Intel Thread Building Blocks, Part II

SPD course 2014-15
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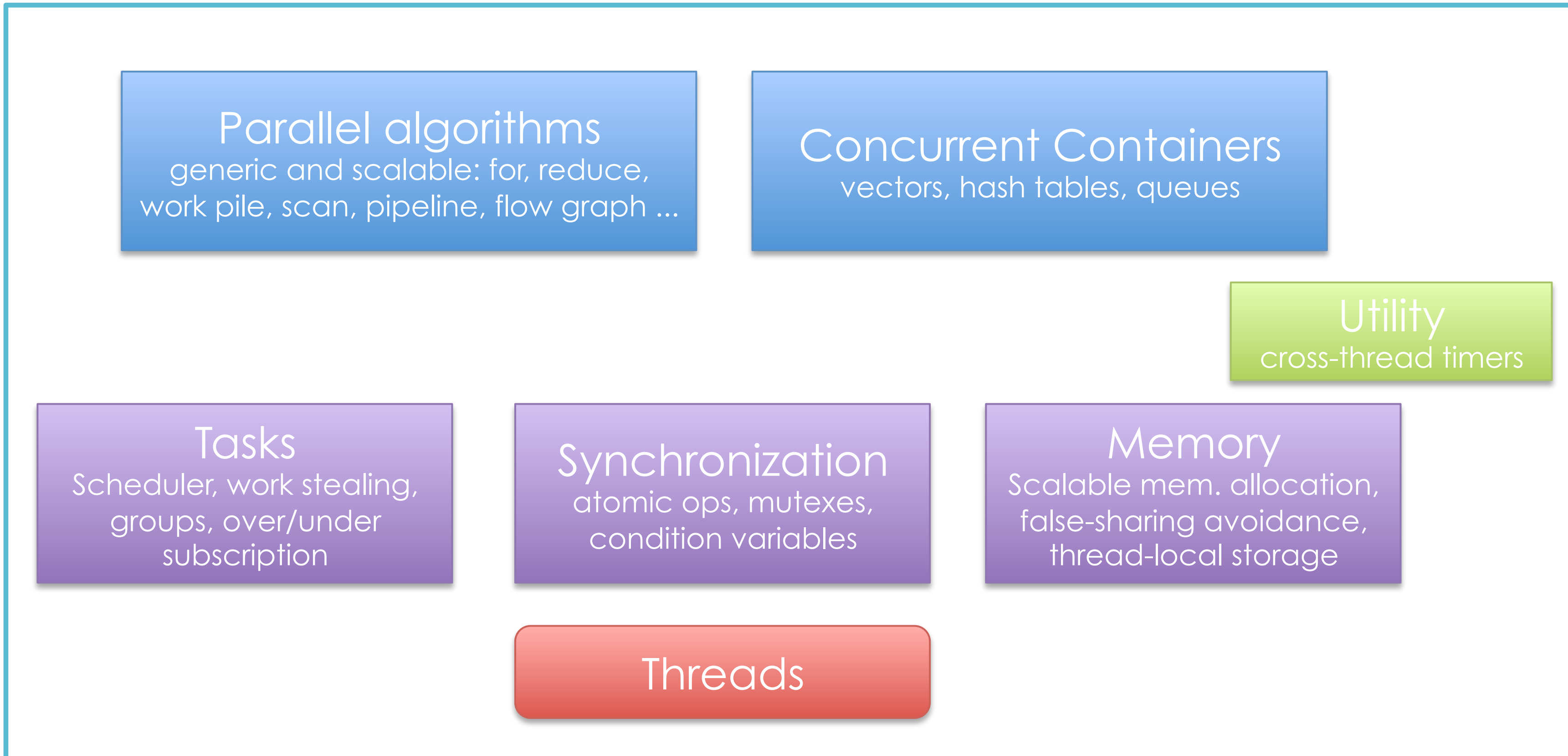
TBB Recap

- Portable environment
  - Based on C++11 standard compilers
  - Extensive use of templates
- No vectorization support (portability)
  - use vector support from your specific compiler
- Full environment: compile time + runtime
- Runtime includes
  - memory allocation
  - synchronization
  - task management
- TBB supports patterns as well as other features
  - algorithms, containers, mutexes, tasks...
  - mix of high and low level mechanisms
  - programmer must choose wisely

