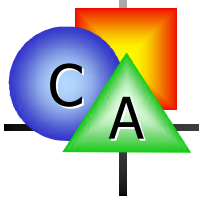
Storing Properties in Grouped Tagged Tuples



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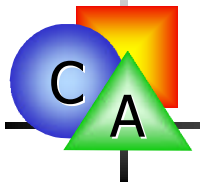
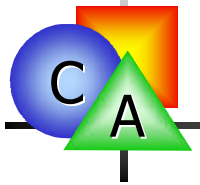


Overview

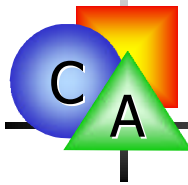
- Motivation and Introduction
- Named Objects Revisited
- Properties and More
- Performance
- Conclusions and Future Work

Motivation and Introduction



Motivation

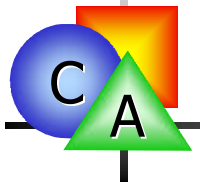
- Cartesian product types:
  Basic building block for composite types
  - Pascal, Ada: records
  - C/C++: structs
  - ML, Haskell, …: tuple types
- Topic: C++ support for tuples and related special purpose constructs (properties)



Tuples in C++

- No built-in tuple type
- Classes considered too heavy-weight/tedious for data passing
  - Namespace pollution
- Jakko Järvi: Boost Tuple Library
  - Access to tuple elements by index or type
  - Handles multiple return values, combine parameters
- Emily Winch
  - Access tuple elements by name
  - Operations on elements synthesized from formal description
    - Constructor, assignment operator, multiple value manipulations, …

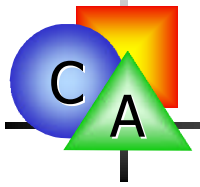
➔ C++ Template Meta-Programming



C++ Template Meta-Programming

- C++ template mechanism takes place at compile time (mandated by C++ standard)

- Expressiveness
  - Values: compile time constants & types
  - Conditions:
    - Pattern matching during partial template specialization for types
    - ?-operator for integral values
  - Loops: recursive instantiation

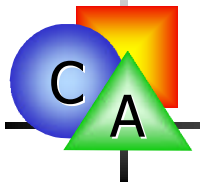


Typelists

- Compile time data structure that stores types
- Well suited to control code generation
  - Visitor pattern: visitation class hierarchy
  - Object factories: product types

```
typedef Loki::TypeList<
  unsigned char, unsigned short,
  unsigned int,  unsigned long
>::type unsigned_types;
// Calculate length of type list.
const int l = Loki::TL::Length<unsigned_types>::value;
```

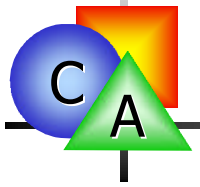
Named Objects Revisited



Source of Inconsistency

- Problem in Winch's object creation
  - Name type: used to access element
  - Implementation type: actually stored data type
  - Name type and Implementation type pairing

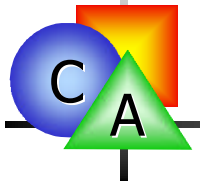
```
// Name types.
struct myBigClass {}; struct age {};
struct myDatabase {};
// Name and implementation type pairing in type constr.
typedef makeVarlistType3<
  BigClass*, myBigClass, int, age,
  Database&, myDatabase
>::list VarlistType;
```



Idea

- Permanently associate name and implementation types: OK, use nested type defintions
- Pass typelist of name types with nested implementations types to type constructor of `Tagged_Tuple`

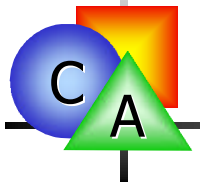
```
// Name and implementation type pairing.
struct myBigClass { typedef BigClass* type; };
struct age { typedef int type; };
struct myDatabase { typedef Database& type; };
// Type constructor.
typedef Tagged_Tuple<
  TypeList<myBigClass, age, myDatabase>::type
> PropType;
```



