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Week 3: Algorithms and Data Structures

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# What are template classes?

MadLibs is a famous word game which requires two participants. The first will come up with a short story and then insert place holders for some of the nouns, verbs and adjectives. Next the second person without knowing the story will provide values for these placeholders. Finally, the story is read a loud and everyone has a good laugh.

Templates are very similar to MadLibs, as the programmer can write the sequence of actions needed for writing a function or class. Within that sequence are placeholders which can be replaced by the compiler as it generates compiled instances of these templates.

For instance, a class could be written to hold a list of integers and expose public methods add, remove, and get. These functions would then perform the necessary actions to manipulate some private integer array structure.

If the software package also needs to hold a list of strings, then the they would likely want to reuse as much of the list of integers code as possible. The code could be manually copied however this introduces challenges as bug fixes must go into multiple places. Instead they would create one template, and then ask the compiler to emit the different versions at build time.

Instead of using templates the developer could have written a class which holds a list of objects. Since everything in object-oriented programming is an object, the one list could have held either the string or the integer. However, this introduces other challenges as the implementation is essentially disabling the type system and its compile time checks. This has the potential to result in runtime errors, such as invalid cast exceptions, as the list can also contain multiple incompatible data types.

# Where are they used? Include a real-world example.

## Data Structures and Algorithms

Templates are often used in data structures and algorithms scenarios, as it is common for the implementation to behave correctly without change across a set of data types. Consider the stack and queue data structures, which maintain a list of things and then push and pop items to either end. It does not matter if these are strings, sockets, or tacos—they will behave the same. Then look at a sorting algorithm such as quick and merge sort. These manipulations can operate across any data type which implements a comparability interface.

## Metaprogramming

Some implementations of templating allow for metaprogramming during the compilation phase. This allows the generation to perform customized actions based on annotations or constant calculations.

For instance, the developer might create an interface with different methods representing different schematized log messages. Using an interface creates a clear separation between the component and the logging system. A factory class could then be used to emit the concrete log client based on the interface definition. This enforces consistency across all log clients as one central location is emitting the each of them.

An Object Relational Models (ORM) is another consumer of the metadata driven model. First a process will connect to a data store and fetch the schema information, this will be used to template serialization definitions for each of the tables. The output of these templates is then fed into another round of templates to provide create, read, update, and delete (CRUD) operations. This results in strongly typed generic code that can be statically verified as being accurate.

# What are some benefits and drawbacks of using template classes?

## Increased Size

Each instantiation of a template results in the generation of more code which needs to live within the binary. This will increase the size requirements of the of the program. For some embedded systems with limited resources this can introduce challenges.

Languages like C# have partially mitigated the code bloat scenario by exposing generics instead of templates. Generics are a runtime constructs that exploit the type system directly instead of relying on code generation. This provides many of the core use cases but is more limited than templates that run at the compilation level. An example of this can be seen with the inability to inject constant values into a generic.

## Recursive Templating

When a template is used to generate a class, that class part of the type system and treated the same as any other class in the system. This property exposes the ability for templates to operate on templates and then pass them to more templates. That enables general algorithms to expand into very specific concrete implementations.

The simplicity of that model makes it easy for developers to abuse the technology and write unmaintainable code. There are still use cases that require a concrete type instead of a mash up of the typed data structures. Consider the scenario of a dictionary that is keyed on a tuple and valued with list of async function pointers which might be written as Dictionary< Tuple<T,U,V>, IList< Func<Task<X,Y,Z> >>. It can be difficult for future developers to make sense of what T or U represent. Alternatively, a container class and small object model being returned. These classes could then be documented, and the intent made clear.

# What are some alternatives to template classes, and where/when would you use them?

Templating technologies are not limited to the compilation phase and can take occur during other stages of the build process.

## Macros

During the preprocessing stage macros can be applied to perform literal manipulations on the code itself.

For instance, an application might defined a macro called ISOK(expression,message); and liberally use it throughout the system. The preprocessor could expand this snippet into a try-catch block that automatically logs a message on error. This makes the code cleaner and easier to read as the redundancies are not shown to the developer.

## Moq Framework

One of the challenges with writing integration tests is that they often become coupled with live services. This can make them expensive to run or error prone as certain failure cases are difficult to reproduce. An innovative solution to this problem can be seen in the Moq framework for .net.

Developers first create an instance of the factory class Mock<T> where T is the interface to be generated. The setup method can be called multiple time and passed expression trees and callback function pointers. The framework then generates a new assembly in memory and constructs the templated instance. By having this technology execute during the runtime layer, it mitigates the lack of support for templates in the language and cleanly hide the generated code.

# What research has been conducted using template classes?

# What is some future research you can envision using template classes? (1 page)

# Create a small code example template classes in a language of your choice

Please see attached files <blah>