TBB "layers"

- All TBB architectural elements are present in the user API, **except** the actual threads



Threads and composability

- Composing parallel patterns
  - a pipeline of farms of maps of farms
  - a parallel for nested in a parallel loop within a pipeline
  - each construct can express more potential parallelism
  - deep nesting → too many threads → overhead
- Potential parallelism should be expressed
  - difficult or impossible to extract for the compiler
- Actual parallelism should be flexibly tuned
  - messy to define and optimize for the programmer, performance hardly portable
- TBB solution
  - Potential parallelism = tasks
  - Actual parallelism = threads
  - Mapping tasks over threads is largely automated and performed at run-time

Tasks vs threads

- Task is a unit of computation in TBB
  - can be executed in parallel with other tasks
  - the computation is carried on by a thread
  - task mapping onto threads is a choice of the runtime
    - the TBB user can provide hints on mapping
- Effects
  - Allow **Hierarchical Pattern Composability**
  - raise the level of abstraction
    - avoid dealing with different thread semantics
  - increase run-time portability across different architectures
    - adapt to different number of cores/threads per core

Summary

- A quick tour of TBB abstractions used to express parallelism
  - A few **C++ Concepts**, i.e. sets of template requirements that allow to combine C++ data container classes with parallel patterns
    - Splittable
    - Range
  - TBB Algorithms, i.e. the templates actually expressing thread (task) parallel computation
  - Data container classes that are specific to TBB
  - Lower-level mechanisms (thread storage, Mutexes) that allow the compentent programmers to implement new abstractions and solve special cases

Splittable Concept

- A type is splittable if it has a so-called *split constructor* that allows splitting an instance in two parts
  - X::X(X& x, split)
    Split X into X and newly constructed object
  - First argument is a reference to the original object
  - Second argument is a dummy placeholder
- Split concept is used to express
  - Range concepts, to allow recursive decomposition
  - Forking a body (a function object) to allow concurrent execution (see the reduce algorithm)
- The binary split is usually in almost equal halves
  - Range classes can have a further split method that also specifies the split proportion

TBB Range classes

- Range classes express intervals of parameter values and their decomposability
  - **recursively** splitting intervals to produce parallel work for many patterns (e.g. for, reduce, scan…)

- The Range concept relies on five mandatory and two optional methods
  - copy constructor
  - destructor
  - is_divisible() true if range is not too small
  - empty() true if range empty
  - split() split the range in two parts
  - *two more methods allow proportional split*

The Range concept

Class R implementing the concept of range must define:

```
R::R( const R& );
R::~R();
bool R::is_divisible() const;
bool R::empty() const;
R::R( R& r, split );
```

Split range R into two subranges.
One is returned via the parameter, the other one is the range itself, accordingly reduced

Blocked Range

- TBB 4 has implementations of the range concept as templates for 1D, 2D and 3D blocked ranges
  - 3 nested parallel for are functionally equivalent to a simple parallel for over a 3D range
  - the 2D and 3D range will likely exploit the caches better, due to the explicit 2D/3D tiling

```
tbb::blocked_range< Value > Class
tbb::blocked_range2d< RowValue, ColValue > Class
tbb::blocked_range3d< PageValue,
                      RowValue, ColValue > Class
```

Proportional split

- Class defining methods that allow control over the size of two split halves
- Passed as argument to methods performing a proportional split
  - ```
    proportional_split( size_t _left = 1,
                        size_t _right = 1 )
    ```
    define a split object using the coefficients to compute the split ratio
  - ```
    size_t left() const
    size_t right() const
    ```
    return the size of the two halves
  - ```
    operator split() const
    ```
    backward compatibility with simpler split (allows implicit conversion)
    ```

Range with proportional split

- Optional methods allowing proportional splits
  - R::R(R& r, proportional_split proportion) optional costructor using a proportional split object to define the split ratio
  - static const bool R::is_splittable_in_proportion true iff the range implementation has a constructor allowing the proportional split

TBB 4 Algorithms (1)

Over time, the distinction between parallel patterns and algorithms may become blurred
TBB calls all of them just “algorithms”

- **parallel_for_each**
  - iteration via simple iterator, no partitioner choice
- **parallel_for**
  - iteration over a range, can choose partitioner
- **parallel_do**
  - iteration over a set, may add items
- **parallel_reduce**
  - reduction over a range, can choose partitioner, has deterministic variant
- **parallel_scan**
  - parallel prefix over a range, can choose partitioner

TBB 4 Algorithms (2)

- *parallel_while* (deprecated, see parallel_do)
  - iteration over a stream, may add items
- **parallel_sort**
  - sort over a set (via a RandomAccessIterator and compare function)

- **pipeline** and **filter**
  - runs a pipeline of filter stages, tasks in = tasks out
- **parallel_invoke**
  - execute a group of tasks in parallel
- **thread_bound_filter**
  - a filter explicitly bound to a serving thread

Parallel For each

