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Deprecating & removing most of Tpetra's template parameters

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Quotes

“The easiest way to make Trilinos build faster would be to rename all .cpp files to .c, and fix the resulting syntax errors.” – Jed Brown

“**I actually enjoy complexity that’s empowering. If it challenges me, the complexity is very pleasant.** But sometimes I must deal with complexity that’s disempowering. The effort I invest to understand that complexity is tedious work. It doesn't add anything to my abilities.” – Ward Cunningham

“Fools ignore complexity. Pragmatists suffer it. Some can avoid it. Geniuses remove it.” – Alan Perlis

TL;DR Plan to purge LO, GO, & Node

1. Fix solver packages so they can build with GO=int OFF
   - Epetra & Tpetra support w/ GO=int OFF?
   - Make sure all tests build & run (some disabled now)
2. Forbid CMake options enabling multiple GO or Node types
3. static_assert that template arguments are enabled types
4. Add “TpetraNew” replacement classes w/ desired interface
   - Reimplement existing “TpetraOld” classes using new ones
   - Concurrently add New tests & migrate Old tests
5. Concurrently introduce new interfaces in solver pkgs
6. Deprecate TpetraOld & replace w/ TpetraNew (how: TBD)
   - Make Tpetra{Old & New} interoperable?
   - Trilinos’ release schedule & policy changes? Version macros?

Why bother?

- Most Tpetra template parameters add very little value
  - LO, GO: If we only ever use 1 value of “class T”, just make it a typedef
  - Node: We understand heterogeneous computing better now
- Unneeded template parameters inflate build times & sizes
  - Can’t hide implementations of templated classes
  - Enable another GO type ➔ rebuild all Trilinos thru MueLu & Stokhos
  - Executable & libraries > 4 GB
  - Need 64-bit linkers, else linker crashes
  - 20-min single-file build times (now; in 2015 we crashed laptops)
- Mitigations make build system complex & brittle

What’s the point of templates?

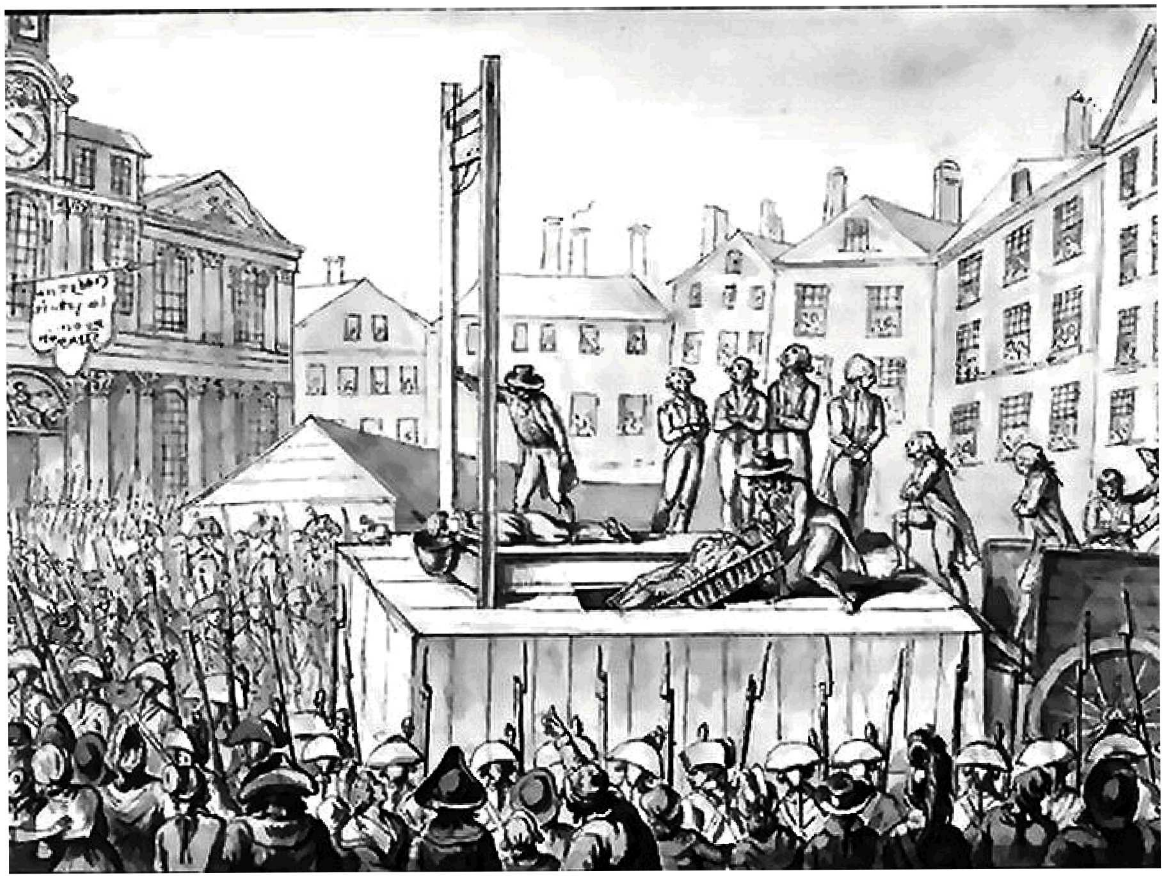
- Compile-time polymorphism
- Compile time: Can’t {use, afford} virtual method dispatch
- Polymorphism: Need “class T” to work for different T
  - Multiple T in the same build, like std::vector<T>
  - Otherwise, make T a configure-time typedef
- Is polymorphism really a requirement?
  - Or only a convenience for testing?
  - Or are we just confusing templates w/ configure-time options?
  - Ask this for each template parameter separately
- Open or closed polymorphism?
  - “Open”: Unbounded (tho SFINAE-constrained) set of valid types
  - “Closed”: Trilinos explicitly allows finite set of types

