Talking ‘bout Code Generation

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“I would rather write programs to help me write programs than write programs.”

Richard L. Sites

In our job we’re sometimes faced with tedious activities. Tedium is often a good indication that automation is possible

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Programme

- An introduction to code generators
- The design of code generators
- A case study: Perceval
- Tools and techniques
- Lessons learned
- Conclusions

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Scope of this presentation

- Practical advice drawn from direct experience
- Little or no theory
- No rocket science
  - You already had too much of it anyway ;-)
- No CASE, Generative Programming, MDA, etc.
  - No connection with the Code Generation conference, but what a coincidence!
- Some Python, some C++

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A Success Story

- A 4,000,000+ code lines application was ported to an altogether different platform, with a different RDBMS, by a single person.
  - From IBM System I (aka iSeries, aka AS/400) to Windows Server 2003
  - From DB/2 to Oracle
- ***How?***

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    - Hint: it's not Java…

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➢ ***How?***
  - By coding in a truly portable language
    - Hint: it's not Java… It's COBOL!
  - By converting automatically the relatively few differences, i.e. by writing a code generator!

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Another Success Story

- At the onset of a new C++ project in early 1999 we decided to write our own persistence layer
- It meant we had to write the interface for all the 35 tables in our database
- Instead I convinced our team leader that we should write a code generator
- In over seven years our application grew a little:
  - Over 300 tables
  - Over 700,000 lines of code
  - Of which some 75,000 automatically generated!
  - But I'll tell you later about the one mistake I made…

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Code Generators are everywhere

- The compiler is a code generator
- Your favourite IDE’s wizards are code generators
- Web applications are often code generators of sorts
- Similar techniques may be applied to other areas of software development
  - Basically, each time you either need to retrieve information from text or to provide information in textual form!

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So why doesn't everybody use them?

- Code Generators are a kind of meta-programming
  - The step to a meta level is unsettling for some people
  - They may introduce an additional language/toolset combination
- Reflection and generic programming reduce the use of CG's
  - C++ template meta-programming solves many of the problems
  - Dynamic languages let you define types at run-time
- However, the resulting code is often more complicated

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Intensive vs. Extensive Programming

- Intensive code has:
  - Perfect factoring: Every concept is expressed once
  - Awful localization: The basic steps of a complex operation are scattered everywhere
- Extensive code has:
  - Awful factoring: lots of repetition
  - Good localization: you see what is happening
- Code generators may give you the best of both worlds

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Our First Code Generator

```
#include <cctype>
#include <iostream>
#include <string>

int main()
{
    std::string s;
    std::cout << "Who do you want to greet? ";
    std::getline(std::cin, s);
    s[0] = toupper(s[0]);
    std::cout << "#include <iostream>\n";
    std::cout << "\n";
    std::cout << "int main()\n";
    std::cout << "{\n";
    std::cout << "\tstd::cout << \"Hello, " + s + "!\\n\";\n";
    std::cout << "}\n";
}
```


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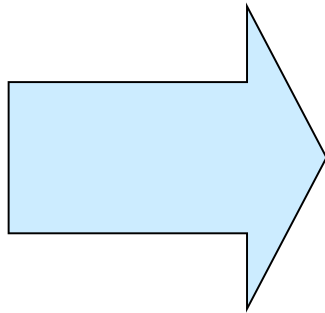
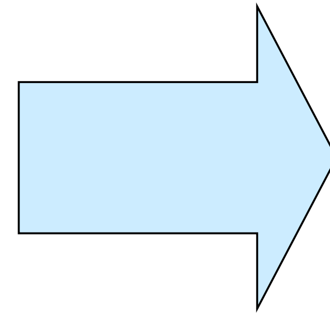
Structure of a code generator

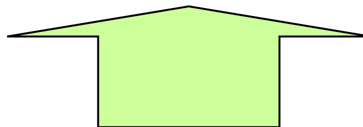
Acquisition

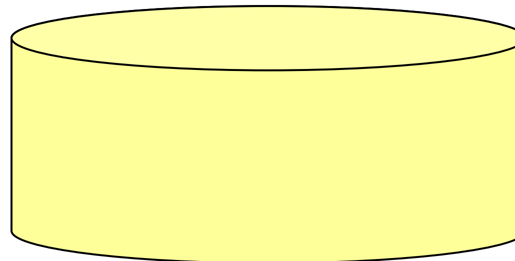
Transformation

Generation









Schema

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Acquisition

- Acquisition is the collection of the information that characterizes each instantiation of the schema patterns
- It is often dominated by the infrastructure required to handle the external representation of the information
- Some examples:
  - Parsing a textual description
    - Code, perhaps?
  - Querying a database
    - To explore its schema
    - To retrieve project wide conventional values

