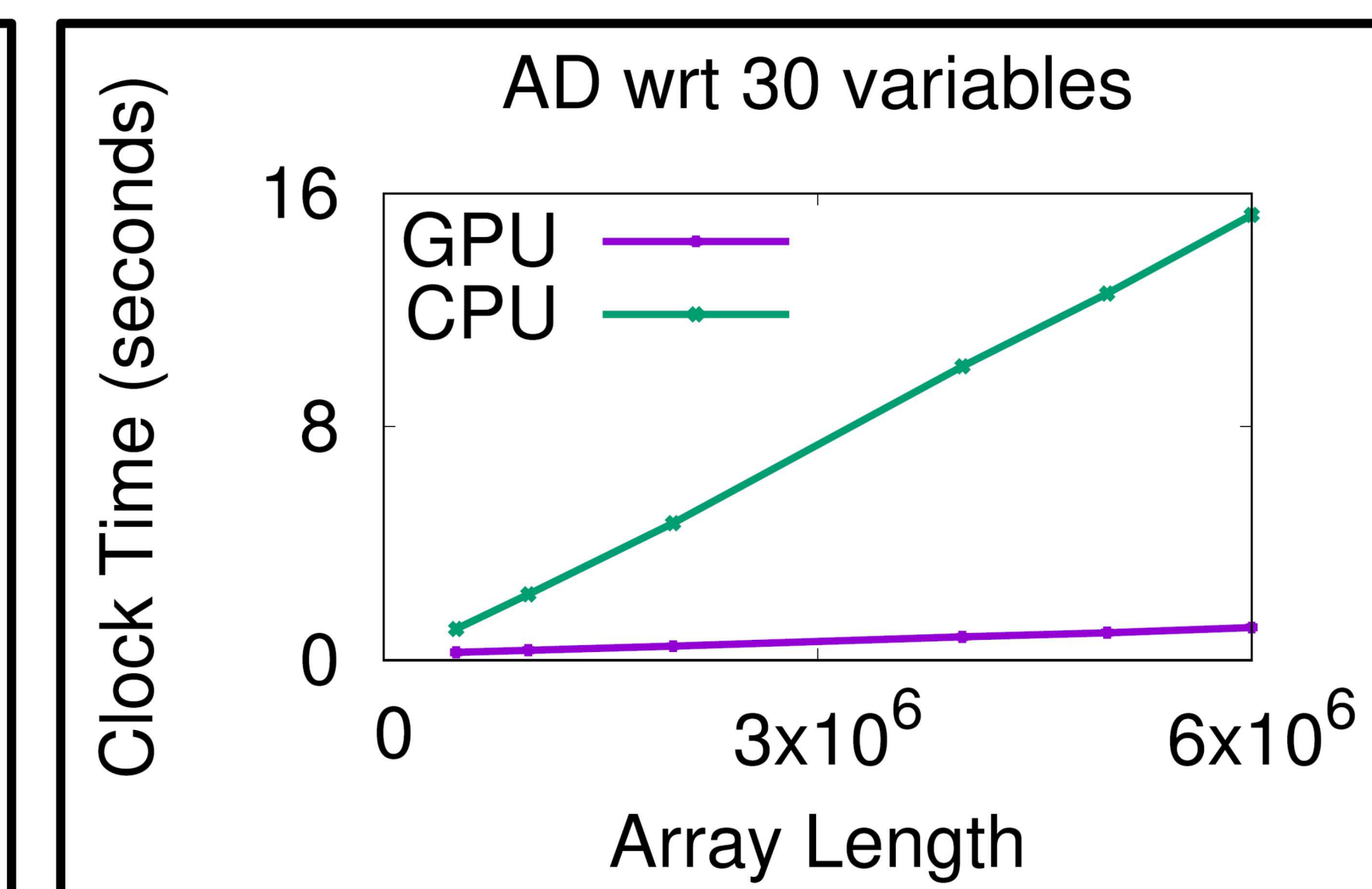
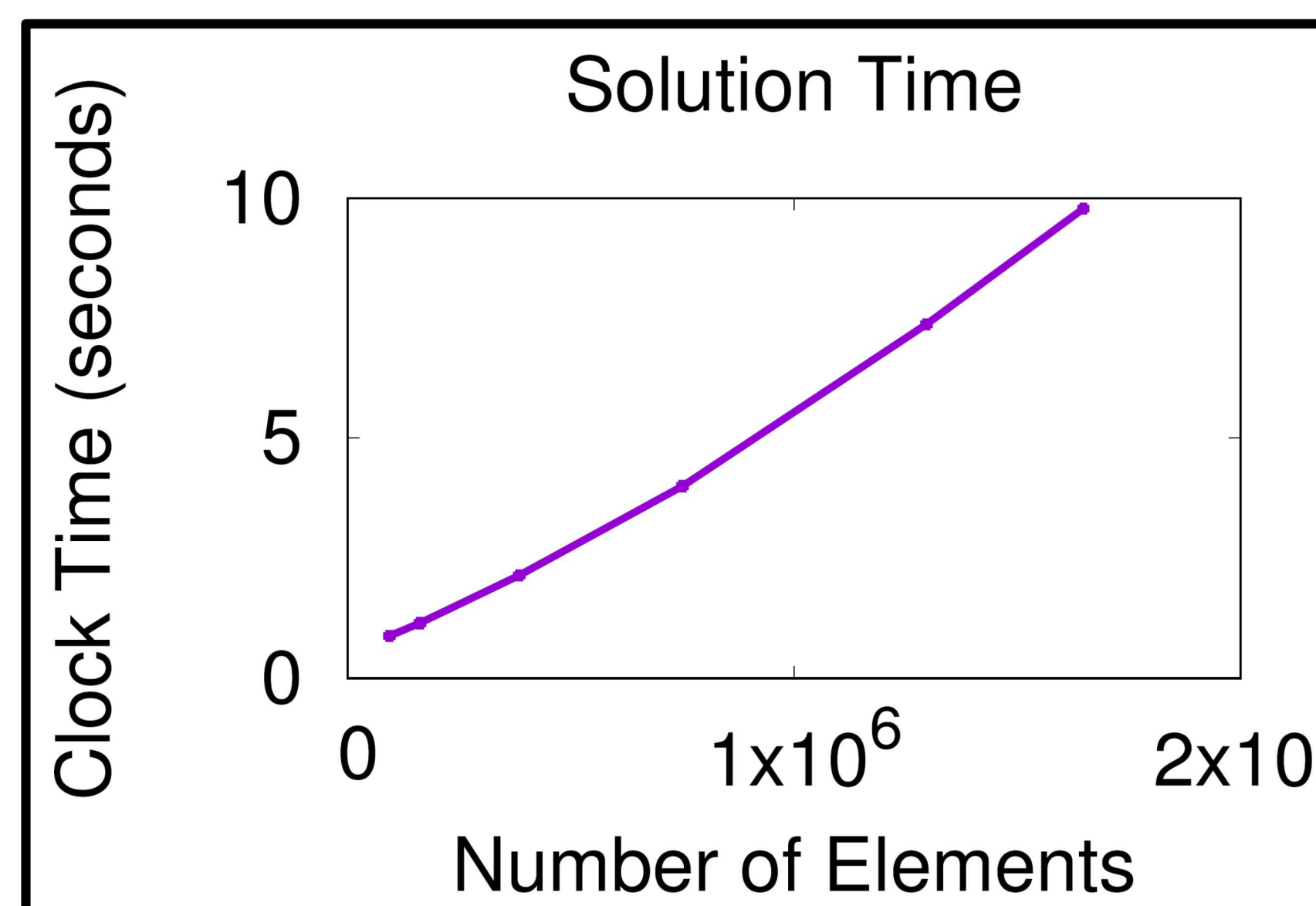
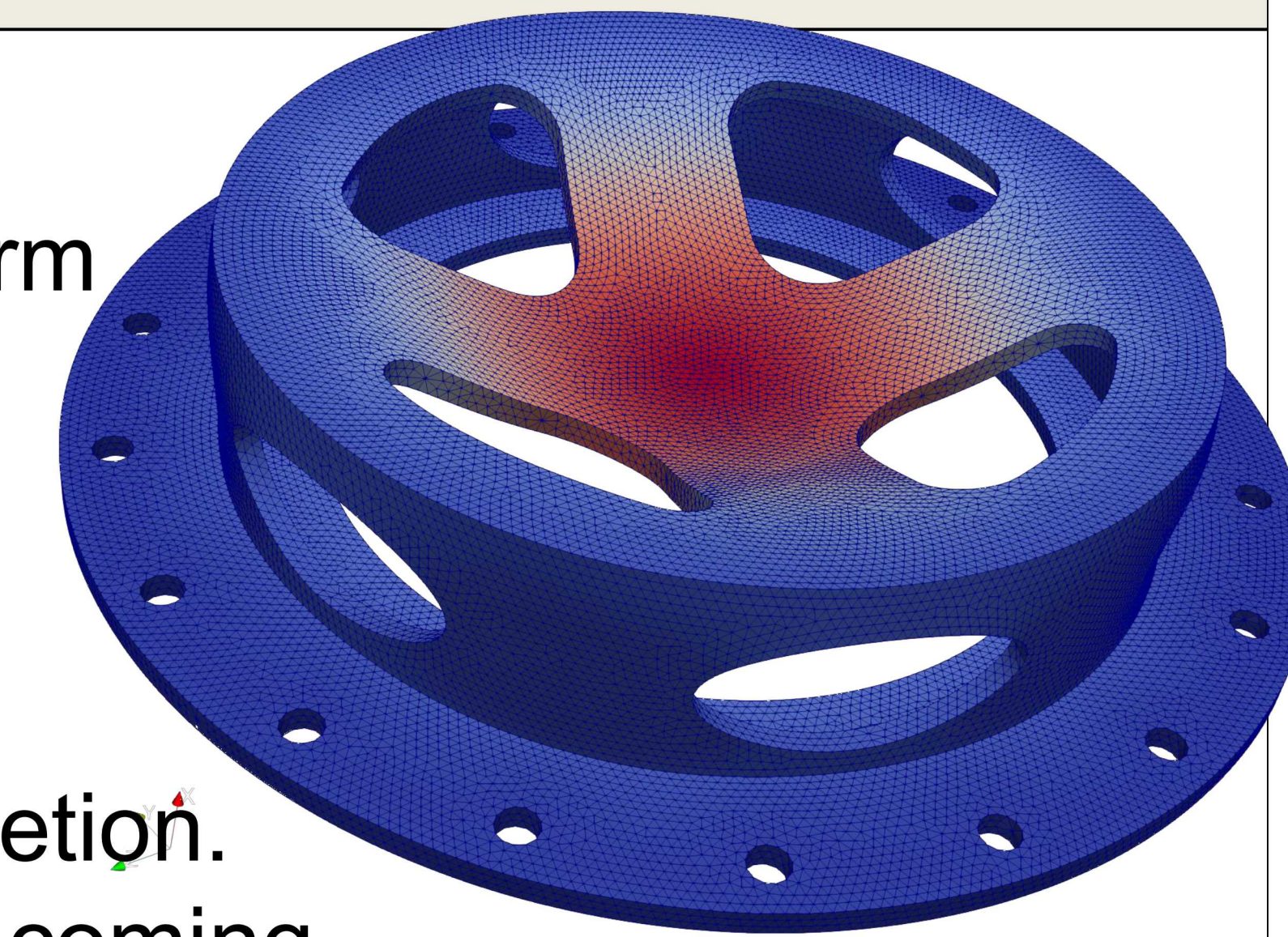
Approach

Partner with and/or leverage existing code efforts (Alexa, Kokkos, Sacado, AmgX):

- Automatic Differentiation (AD) with Sacado to compute derivatives of objectives and constraints.
- Kokkos for portable performance (GPU, many-core, multi-thread)
- Alexa for fast, device-centered computing
- AmgX for multi-grid preconditioning on the GPU.

Progress/Results

- Physics: mechanical, thermal
- Objectives: compliance, stress p-norm
- Constraints: volume/mass
- All of the above with gradients with respect to design, solution, and reference configuration.
- Integration with Plato nearing completion.
- More physics/objectives/constraints coming



Summary

- Plato/Alexa uses AmgX (Nvidia) for fast linear solves on the GPU.
- Plato/Alexa uses AD (Sacado) with Kokkos to compute essential gradients.
- Objectives and constraints are templated on AD types so a single implementation is used for computing values and all gradients.
- Plato/Alexa implements a Plato::Application for Multiple Program, Multiple Data (MPMD) parallel calculations. This permits simultaneous evaluation of multiple load scenarios and/or samples for uncertainty quantification and propagation.
- Initial comparisons between global stiffness computed directly and with AD show negligible performance cost.