```
void    tbb::parallel_for_each (InputIterator first,
               InputIterator last, const Function &f)
```

- simple case, employs iterators
- drop-in replacement for std for_each with parallel execution
  - Easy-case parallelization of existing C++ code
- it was a special case of for in previous TBB
- Serially equivalent to:

```
for (auto i=first; i<last; ++i) f(i);
```

- There is also the variant specifying the context (task group) in which the tasks are run

Passing args to parallel patterns

- Beside the range of values we need to compute over, we nee to specify the inner code of C++ templates implementing parallel patterns
- Most patterns have two separate forms
  - Args are a function reference (computation to perform to perform) and a series of parameters (to the parallel pattern)
  - Args contain a user-define class "*Body*" to specify the pattern body,
    - *Body* is a concrete class instantiating a virtual class specified by TBB as a model for that pattern
    - TBB docs calls "requirements" the methods that the *Body* class provides and will be called by the pattern implementation
- Example: for_each uses the first method

Passing args to parallel patterns

- Advantages and disadvantages
- Using functions (TBB documentation calls it the "functional form"...)
  - Easier to use lambda functions
  - We are passing around function references
  - Static (compilation-time) type checking is in some cases limited as the template needs to be general enough
- Using Body classes (TBB calls it "imperative")
  - Slightly more lengthy code
  - Better static type-checking
  - Body classes can more easily contain data/ references – they can have state that simplifies some optimization (ex. see the parallel_reduce pattern)

Optional args to parallel patterns

- A partitioner
  - A user-chosen partitioner used to split the range to provide parallelism
  - see later on the properties of auto_partitioner, (default in any recent TBB) simple_partitioner, affinity_partitioner
- task_group_context
  - Allows the user to control in which task group the pattern is executed
  - By default a new, separate task group is created for each pattern

Parallel For

```
parallel_for (
  tbb::blocked_range<size_t> (begin, end,
  GRAIN_SIZE), tbb_parallel_task());
```

- Loops over integral tipes, positive step, no wrap-around
- one way of specifying it, where tbb_parallel_task is a *Body* user-defined class
- uses a class for parallel loop implementations.
  - The actual loop "chunks" are performed using the () operator of the class
  - the computing function (operator ()) will receive a range as parameter
  - data are passed via the class and the range
- The computing function can also be defined in-place via lambda expressions

Parallel For

```
parallel_for (
  tbb::blocked_range<size_t> (begin, end,
  GRAIN_SIZE), tbb_parallel_task(), partitioner);
```

- Extended version
- the partitioner is one of those specified by TBB (simple, auto, affinity)
- no real choice usually, just allocate a const partitioner and pass it to the parallel loops:

```
tbb::affinity_partitioner ap;
```

  – (unless you want to define your own partitioner)

Parallel_for, 1D alternate syntax

- template<typename Index, typename Func>
  Func parallel_for(Index first, Index_type last,
  const Func& f
  [, partitioner
  [, task_group_context& group]]);
- template<typename Index, typename Func>
  Func parallel_for(Index first, Index_type last,
  Index step, const Func& f
  [, partitioner
  [, task_group_context& group]]);
- Implicit 1D range definition, employs a function reference (e.g. lambda function) to specify the body

partitioners

- simple
  - generate tasks by dividing the range as much as possible (remember about the grain size!)
- auto
  - divide into large chunks, divide further if more tasks are required
- affinity
  - carries state inside, will assign the tasks according to range locality to better exploit caches

Combining the elements

- Apply a range template to your elementary data type
- Define a class computing the proper for-body over elements of a range
- Call the parallel_for passing at least the range and the function
- specify a partitioner and/or a grain size to tune task creation for load balancing

Example (with lambda)