Extract Implementation Types

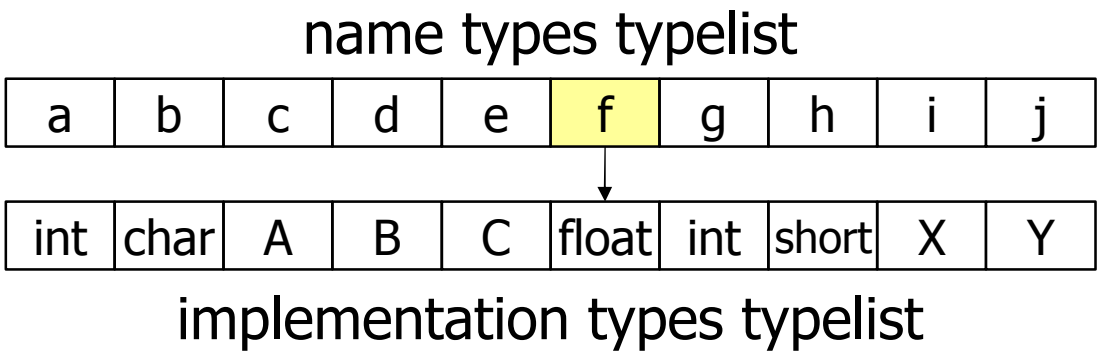
- How to extract implementation types?
  → needed for tagged tuple's internal data

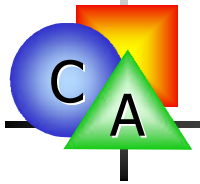
  - Use C++ template meta-program:
    `ExtractTypes: TL -> TL`
  - `ExtractTypes` generates new typelist that holds implementation types
  - New typelist can be passed to tuple constructor for internal data



Element Access

- Complication:
  - Element access by name type
  - Implementation tuple knows only impl. types
- Name type and implementation type located at same position in type lists
  → element index into implementation tuple



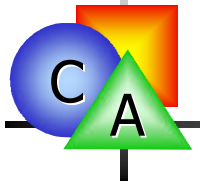


Element Access

```
// Access element with tag PropT.
template <class PropT>
typename return_t<PropT, tuple_type, TL>::type at() {
  return Loki::Field<
    Loki::TL::IndexOf<props_tl, PropT>::value
  >(m_props);
}
// Usage:
std::string name = data.at<Name>();
```

- Same functionality as Winch's approach
- Name and implementation type pairing fixed with typelists and template meta-programming

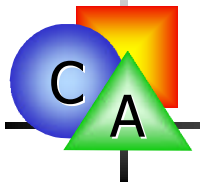
Properties and More



Properties

- Section of internal data describing an object's state that are…
- Publicly exposed through standardized access methods
- Examples: color, name, …

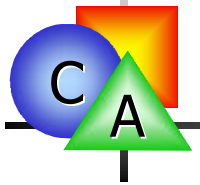
- Discussed `Tagged_Tuple` type typical linear property container



Well Known: Java Properties

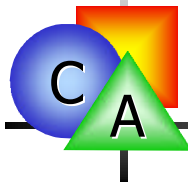
- Basic component technology in Java
- Tools inspect code for standard naming schemes (e.g. get-/set-methods)

- Programmer has to provide access methods for every property
- `Tagged_Tuple`: access methods generated for all listed properties



