Managing Asynchronous Data in ATLAS's Concurrent Framework

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Asynchronous Data and Events

- Data that can change during the course of a job, but less frequently than once per Event (beam collision)
  - period for which any piece of data is valid is referred to as an *Interval Of Validity (IOV)*

- Classify into 3 broad types:
  - **Conditions**
    - eg high voltages, calibrations, etc
  - **Detector Geometry and Alignments**
    - eg: position changes
  - **Asynchronous Callbacks (Incidents)**
    - functions that need to be executed at non-predetermined intervals
    - eg: respond to a file open/close

- These are often inter-related
  - a condition change can trigger a callback
Asynchronous Data and Concurrency

► Serial processing:
  • one Event at a time
  • all framework elements process data from the same IOV
  • clients are blind to the IOV, and cache data locally
    • Services handle updating the data given the current Event time/ID. Only one copy (the current one) of any object needs to maintained

► Concurrent processing:
  • multiple Events processed simultaneously
  • different elements of the framework may have to process data from different IOVs
    • Services must now handle multiple versions of the same data, and deliver the appropriate one to each client, depending on which Event the client is processing

► AthenaMT allows cloning of Algorithms to enhance sub-event parallelism. Association between Algorithm instance and an Event is never guaranteed.
Further Complications for Concurrency

- Two types of Asynchronous Data
  - **Raw** – read directly from a database
  - **Calibrated** – after reading from database, the data is processed in some way by a function

- In Athena, this processing is managed by a Service (IOVSvc), and performed by special functional objects (usually AlgTools)
  - at the start of every Event, before Algorithms are processed, IOVs are checked and any necessary updates are triggered by the execution of these IOVSvc callback functions
  - shared instance of each AlgTool
  - the AlgTools tend to cache data

- The current callback AlgTools are **NOT** thread-safe, and even if they were made thread-safe, could **NOT** run with multiple concurrent Events from different IOVs due to the local caches
  - IOV infrastructure needs to be modified for MT
Requirements for AthenaMT

- **AthenaMT**: ATLAS's next generation, multi-threaded reconstruction/simulation framework
  - multiple simultaneous Events
  - sub-Event concurrency
  - multi-threaded
    - each Algorithm processes its Event in its own thread

- Try to minimize changes to User code
  - there's lots and lots of it!
  - avoid forcing Users to implement fully thread-safe code by handling most thread-safety issues at the framework / Services level

- Leverage MT design to minimize memory footprint
  - ATLAS reconstruction is very large
  - ratio of physical memory / CPU is constantly decreasing

- All access to Event data via DataHandles, which also declare data dependency relationship to the framework
Possible Solutions: Scheduling Barrier

**Event Scheduling Barrier**
- The framework only concurrently processes Events from within one IOV at a time. When a boundary is reached, it finishes processing all Events from the first IOV before starting to schedule Events from the next IOV.

**BENEFIT:**
- completely transparent to Users
- no code changes for Services
- could make callbacks (inefficiently) thread safe with a big mutex

**PROBLEMS:**
- loss of concurrency / throughput if boundaries are frequent – processor is often idle
- requires Events to be processed in order, or the ability to cache and shuffle incoming Events to avoid bouncing back and forth
Possible Solution: Multiple Stores

► Multiple Conditions Data Stores
  • Data is stored in EventStore-like structures, with one Store per concurrent Event
  • Clients access data via smart DataHandles, which point to the correct Store
  • Services update the data in the appropriate Store, depending on the associated Event

► BENEFIT:
  • only small changes needed to Client code (use of DataHandles), mostly hidden behind a layer of indirection

► PROBLEMS:
  • large memory overhead due to duplicate stores
  • duplication of re-calculations
Solution: Multi-Cache Condition Store

- Single multi-cache Store for Conditions data
  - Each Store element is a **container** that holds multiple instances of the Conditions data objects (**ConditionContainer**), one per IOV
  - Clients access the data via smart **ConditionHandles**, that point to the appropriate entry in the **ConditionContainer** objects for a given Event
    - **ConditionHandles** are constructed with an **EventContext** object
    - from the Client's point of view, these objects look like any other object in the EventStore (keyed with a unique identifier)
      - Client Algorithms declare a data dependency on the conditions data object

- Updating functions are scheduled by the framework, that load new elements from the DB, and perform any necessary computations
  - IOVSvc callback functions are migrated into **ConditionAlgorithms**
  - these Algorithms are only scheduled when they enter a new IOV
Memory Management

- While this makes optimal use of memory (no duplication of objects), the store will continue to grow with time.

- Depending on memory constraints, may become necessary to perform garbage collection:
  - prune ConditionContainers of old, unused entries
  - only keep N copies
  - keep reference count of which entries are in use, purge old entries
Detector Geometry Alignment

- GeoModel tree is not exposed to Detector Description clients
- Readout geometry layer consists of subsystem specific Detector Elements
- Each Detector Element has a pointer to Full Physical Volume

**Physical Volume** (basic GeoModel building block)

**Full Physical Volume**

**Cached Position**

**Transform** (fixed after construction)

**Alignable Transform** (modifiable at will)

**Delta Transform**
The **Alignment Object** is a regular **ConditionContainer**, so it should be handled as any other Conditions Object in AthenaMT

- Created by a **ConditionAlgorithm** (replacement of current callback function)
- Accessed from the FPV and ATF via **Conditions Handle**

By making Detector Elements aware of the Alignment Objects we can make the transition transparent to Detector Description clients
Asynchronous Incidents

- **IncidentSvc**: manages asynchronous callbacks for clients which register as observers to specific events
  - *eg*: `BeginEvent`, `EndInputFile`, `MetaDataStop`
  - very flexible: callbacks can be triggered at any time
  - Clients can be anything: Algorithms, Services, Tools

Absolutely **disastrous** in an environment with multiple concurrent events, and multiple instances of each Algorithm
Study: IncidentSvc is overused / abused
- mostly fired outside of the event loop
- Incidents can be re-classified as discrete state changes

Incidents become **schedulable**, managed by framework
- Incident handlers / observers become discrete Algorithms, that interact with Services which are aware of the EventContext

![Diagram of IncidentSvc in AthenaMT](image)
Conclusions

► Managing Asynchronous data in a concurrent environment will require a paradigm shift
  • no solution is fully transparent or plug-and-play, unless we choose to sacrifice concurrency and performance
  • dealing with multiple threads as well as multiple concurrent events is doubly challenging

► Have been able to minimize impact on User code via strategic modifications at the framework and Service level

► New versions of all three aspects of Asynchronous Data and Event infrastructure have been implemented, and migration of client code is ongoing, in conjunction with universal migration to DataHandles
  • so far, migration has been relatively straight-forward, and anticipate finishing by end of 2016