```
void relax( double *a, double *b,
            size_t n, int iterations)
{
   tbb::affinity_partitioner ap;
   for (size_t t=0; t<iterations; ++t) {
      tbb::parallel_for(
         tbb::blocked_range<size_t>(1,n-1),
         [=]( tbb::blocked_range<size_t> r) {
            size_t e = r.end();
            for (size_t i=r.begin(), i<e; ++i)
               /*do work on a[i], b[i] */;
         },
         ap);
      std:swap(a,b); // always read from a, write to b
   }
}
```

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reduce

- Reduce has also two forms
  - "*Functional*" from, nice with lambda function definitions
  - "*Imperative*" form, minimizes data copying
  - *Please remember this is just TBB terminology*

```
template<typename Range, typename Value, typename
        Func, typename Reduction>

Value parallel_reduce( const Range& range,
        const Value& identity, const Func& func,
        const Reduction& reduction,
        [, partitioner[, task_group_context& group]] );


template<typename Range, typename Body>

void parallel_reduce( const Range& range,
        const Body& body
        [, partitioner[, task_group_context& group]] );
```

“Functional” form

- Beside the function, several other objects have to be passed to the reduce
- Value Identity
  - left identity for the operator
- Value Func::operator()(const Range& range, const Value& x)
  - must accumulate a whole subrange of values starting from x (“sequential reduction”)
- Value Reduction::operator()(const Value& x, const Value& y);
  - Combines two values (“parallel” reduction)

Object-oriented form

- Computes the reduction on its Body object together with the associated Range
  - Data (reference) is held within the Body
  - The reduce can split() the body parameter, and will split() the range accordingly
  - Can also split only the range, and compute over a range that is smaller than the Body's data
    - This may allow saving some data copy operation when we exploit parallel slackness together with affinity
  - Results form each side will the be combined
- Body object's state contains the reduced value
  - Final result is accumulated in initial Body object

Reduce

- Both the function-based form and the OO one can specify a custom partitioner
- Both forms can specify a task group that will be used for the execution

Reduce – deterministic variant

- parallel_deterministic_reduce
- Performs a deterministically chosen sets of splits, joins and computations
- Exploits the simple_partitioner → no partitioner argument allowed
- Computes the same regardless of the number of threads in execution
  - no adaptive work assignment is ever performed
  - grain size must be carefully chosen in order to achieve ideal parallelism
- Has both the functional form and the OO one

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pipeline

- Pipeline pattern
  - pipeline class   not strongly typed
  - parallel_pipeline   strongly typed interface
- Implements the pipeline pattern
  - A series of filter applied to a stream
    - You need to subclass the abstract filter class
  - Each filter can work in one of three modes
    - Parallel
    - Serial in order
    - Serial out of order

Pipeline class

- Pipeline is dynamically constructed
  - pipeline() create an empty pipeline
  - ~pipeline() destructor
  - void add_filter(filter& f) add a filter
  - clear() remove all filters
  - void run(size_t max_number_of_live_tokens [, task_group_context& group])
- Run until the first filter returns NULL
- Actual parallelism depends on pipeline structure, and on parameter
  - max_number_of_live_tokens
- Pipelines can be reused, but NOT concurrently
- Stages can be added in between runs
- Can have all tasks belong in a specified optional group, by default a new group is created

filter

- Abstract class implementing filters for pipelines
- Three modes, specified in the constructor
  - Parallel can process/produce any number of item in any order (e.g. nested parallelism)
  - Serial out of order filter processes items one at a time, and in no particular order
  - Serial in order filter processes items one at a time, in the received order
- Computation is specified by overriding the operator ()
  - virtual void* operator()(void * item)
  - Process one item and return result, via pointers
  - First stage signals with NULL the end of the stream
  - Result of last stage is ignored

Parallel_pipeline

- void parallel_pipeline(
  size_t max_number_of_live_tokens,
  const filter_t<void,void>& filter_chain
  [, task_group_context& group]);
- Strongly typed, can use lambdas
  - parallel_pipeline(max_number_of_live_tokens,
    make_filter<void,I1>(mode0,g0) &
    make_filter<I1,I2>(mode1,g1) & ...
    make_filter<In,void>(moden,gn));
- Employ the make_filter template to build filters on the spot from their operator() function
- Types are checked at compilation time
  - First stage must invoke fc.stop() and return a dummy value to terminate the stream

Parallel_do