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Transformation

- Transformation builds an internal representation of the collected information
- Specific domains have consolidated representations
  - e.g. compilers have augmented syntax trees
- In general, however, you’re on your own

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Generation

- Generation navigates the internal representation and “splices” the information onto the schema patterns to produce an original instance
- This area too is dominated by the infrastructure required to handle the external representation
- Ideally it should combine the internal representation with a structured representation of the desired output

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Passive vs. Active Generators

- Hunt and Thomas [Hunt2000] distinguish *passive* from *active* generators
- Passive generators can only be run once for each output instance
- Active generators may be executed as many times as desired

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Passive Generators

- Usually generate code that requires manual modification
  - IDE wizards are a typical example
- Good for boilerplate code
  - Company standard header comments
  - Custom IDE project types
- Good for getting the easy 80% done quickly

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Active generators

- May produce successive versions of an output instance
  - GUI builders should be active generators!
- The key is the separation between the generated code and its customizations
  - “Do not modify above this line” is a very fragile approach

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The GENERATION GAP pattern

- Formulated by the GoF and documented byJohn Vlissides [Vlissides1998]
- Put the generated code in a base class
- Customize it by subclassing it
- Examples:
  - ICS's Builder xCessory
  - C# partial classes

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Our case study: Perceval

- A C++ Object Relational mapping
- For each DB table there are:
  - A class that directly represents it: one column – one data member
  - A set of class templates that handle reading and writing
  - A factory/container of instances that handles caching and on demand reading
  - An internal representation class that uses the persistent state
  - A factory of such internal representation
  - A GUI/report oriented representation class
  - Possibly a GUI frame

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The “Fake Template” idiom

- The declaration is generic
- All implementations are specific
- Good for providing building blocks for generic programming
- Extremely tedious

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The original DB table

```
create table cambio_maf (
  id                   numeric(11)      identity,
  cod_cambio           char(10)         not null,
  dta_reference        datetime         not null,
  num_exchange_rate    numeric(30,10)   not null,
  data_load            datetime         not null,
  constraint cambio_maf42 primary key (id)
)
go
```


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The corresponding persistent class

```
class CambioMaf : public Owf::Port::Pers::Persistent
{
    public:
        std::string         getCodCambio() const { return codCambio; }
        Owf::DateTime       getDtaReference() const { return dtaReference; }
        Owf::Pers::Money    getNumExchangeRate() const { return numExchangeRate; }
        Owf::DateTime       getDataLoad() const { return dataLoad; }

        void                setCodCambio(const std::string & arg) { codCambio = arg; }
        void                setDtaReference(Owf::DateTime arg) { dtaReference = arg; }
        void                setNumExchangeRate(Owf::Pers::Money arg)
                                                               { numExchangeRate = arg; }
        void                setDataLoad(Owf::DateTime arg) { dataLoad = arg; }

    private:
        friend class Owf::Port::Pers::PRecord<CambioMaf>;

        std::string         codCambio;
        Owf::DateTime       dtaReference;
        Owf::Pers::Money    numExchangeRate;
        Owf::DateTime       dataLoad;
};
```


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A first try: handwritten C++

- Formal language recognition is one of the most well understood fields in computer science
- The architecture is standard
  - Valid “words” are recognized by a lexical analyzer, or scanner
  - The “sentences” in which they are combined are recognized by a parser

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The scanner

- The primitive elements of programming languages can be recognized by regular expressions
  - E.g. identifiers: [A-Za-z_][A-Za-z_0-9]*
- Simple ones are easily implemented by hand:
  - Draw the Deterministic Automaton diagram
  - Code the loop around a switch, with one case per state

