Content Conversion and Generation on the Web: A Pattern Language

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EuroPLoP 2002 Conference Draft

Abstract. Content conversion and generation is required by many interactive, web-based applications. Simplistic implementations of content converters, builders, and templates often cannot satisfy typical requirements such as high performance, end-user customizability, personalization, dynamic system updates, and integration with multiple channels. We present a pattern language resolving central forces in this context. A GENERIC CONTENT FORMAT can be used to integrate content from different supported content sources. PUBLISHER AND GATHERER are central instances to trigger back and forth conversion to the GENERIC CONTENT FORMAT, and to handle other central content management tasks such as cache lookup and storage. Conversions are performed by CONTENT CONVERTERS. There are three alternative patterns to generate content on request: CONTENT FORMAT BUILDERS, CONTENT FORMAT TEMPLATES, and FRAGMENTS. A CONTENT CACHE is used to store and retrieve the content in a central repository, and FRAGMENTS are the basic elements stored in the cache.

1 Introduction

Interactive, web-based applications usually generate formatted content on request. That is, the content is not or only partially available in pre-built files. The generated content often has to be formatted in different markup languages, such as HTML, WML, and XML. Often other formats, such as graphical user interfaces or textual representations, are supported as well. Moreover, the content usually is provided to different channels with different protocols as well, such as HTTP, COM, CORBA, MMS, and WAP.

In first place, interactive, web-based applications represent their services using HTML pages. An HTTP server transfers HTML pages with the HTTP protocol. A web user agent, such as a browser, communicates with a web server, and the web server "understands" that certain requests are handled interactively. Thus, it forwards the request and all its information to another module, thread, or process. This handler may handle the request solely and generate an HTML page in response. Or it may translate and forward the HTTP request to a legacy system's API, and then the response has to be decorated with HTML markup.

On the first glance, content creation on the web seems to be a simple effort, especially when a given legacy system with a distinct API should be reengineered to the web. In our experience, this naive view is fundamentally wrong, and it leads to severe problems when the resulting system have to be further evolved later on (see [Zdun02b] for a detailed discussion). In many systems HTML pages are simply generated by string concatenation:

```
StringBuffer htmlText = new StringBuffer();
String name = legacyObject.getName();
...
htmlText.append("<BR> <B> Name: </B>");
htmlText.append(name);
```

Such hard-coding of HTML markup in the program will inevitably lead to problems because central requirements of modern web engineering are violated. Such central requirements for interactive, web-based applications are:

- Content, representation style, and application behavior should be changeable ad hoc.
- Web-based applications typically have to represent the business logic on the web in a coherent way, say, in a common representation style.
- In many cases, the same content is presented to other channels, possibly with different representation formats than HTML, as well.
- Often rapid integration of new functionality is required, perhaps within a few hours, and it should be possible to evolve the system incrementally.
- In many cases, the running system cannot be stopped during changes.
- Many (large-scale) web applications have very high performance and memory demands.
- Many applications require highly personalized presentations of content.
- Customization of content and behavior by non-programmers, such as content editors, domain experts, and end-users, is often required.

These requirements are met by many different web architectures. In this paper we discuss a pattern language that documents "successful" solutions in the realm of converting and generating content on the web. These patterns lead, in a mostly technology neutral form, to flexible and generic software architectures for web applications. The pattern's consequences and variants lead to the decision which technological choices are appropriate. During the stepwise and sequential application of the patterns different consequences and forces have to be compared with the technological options and the concrete application's requirements.

1.1 Intended Audience

This paper is intended for software and information architects faced with the development of highly dynamic, personalized, and content-centric web applications. The patterns within this paper can be used as a roadmap for building architectures capable of serving clients with dynamic web pages in a consistent and efficient manner. This is a living document and therefore your input and participation is very much appreciated. Thus, if you harvest new patterns, variants or can supply known uses feel free to contact one of the authors.

1.2 A Note on the Form

For convenience and clarity each of our patterns has the same format. In this paper we use a modification of a form called Alexandrian form that is inspired by the writings of Christopher Alexander, especially "A Pattern Language" [AIS+77]. Each of our patterns begins with a name. This is followed by an introductory paragraph, which sets the context of the pattern and its basic relations to other patterns in the pattern language. Then, there are three diamonds to mark the beginning of the problem, and, in bold type, the problem is summarized in one or two sentences. The following body of the problem explains the problem in more detail, and especially discusses the set of forces in focus of the pattern. Then, again in bold type, the solution is given in form of an instruction. In the following paragraphs, the solution is discussed in more detail, diagrams visualize the solution, dependencies to contained patterns are introduced, and consequences of applying the pattern are discussed. Another three diamonds show that the main body of the pattern is finished. And finally, there is a discussion of variants of the pattern and variations in relationships to other patterns.