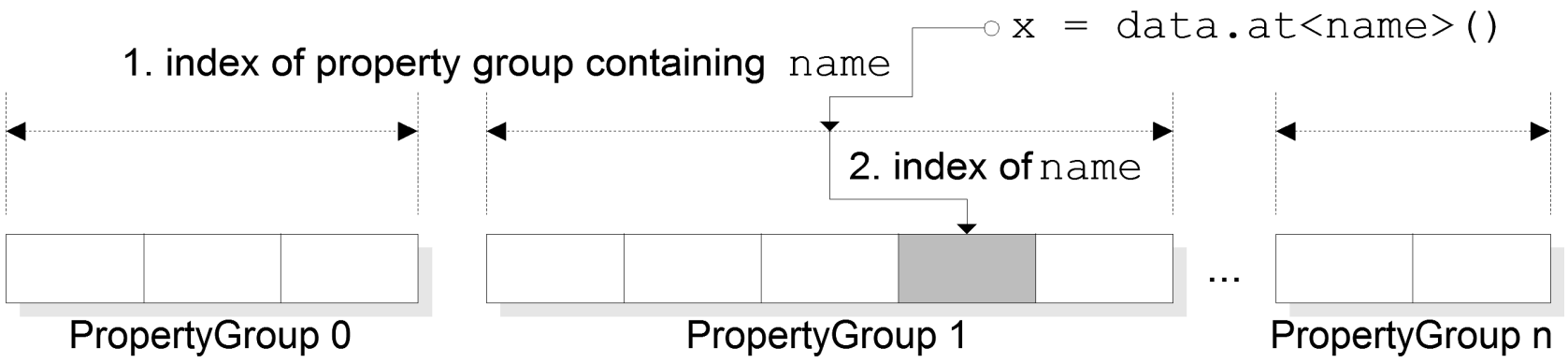
Groups of Properties

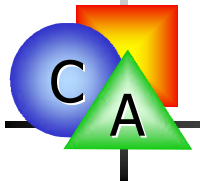
- Related properties commonly reused in several classes/components
  - Debug information, colors, …
  - HTML/XML attributes, nodes in symbol table, …
- Class template's `Named_Properties` requirements
  1. Type-safe element access
  2. Related properties grouped
  3. Combine groups of properties
  4. Flat access to properties by name
- R1, R2: `Tagged_Tuple`
- R3: Tuple of `Tagged_Tuple(s)`
- R4: Extensive meta-programming



Flat Element Access

- Two actions
  - Determine named property's type
  - Locate named property's data
- Both two-level processes
  1. Locate tagged tuple containing name type
  2. Access type/data at correct position in located tagged tuple



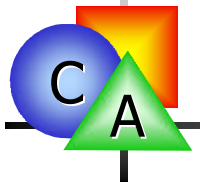


Flat Element Access

```
// Access element with tag PropT.
template <class PropT>
typename return_t<PropT, tuple_type, TL>::type at() {
  return Loki::Field< IndexOfNP<TL, PropT>::value >
    (m_props).template at<PropT>();
}
```

- 3-level access possible, name clashes likely
- Error handling:
  - PropT tag not present: compile time error
  - PropT tag present multiple times: returns first found

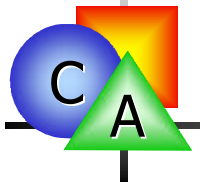
Performance



Performance

- How do generated data structures compare to handwritten data structures w.r.t. …
  1. Memory efficiency?
  2. Runtime performance?

- Artificial benchmarking application
  1. Create homogeneous container
  2. Read and write to all properties present in element type



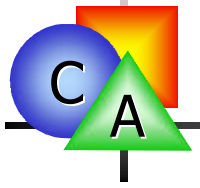
Element Type

Handwritten

```
struct debug_props {
  size_t debug_line_prop;
  size_t debug_column_prop;
  string debug_name_prop;
  string debug_source_prop;
  // Access operations.
  size_t& at_dlp() { return debug_line_prop; }
  size_t& at_dcp() { return debug_column_prop; }
  string& at_dnp() { return debug_name_prop; }
  string& at_dsp() { return debug_source_prop; }
};
struct id_props {
  string id_prop;
  double rate_prop;
  // Access operations.
  string& at_ip() { return id_prop; }
  double& at_rp() { return rate_prop; }
};
// Property group.
struct test_props {
  debug_props p1;
  id_props p2;
};
```

Generated

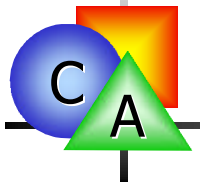
```
struct debug_line_prop { typedef size_t type; };
struct debug_column_prop { typedef size_t type; };
struct debug_name_prop { typedef string type; };
struct debug_source_prop { typedef string type; };
// Associated type list.
typedef Loki::TypeList<
  debug_line_prop, debug_column_prop,
  debug_name_prop, debug_source_prop
>::type debug_prop_tl;

struct id_prop { typedef string type; };
struct id_rate_prop { typedef double type; };
// Associated type list.
typedef Loki::TypeList<id_prop, id_rate_prop>::type
  id_prop_tl;

// Single properties.
typedef Tagged_Tuple<debug_prop_tl> debug_np;
typedef Tagged_Tuple<id_prop_tl> id_np;

// Property group.
typedef Named_Properties<
  Loki::TypeList<debug_np, id_np>::type> test_nps;
```



Memory Efficiency

	Handwritten	Generated
g++ 3.2	32	32
Metrowerks 8.3	56	56
Visual Studio 2003	104	**112**

- Object sizes differ because of string implementations:
  GCC (4 Bytes) – MW (12 Bytes) – VS (28 bytes)