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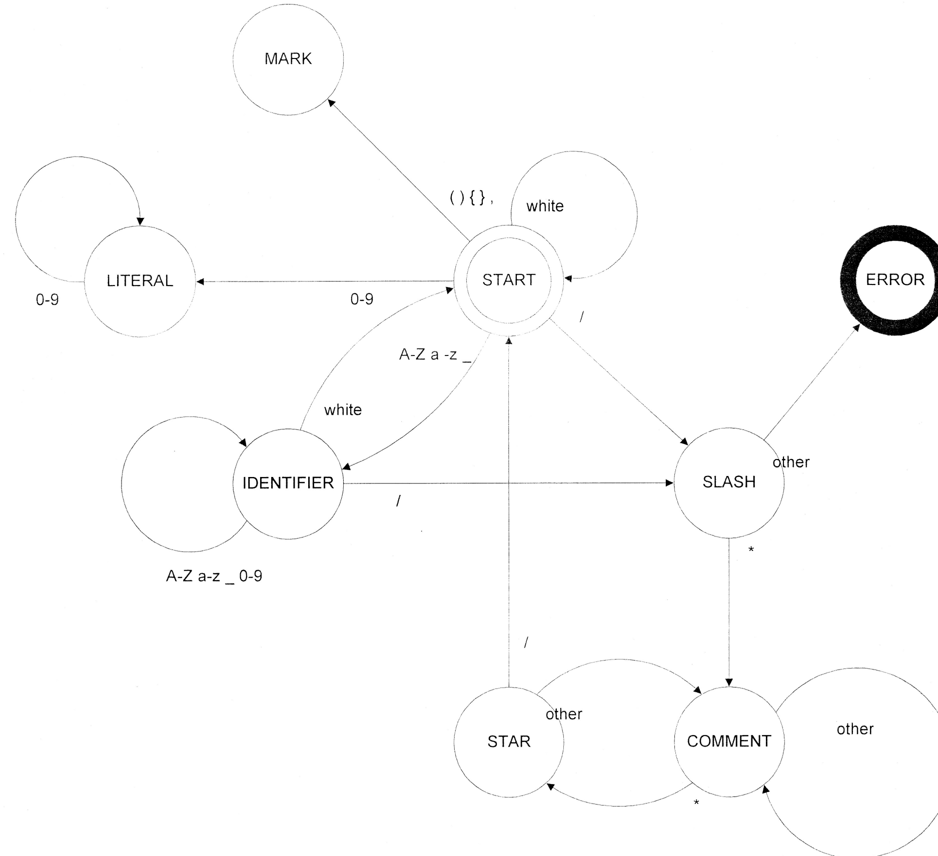
A Deterministic Finite Automaton



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The parser

- Two big families
  - Bottom up are great for automatic generation
  - Top down are more easily coded by hand
- There are caveats
  - It's easy to introduce infinite recursion
  - Some languages take a long time to parse (On^2)
- Languages should be kept simple
  - Python is among the simplest ones
  - Java is simple enough for tools to handle it
  - C++ is extremely hard

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Hand writing the parser

- SQL DDL is a tractable language
  - Declarative languages often are
- Recursive descent is simple and regular
  - One function (or class) for each symbol
  - If the language is recursive, so is the parser
- “The parser is the AST”
  - One class per symbol
  - Each symbol’s children are recognized in the parent’s constructor

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Generation

- Make a “tracer bullet”: hand code a working example of the whole source code sequence for a single table
- Prepend “std::cout <<“ to all your source lines!
- Seek a methodology that limits the modifications you need to apply to your reference code

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Here my trouble began

- We switched from Sybase ASE to Sybase ASA
  - Same supplier, different syntax
  - It turned out to be simpler to convert the syntax than to change the generator
- Over time we thought of improvements to our reference architecture
  - Wading through a miriad of ‘std::cout << …;’ statements wasn’t any fun

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Code Generators revisited

- Beware of change: C++ handwriting may be OK for version 1.0, but takes too long to maintain
- It's also a matter of timing: at the onset of a new project all deadlines appear so far away…
- Why don't we also…
  - If you have a regular architecture, there's always at least one other thing you can generate from the same data

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The right approach

- Establish an architecture!
- Acquisition: use a parser generator, or at least a well devised set of regular expressions
- Generation: use a macro processor, or a template engine
- Overall: use an agile language
  - If performance is an issue for your generator, you're in deep trouble

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Perceval 2.0

- Acquisition: use a parser generator
  - PLY: A Python implementation of Lex & Yacc
- Generation: use a template engine
  - Cheetah: A non XML, non HTML specific engine
- Python is the language
  - Pleasant to code in
  - Maintainable
  - “Batteries included” and many more within easy reach

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Conclusions

- Writing code generators is easy!
  - The domain is our own
  - We control the requirements… sort of
- Use tools!
- Use a suitable language!

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Q & A

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[Vlissides1998]	Vlissides, J., *Pattern Hatching – Design Patterns Applied*, Addison Wesley, 1998
PLY	http://ply.dabeaz.com
Cheetah	http://www.cheetahtemplate.org

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Colophon

- The presentation title was inspired by the refrain from The Who's first and greatest hit single: "My Generation"
- The presentation scheme was inspired by the work of Swiss artist Max Bill
- This colophon was inspired by the ones you find in all O'Reilly books :-)

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