1.3 Pattern Language Overview

The pattern language consists of the patterns summarized in Table 1 as thumbnails. As some of the pattern descriptions reference later described patterns, we give a thumbnail table here as an initial overview of our pattern language.

Pattern Name	*Problem*	*Solution*
GENERIC CONTENT FORMAT	How can we use content from different sources like legacy systems, DBMS or web services without having to know its concrete representation?	Provide a GENERIC CONTENT FORMAT which is used to represent content from any content source. Convert the content by using CONTENT CONVERTERS from its concrete representation into the generic representation before you process it within your web application.
PUBLISHER AND GATHERER	How can we convert to and from a GENERIC CONTENT FORMAT (semi-) automatically, provide access to all content required on the target platforms centrally, and integrate other content management tasks such as caching?	Provide PUBLISHER AND GATHERER as central instance(s) to retrieve and store all content either in the GENERIC CONTENT FORMAT(s), or in other formats delivered to target platforms. The PUBLISHER AND GATHERER trigger conversions, lookup in the cache, and other central content management tasks.
CONTENT CONVERTER	How can we automatically convert content in one format to a different format, and/or update the content according to a set of change rules?	For each required conversion type, provide a CONTENT CONVERTER that has callback methods to be called when a conversion should take place. In general, content conversion includes input processing of the input format, data conversion/manipulation, and output processing to the target format.
CONTENT FORMAT BUILDER	How can we build up content in different content formats dynamically and reuse the same code for different content formats? How do we avoid hard-coding content format specifics in the business logic code?	Provide an abstract CONTENT FORMAT BUILDER class that determines the common denominator of the used interfaces. Build special classes that implement that interface for each supported content format, as well as special methods (e.g. as callbacks) for required specialties.
CONTENT FORMAT TEMPLATE	How can we build up content in target content format and allow the content editor to add highly dynamic content parts in a simple way that yields a high performance?	Provide a template written in the content format that contains special code in a template language to be substituted by a template engine.
FRAGMENTS	How can web pages be designed in order to allow the generation of web pages dynamically by assuring the consistency of its content? Moreover, how do you provide these dynamic web pages in a highly efficient way?	Provide an information architecture which represents web pages from smaller building blocks called FRAGMENTS. Connect these FRAGMENTS so that updates and changes can be propagated along a FRAGMENTS chain.
CONTENT CACHE	How can you increase the performance of web page delivery and thereby increase efficiency of the underlying web architecture?	Provide a central CONTENT CACHE for caching already created dynamic content. Consider the life time of the content and cache them as long as it is still valid in the application's context.

Table 1. Pattern Thumbnails

In Section 2 these patterns are presented in our variant of the Alexandrian form. In Section 3 we will discuss the pattern language as a whole, in Section 4 we will give integrated examples in Java, and in Section 5 we discuss Known Uses of the pattern language.

2 Patterns for Converting and Generating Content on the Web

In this section, we present six individual patterns that we have mined for content conversion and generation on the web.

GENERIC CONTENT FORMAT

You are developing a web application that provides content in different formats to different types of clients over different channels, like HTTP and WAP.

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Each channel has its own presentation format that requires you to convert content into the channel-specific format before publishing it on the channel. Moreover, content can be retrieved from different backend systems characterized by their own content formats. This can lead to an N*M combination problem as potentially N source formats (backend formats) have to be converted into M target formats (channel formats). How can we integrate content from different sources like legacy systems, DBMS, or web services?

The code for *conversion to and from different formats should be reusable*, and the *number of conversion should be minimal*. Often different programming languages and programs should be able to access the same information base. Suppose you are developing a web application, which retrieves content from a RDBMS and displays it using HTML. Usually the logic necessary to generate the HTML page operates directly on the content. Therefore it has to know its concrete format (the database schema in this case). This approach works well, if the number of input formats (N) and the number of output formats (M) are very small as there is a *N*M conversion between the different formats*.

If there is a large number of different formats or if new formats shall be supported in the future this approach requires a *new CONTENT CONVERTER for each new combination of an input and an output format*. This leads to a very c*omplex software architecture* and increased *maintenance efforts*. Changes in any content format influence the *channel-specific presentation logic* directly and prohibits the straightforward *integration of new content sources* as a change in one of the N formats might require changes in all M output formats or their CONTENT CONVERTERS respectively.