Templating adds build complexity

- Can’t hide implementations of templated classes
- Partial work-around: Explicit template instantiation (ETI)
  - Speeds up building code that uses Tpetra classes & functions
  - Makes build system obfuscated & brittle
    - e.g., {decl,def}.hpp, auto-gen’d .cpp, macros
    - Some of these needed so .cpp files build in <= 2 GB & < 5 mins
    - Remember when we tried to outsource a major ETI change?
  - Complicates app config & use (bjam)
  - Doesn’t solve “add another GO type, rebuild all of Trilinos” problem; in fact, makes this worse for Trilinos developers
  - Implications for open vs. closed polymorphism…

Trilinos: Closed polymorphism

- Trilinos' ETI requires closed polymorphism
  - Must know set of types at configure time, for which you want to instantiate classes & functions
- Trilinos has been depending more on configure-time knowledge of types, even w/out ETI
  - Packages use "ETI" macros to define tests, even w/ ETI OFF
  - (We've purged hacky tests that include _def &/or require ETI OFF)
  - "Solver factory" dependency injection & inversion (DII)
- "extern template" ETI approach relaxes this, but:
  - Only get build time benefit for closed set; DII too
  - Can't hide implementation (e.g., users see header files)
  - Christian & I first tried this in kokkos-kernels, but k-k & even Kokkos (for ViewCopy & ViewFill) starting to favor an "ETI-only" approach



Put Tpetra's template parameters on trial

Look one-by-one at Scalar, LocalOrdinal, GlobalOrdinal, & Node

Scalar & Packet live: Both add value

- Mixed-precision arithmetic (original Tpetra design goal)
  - Some features removed over time to reduce build complexity
    - CrsMatrix's templated local sparse mat-vec & local triangular solve
    - Ifpack2 Container templated apply
  - Still possible with Operator interface (matrix Scalar != vector Scalar)
- Interesting features like automatic differentiation (AD)
- Large apps use multiple Scalar types in 1 build
  - double & complex<double>
  - double & AD
- DistObject's "Packet" a key part of Petra Object Model
  - Decouples boundary exchange implementation from data structure

LO & GO die: Little value, high cost

- LO: LocalOrdinal (type of local indices)
  - Stored in sparse matrices; used in computational kernels
  - Flexibility could pay: Save memory/time vs. large single-process solve
  - But: 64-bit LO doesn’t build (1 externally contributed PR touched all of Trilinos, except for Kokkos (where it matters), but added no tests)
  - Interface could have hidden storage representation mostly from users, just like Tpetra did once w/ CRS row offset type
- GO: GlobalOrdinal (type of global indices)
  - Why would you want anything other than int64_t ?
  - If you store & use GO a lot, you’re slow anyway
- Mixing multiple (LO,GO) in one build?
  - Old Ifpack2 Container example: Intraprocess domain decomp
  - But: GO causes most build complexity & outstanding issues

Node dies: Wrong model, high cost

- Original heterogeneity model: Per object
  - Node determines memory & execution spaces (anachronism)
  - Rarely used (Stokhos LDRD, CASL VERA), mainly thru clone()
  - HybridPlatform (per-process choice) never used, hard to load balance
  - True concurrency never tested & likely broken due to MPI
  - Node: leftover from Chris Baker's Kokkos 1.0
- Proposed new model: Per kernel, not per object
  - Choose default Kokkos exec. (& memory) space(s) at config time
  - Users may ask to view an object's data in a given memory space
  - Users may give each kernel an optional execution space instance
    - May use enum / wrapper, to avoid exposing implementation

Must break backwards compatibility

- Can’t change template parameters w/out breakage
- We tried using type aliases to hide/ease changes
  - Make e.g., Tpetra::Vector an alias to Tpetra::Classes::Vector
  - Use C++11 parameter pack & fancy deduction to let us deprecate & remove template parameters w/out changes to user code

```
template<class ... Args>
using Vector =
  typename FourArg<Classes::Vector, Args...>::type;
```

~ 200 LOC, fancy

  - Problem: Partial specialization doesn’t take type aliases
    - Breaks Belos::MultiVecTraits & other traits classes
  - Technique thus not a complete solution; can’t hide “Classes::$CLASS"

Remaining questions

- Epetra & Tpetra both enabled in Amesos2 & Xpetra?
  - Amesos2 & Xpetra both define wrappers / adapters for {E,T}petra
  - Wrappers take same template parameters as Tpetra
  - Wrappers do no index conversion: Wrappers' GO == Tpetra's GO
  - Problem: Epetra requires GO=int in the wrapper
  - Do users ever need to enable Epetra, & Tpetra with GO != int?
    - If so, must change wrappers to do index conversion
    - MueLu willing to exclude this
    - 1 app needs Amesos2 w/ both Epetra & Tpetra enabled; still waiting to hear whether they need Tpetra w/ GO != int in this case
- How to manage backwards compatibility?
  - Need Trilinos to state & follow a release & deprecation policy
  - If not, Tpetra will need to imitate Kokkos in defining its own policy & release cycle

Questions?

Concurrent build times/sizes efforts

- New forward declaration headers
  - Help apps get advantages of fwd decls, but maintain backwards compatibility (vs. just fwd-decl’ing themselves – an issue w/ deprecation of the bool “classic” template parameter)
- Purge unneeded header includes
  - Historically has broken downstream apps e.g., Albany
- Distributor
  - Hide underlying implementation
  - Planned anyway as part of comm/comput. overlap & better MPI/{CUDA,OpenMP} interactions
- General code discipline (everyone’s job!)
  - DefaultPlatform deprecation & removal
  - Avoid exposing TPL header includes