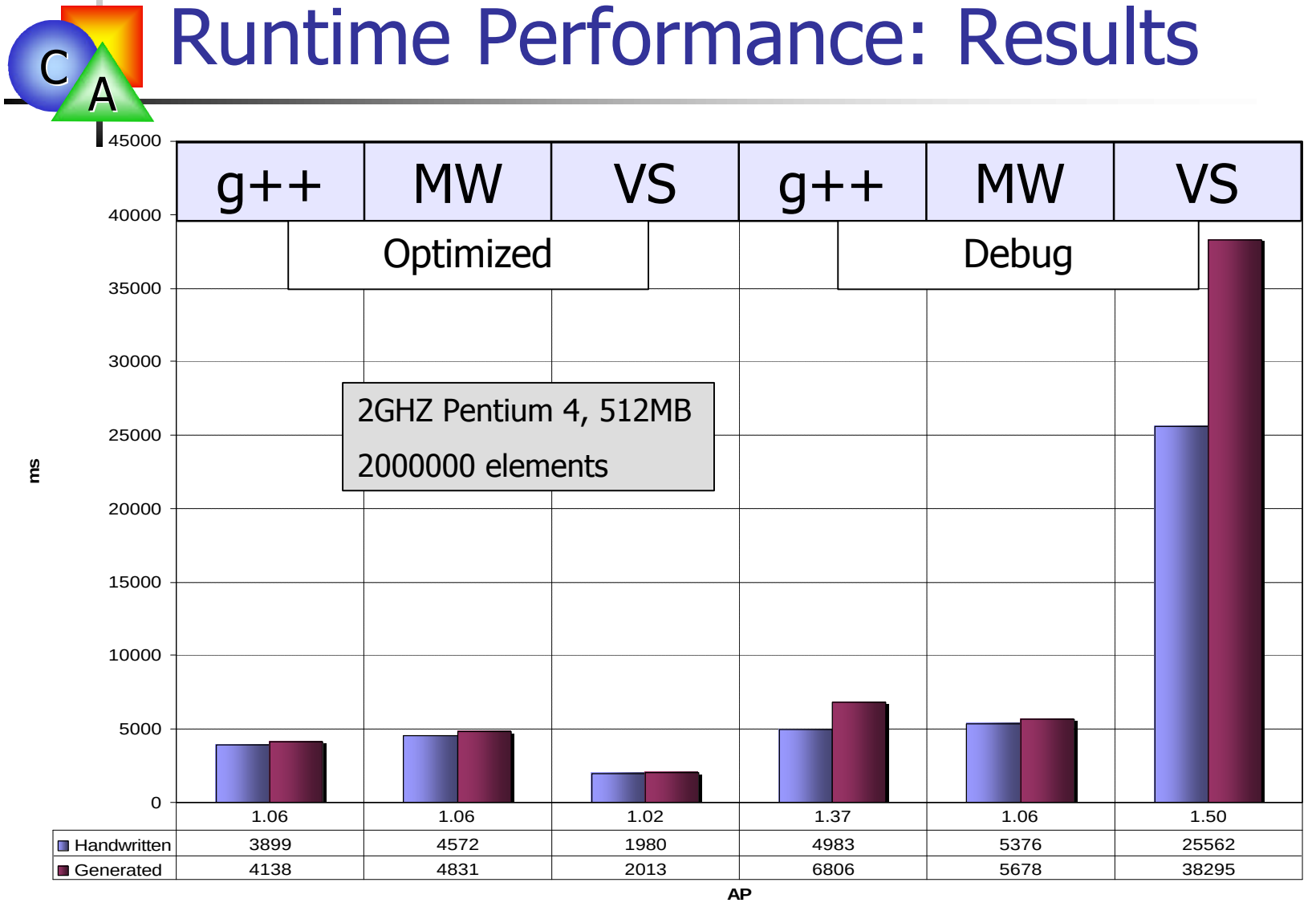


Runtime Performance

- Meassure abstraction penalty

$$AP = \frac{runtime(abstract\ version)}{runtime(low\ level\ version)}$$

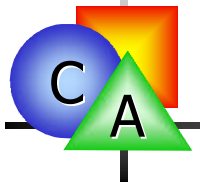
  - Abstract version: generated properties group
  - Low level version: handwritten properties group



Runtime Performance: Results

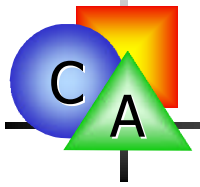
	g++	MW	VS	g++	MW	VS
	1.06	1.06	1.02	1.37	1.06	1.50
Handwritten	3899	4572	1980	4983	5376	25562
Generated	4138	4831	2013	6806	5678	38295

Conclusions and Future Work



Conclusions

- `Named_Properties` provide convenient and type-safe property storage
- Template meta-programming allows efficient data structure generation (BGL, MTL, Blitz++)
- C++ compiler technology now mature (5 years after standard's publication)



Future Work

- Add bounds/constraints to named properties like JavaBeans
- Enable programming languages with intended inherent code generation facility
- C# Attributes: provide meta-data in code