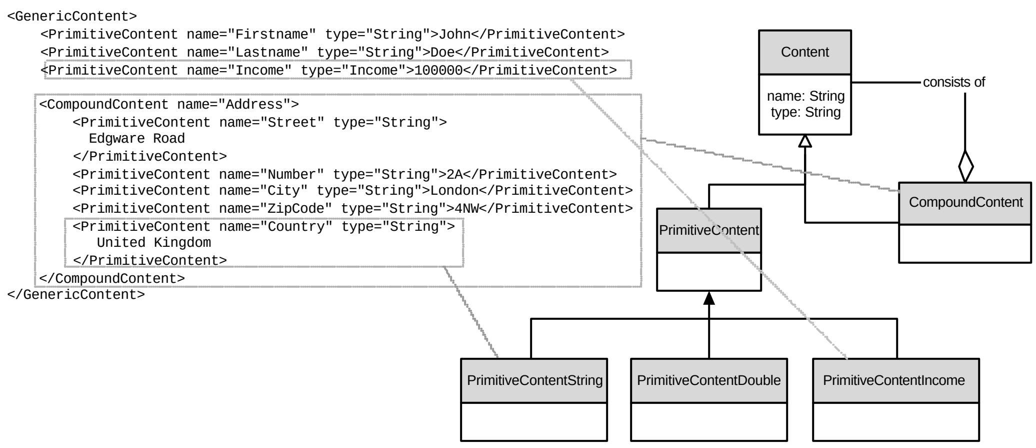
A simple and straightforward mapping of content formats and information architecture representation is necessary for *efficient content conversion and generation.*

Therefore:

Provide a GENERIC CONTENT FORMAT that is used to represent content from any supported content source with application-specific content types. For each content type in the GENERIC CONTENT FORMAT, provide a corresponding class in the information architecture. Convert the content by using CONTENT CONVERTERS from its concrete representation into the generic representation before you process it within your web application.

The generic representation is usually readable and changeable easily, so that, for instance, end users can manipulate it without programming experience. Nowadays XML is often used to represent the GENERIC CONTENT FORMAT. The GENERIC CONTENT FORMAT should enable the representation of arbitrary content models including primitive types like String, Integer, and Double as well as compound types like Address, Customer, or Account. Furthermore binary data such as images and multimedia formats should be supported. By using a GENERIC CONTENT FORMAT new content sources can be integrated without having to modify the presentation logic responsible for generating output formats like HTML and WML. The number of potential conversions from the input to the output formats is thereby reduced to N+M.

The GENERIC CONTENT FORMAT represents the application-specific superset of content types. Thus, the ontological problem of integrating content from any source is not tackled by the pattern. Each content type is described by one class of the information architecture.



```
<GenericContent>
    <PrimitiveContent name="Firstname" type="String">John</PrimitiveContent>
    <PrimitiveContent name="Lastname" type="String">Doe</PrimitiveContent>
    <PrimitiveContent name="Income" type="Income">100000</PrimitiveContent>

    <CompoundContent name="Address">
        <PrimitiveContent name="Street" type="String">
          Edgware Road
        </PrimitiveContent>
        <PrimitiveContent name="Number" type="String">2A</PrimitiveContent>
        <PrimitiveContent name="City" type="String">London</PrimitiveContent>
        <PrimitiveContent name="ZipCode" type="String">4NW</PrimitiveContent>
        <PrimitiveContent name="Country" type="String">
           United Kingdom
        </PrimitiveContent>
    </CompoundContent>
</GenericContent>
```

Figure 1. Generic Content Format Representation Using the Composite Pattern

Figure 1 illustrates a possible generic structure of an information architecture following the GENERIC CONTENT FORMAT pattern concept. Here, we use dynamic typing with a string-based *type* property. Of course, static types can as well be used. Often content is represented using a XML vocabulary expressing the abstractions necessary to model a GENERIC CONTENT FORMAT. In the example, we can see that there is a one-to-one correspondence of types in the XML vocabulary and the class hierarchy. In the example, compound types in the XML vocabulary are modeled as COMPOSITE [GHJV94] classes.

PrimitiveContent abstractions are used to represent primitive data types like Integer, String, and Double as well as Images or arbitrary binary content. *CompoundContent* can contain other content like *PrimitiveContent* or other *CompoundContent*. An Address may consist of a *PrimitiveContent* Street of type String and a *PrimitiveContent* Number of type String.

The GENERIC CONTENT FORMAT pattern offers a set of benefits: GENERIC CONTENT FORMAT serves as a "*data glue*" for integrating content from heterogeneous sources. It reduces the necessary *number of converters* to N input format converters plus M target format converters. *Automatic conversions* with CONTENT CONVERTERS often rely on a GENERIC CONTENT FORMAT as a central conversion (and storage) format. A GENERIC CONTENT FORMAT helps us to implement an *efficient content conversion and generation* architecture, which is a primary intent of the pattern language.

The GENERIC CONTENT FORMAT pattern can also incur the following liabilities: A GENERIC CONTENT FORMAT has to be defined centrally; thus, as applications evolve, it may be *hard to evolve the GENERIC CONTENT FORMAT non-centrally* (in a distributed and collaborative working environment). Therefore, initial formats have to be well designed for the particular domain, and extension processes have to be defined. Conversion can mean to *loose information* if the expressive power of other supported formats and the GENERIC CONTENT FORMAT are significantly different. It may be hard to guess automatically in unknown documents, which parts of the GENERIC CONTENT FORMAT conform to which part of the unknown document.