```
template<typename InputIterator,
                  typename Body>
void parallel_do( InputIterator first,
              InputIterator last, Body body
              [, task_group_context& group] );
```

- Only has the object oriented syntax
- Applies a function object body to a specified interval
  - The body can add additional tasks dynamically
  - Replaces completely the deprecated parallel_while
  - Iterator is a standard C++ one
  - A purely serial input iterator is a bottleneck: use iterators over random-access data structures

Adding items in a do

```
B::operator()( T& item,
    parallel_do_feeder<T>& feeder ) const
```

```
B::operator()( T& item ) const
```

- The body class need to operate on the template T type
- It needs a copy constructor and a destroyer
- Two possible signatures for Body operator()
  - You can't define both!
  - First signature, with extra parameter, allows each item to add more items dinamically in the do → e.g. dynamically bound parallel do, divide & conquer
  - Second signature means the do task set is static

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Containers

- container_range
  - extends the range to use a container class
- maps and sets:
  - concurrent_unordered_map
  - concurrent_unordered_set
  - concurrent_hash_map
- Queues:
  - concurrent_queue
  - concurrent_bounded_queue
  - concurrent_priority_queue
- concurrent_vector

container: Container Range

- extends the range class to allow using containers as ranges
(e.g. providing iterators, reference methods)
  - Container ranges can be directly used in parallel_for, reduce and scan
- some containers have implementations which support container range
  - concurrent_hash_map
  - concurrent_vector
  - you can call parallel for, scan and reduce over (all or) part of such containers

Extending a container to a range

- Types
  - R::value_type Item type
  - R::reference Item reference type
  - R::const_reference Item const reference type
  - R::difference_type Type for difference of two iterators
- What you need to provide
  - R::iterator Iterator type for range
  - R::iterator R::begin() First item in range
  - R::iterator R::end() One past last item in range
  - R::size_type R::grainsize() const Grain size
- AND all Range methods: split(), is_divisible()…

concurrent map/set templates

- The key issue is allowing multiple threads efficient concurrent access to containers
  - keeping as much as possible close to STL usage
  - at the cost of limiting the semantics
  - A (possibly private) memory allocator is an optional parameter
- containers try to support concurrent insertion and traversal
  - semantics similar to STL, in some cases simplified
  - not all containers support full concurrency of insertion, traversal, deletion
  - typically, deletion is forbidden / not efficient
  - some methods are labeled as concurrently unsafe
    - E.g. erase

Types of maps

- We wish to reuse STL – based code as much as possible
  - However, STL maps are NOT concurrency aware
- Two main options to make them thread-nice
  - Preserve serial semantics, sacrifice performance
  - Aim for concurrent performance, sacrifice STL semantics
- Choose depending on the semantics you need
- concurrent_hash_map
  - Preserves serial semantics as much as possible
  - Operations are concurrent, but consistency is guaranteed
- concurrent_unordered_map, concurrent_unordered_multimap
  - Partially mimic STL corresponding semantics
  - drops concurrent performance hogging features
  - no strict serial consistency of operations

Concurrent_hash_map

- concurrent_hash_map
  - Preserves serial semantics as much as possible
  - Operations are concurrent, but subject to a global ordering to ensure consistency
  - Relies on extensive built-in locking for this purpose
  - Data structure access is less scalable, may become a bottleneck
  - Your tasks may be left idle on a lock until data access is not available

concurrent unordered (multi)map

- concurrent_unordered_map
- concurrent_unordered_multimap
  - associative containers, concurrent insertion and traversal
  - semantics similar to STL unordered_map/multimap but simplified
  - omits features strongly dependent on C++11
    - Rvalue references, initializer lists
  - some methods are prefixed by unsafe_ as they are concurrently unsafe
    - unsafe_erase, unsafe_bucket methods
  - inserting concurrently the same key may actually create a temporary pair which is destroyed soon after
  - the iterators defined are in the forward iterator category (only allow to go forward)
  - supports concurrent traversal (concurrent *insertion* does not invalidate the existing iterators)

Comparison of maps

- Choose depending on the semantics you need
- concurrent_hash_map
  - Permits erasure, has built-in locking
- concurrent_unordered_map
  - Allows concurrent traversal/insertion
  - No visible locking
    - minimal software lockout
    - no locks are retained that user code need to care about
  - Has [ ] and "at" accessors
- concurrent_unordered_multimap
  - Same as previous, holds multiple identical keys
  - Find will return the first matching <key, Value>
    - But concurring threads may have added stuff before it in the meantime!

Map templates

- template <typename Key,
            typename Element,
            typename Hasher = tbb_hash<Key>,
            typename Equality = std::equal_to<Key >,
            typename Allocator =
  tbb::tbb_allocator<std::pair<const Key, Element > > >
  class concurrent_unordered_map;

- template <typename Key,
            typename Element,
            typename Hasher = tbb_hash<Key>,
            typename Equality = std::equal_to<Key >,
            typename Allocator =
  tbb::tbb_allocator<std::pair<const Key, Element > > >
  class concurrent_unordered_multimap;

Concurrent sets

- ```
  template <typename Key,
          typename Hasher = tbb_hash<Key>,
          typename Equality = std::equal_to<Key>,
          typename Allocator = tbb::tbb_allocator<Key>
  class concurrent_unordered_set;
  ```

- ```
  template <typename Key,
          typename Hasher = tbb_hash<Key>,
          typename Equality = std::equal_to<Key>,
          typename Allocator = tbb::tbb_allocator<Key>
  class concurrent_unordered_multiset;
  ```

- concurrent_unordered_set
  - set container supporting insertion and traversal
  - same limitations as map: C++0x, unsafe_erase and bucket methods
  - Forward iterators, not invalidated by concurrent insertion
  - For multiset, same find() behavior as with the maps

Concurrent queues

- STL queues, modified to allow concurrency
  - Unbounded capacity (memory bound!)
  - FIFO, allows multiple threads to push/pop concurrently with high scalability
- Differences with STL
  - No front and back access → concurrently unsafe
    - Iterators are provided only for debugging purposes!
    - unsafe_begin() unsafe_end() iterators pointing to begin/end of the queue
  - Size_type is an integral type
  - Unsafe_size()   number of items in queue, not guaranteed to be accurate
  - try_pop(T & object)
    - replaces (merges) size() and front() calls
    - attempts a pop, returns true if an object is returned

Bounded_queue

- Adds the ability to specify a capacity
  - set_capacity() and capacity()
  - default capacity is practically unbounded
- push operation waits until it can complete without exceeding the capacity
  - try_push does not wait, returns true on succes
- Adds a waiting pop() operation that waits until it can pop an item
  - Try_pop does not wait, returns true on success
- Changes the size_type to a signed type, as
  - size() operation returns the number of push operations minus the number of pop operations
  - Can be negative: if 3 pop operations are waiting on an empty queue, size() returns -3.
- abort() causes any waiting push or pop operation to abort and throw an exception

concurrent_priority_queue

- Concurrent push/pop priority queue
  - Unbounded capacity
  - Push is thread safe, try_pop is thread safe
- Differences to STL
  - Does not allow choosing a container; does allow to choose the memory allocator
  - top() access to highest priority elements is missing (as it is unsafe)
  - pop replaced by try_pop
  - size() is inaccurate on concurrent access
  - empty() may be inaccurate
  - Swap is not thread safe

Concurrent priority queue examples

- concurrent_priority_queue(const allocator_type& a = allocator_type())
  - Empty queue with given allocator
- concurrent_priority_queue(size_type init_capacity, const allocator_type& a = allocator_type())
  - Sets initial capacity
- Priority is provided by the template type T

Concurrent vector

- Random access by index
- Concurrent growth / append
- Growing does not invalidate indexes
- Some methods are NOT concurrent
  - Reserve, compact, swap
- Shrink_to_fit compacts the memory representation
  - Not done automatically to preserve concurrent access, invalidates indexes
- Implements the range concept
  - Can be used for parallel iteration
- Size() can be concurrently inaccurate (includes element in construction)
- Provides forward and reverse iterators

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thread local storage

- **enumerable_thread_specific**
- a container class providing local storage to any of the running threads
  - outside of parallel contexts, the contents of all thread-local copies are accessible by iterator or using combine or combine_each methods
  - thread-local copies are lazily created, with default, exemplar or function initialization
  - thread-local copies do not move (during lifetime, and excepting clear()) so the address of a copy is invariant.
    - the contained objects need not have operator=() defined if combine is not used.
    - enumerable_thread_specific containers may be copy-constructed or assigned.
    - thread-local copies can be managed by hash-table, or can be accessed via TLS storage for speed.

Synchronization mechanisms

- Low level mechanism to control low-level concurrent access to data structures
- Use with great care
  - Can cause software lockout
- Mutexes
  - data structures that allow adding generick locking mechanisms to any data structures
- Atomic
  - template that add very simple, low overhead, hw-supported atomic behaviour to a few machine types available in the language
- PPL Compatibility
  - 2 constructs added for compatibility with Microsoft Parallel Pattern Library
- C++11 syncronizations
  - Supports a subset of the N3000 draft of the C++11 standard
  - will change in future implementations of TBB

atomic objects

- template<typename T> atomic;
- Generate special machine instructions to ensure that operating on a variable in memory is performed atomically
- atomics within the C++11 standard (TBB goes beyond it)
- Integral type, enum type, pointer type
- Template supports atomic read, write, increment, decrement, fetch&add, fetch&store, compare&swap operations
- Arithmetic
  - Pointer arithmetic is T is a pointer
  - not allowed if T is enum, bool or void*

atomic objects

- Copy constructor is never atomic
  - It is compiler generated
  - Need to default construct, then assign

```
atomic<T> y(x);        // Not atomic
atomic<T> z; z=x;      // Atomic assignment
```

  - C+11 uses the constexpr mechanism for this

- atomic <T*> defines the dereferencing of data as
  - T* operator->() const;

Atomic methods

- value_type fetch_and_add(value_type addend)
  - Add atomically
- value_type fetch_and_increment()
- value_type fetch_and_decrement()
  - Increment/decrement atomically
- value_type compare_and_swap(value_type new_value, value_type comparand)
  - If the atomic has value "comparand" set it to "new_value"
- value_type fetch_and_store(value_type new_value)

Mutexes

- Classes to build *lock objects*
- The new lock object will generally
  - Wait according to specific semantics for locking
  - Lock the object
  - Release lock when destroyed
- Several characteristics of mutexes
  - Scalable
  - Fair
  - Recursive
  - Yield / Block
- Check implementations in the docs:
  - mutex, recursive_mutex, spin_mutex, queueing_mutex, spin_rw_mutex, queueing_rw_mutex, null_mutex, null_rw_mutex
  - Specific reader/writer locks
  - Upgrade/downgrade operation to change r/w role

Mutexes primitives

Pseudo-Signature	Semantics
`M()`	Construct unlocked mutex.
`~M()`	Destroy unlocked mutex.
`typename M::scoped_lock`	Corresponding scoped-lock type.
`M::scoped_lock()`	Construct lock without acquiring mutex.
`M::scoped_lock(M&)`	Construct lock and acquire lock on mutex.
`M::~scoped_lock()`	Release lock (if acquired).
`M::scoped_lock::acquire(M&)`	Acquire lock on mutex.
`bool M::scoped_lock::try_acquire(M&)`	Try to acquire lock on mutex. Return true if lock acquired, false otherwise.
`M::scoped_lock::release()`	Release lock.
`static const bool M::is_rw_mutex`	True if mutex is reader-writer mutex; false otherwise.
`static const bool M::is_recursive_mutex`	True if mutex is recursive mutex; false otherwise.
`static const bool M::is_fair_mutex`	True if mutex is fair; false otherwise.

Types of mutexes

	Scalable	Fair	Reentrant	Long Wait	Size
`mutex`	OS dependent	OS dependent	No	Blocks	>=3 words
`recursive_mutex`	OS dependent	OS dependent	Yes	Blocks	>=3 words
`spin_mutex`	No	No	No	Yields	1 byte
`speculative_spin_mutex`	No	No	No	Yields	2 cache lines
`queuing_mutex`	Yes	Yes	No	Yields	1 word
`spin_rw_mutex`	No	No	No	Yields	1 word
`queuing_rw_mutex`	Yes	Yes	No	Yields	1 word
`null_mutex`	-	Yes	Yes	-	empty
`null_rw_mutex`	-	Yes	Yes	-	empty