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The COMPOSITE [GHJV94] pattern can be applied to model the information architecture required to support GENERIC CONTENT FORMAT in the software architecture of a web application system. However, the GENERIC CONTENT FORMAT does not mandate the use of the COMPOSITE pattern. The COMPOSITE pattern is just a convenient and proven way to model tree structures.

The pattern also occurs in non-hierarchical structures. For instance, RDF [LS99] is a graph-based GENERIC CONTENT FORMAT that can be linearized to hierarchical XML structures.

Usually, if a Fragments architecture is supported, the FRAGMENTS architecture is also used as the information architecture of the GENERIC CONTENT FORMAT pattern.

We have discussed typed data for the GENERIC CONTENT FORMAT. In some variants types are omitted, and a central data conversion type such as a String is used for all data. Then, each supported type must be convertible to and from Strings.

PUBLISHER AND GATHERER

In the context of a GENERIC CONTENT FORMAT, several issues with regard to central content management are important: delivering content to clients, receiving incoming content, content conversion and generation in different formats, content caching, ensuring content consistency, and other content management tasks.

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In a content conversion and generation architecture we have to handle incoming and outgoing requests. How can we integrate central content management task with request handling?

Multiple different clients access content in the GENERIC CONTENT FORMAT. A *central entity* that can be accessed from all client platforms should provide access to content in the GENERIC CONTENT FORMAT. Some parts of the content do not have to be converted to the GENERIC CONTENT FORMAT because all target platforms are able to deal with a given input format, such as JPEG or GIF images.

Sometimes, *multiple GENERIC CONTENT FORMATS* have to be created. For instance, in the web context, often web content is converted to XML, unsupported image formats are converted to GIF or JPEG, and proprietary text formats are converted to PDF. Some instance has to coordinate what should be converted to what.

Some content is delivered statically, some other content is dynamically processed on-the-fly. Content change detection and content change propagation can also induce dynamic changes in already processed static content. Centrally handling and integrating *static and dynamic content* is crucial.

Clients should access *different devices* on which the content is stored, such as disk drives, network devices, databases, optical devices, etc., via a unique interface so that clients can abstract from the storage devices used.

Central access points to web portals and services often have very high hit rates; therefore, high *scalability* is required.

Therefore:

Provide a PUBLISHER AND GATHERER as central instance(s) to retrieve and store all content either in the GENERIC CONTENT FORMAT(S), or in other formats delivered to target platforms. The PUBLISHER AND GATHERER trigger conversions, lookup in the cache, and take care of other central content management tasks.

PUBLISHER AND GATHERER are usually two entities like objects or processes. Sometimes, say in smaller systems, they are represented by the same entity. Usually, there are distinct access points on these entities for each specific type of content, say, PUBLISHER AND GATHERER are two objects with handler methods for each request type or they are realized as two daemons that fork handlers for each individual request. The content may be stored in a cache and/or on different devices, say, on the disk, in the memory, in a database, on optical devices, or on a network device. A CONTENT CACHE is used to abstract from these storage device specifics.

For each specific content type supported, the PUBLISHER AND GATHERER can access CONTENT CONVERTERS for back-and-forth conversion to the GENERIC CONTENT FORMAT. The CONTENT CONVERTERS may have to operate on the fly. Once the content is converted to the GENERIC CONTENT FORMAT, it is stored in the PUBLISHER AND GATHERER'S CONTENT CACHE. FRAGMENTS of the CONTENT CACHE are the basic internal information entity used by the PUBLISHER AND GATHERER.

Content consistency issues are central content management tasks as well. For instance, content changes and updates may be induced by content change detection and content change propagation.

As central access points, the PUBLISHER AND GATHERER handle integration with other channels than the web, if it is required. Depending on the URL different channels can be served. Usually the publisher is triggered by a MESSAGE REDIRECTOR [GNZ01] used for indirecting URL calls to implementations. Each of these implementations is a service that should be published to the web (and other channels). The URL usually denotes which document or service is requested, which format is required, and which protocol is used. One or more publishers can be integrated as services into this architecture (see Figure 2), or the MESSAGE REDIRECTOR can be part of the publisher, if the publisher is the only service supported. The presented structure is a SERVICE ABSTRACTION LAYER [Vogel01]. It is quite common for PUBLISHERS AND GATHERERS to be combined with a SERVICE ABSTRACTION LAYER if multiple services are offered to a number of channels.

PUBLISHER AND GATHERER architecturally integrate the patterns of our pattern language, and they also integrate other related services and channel abstractions.

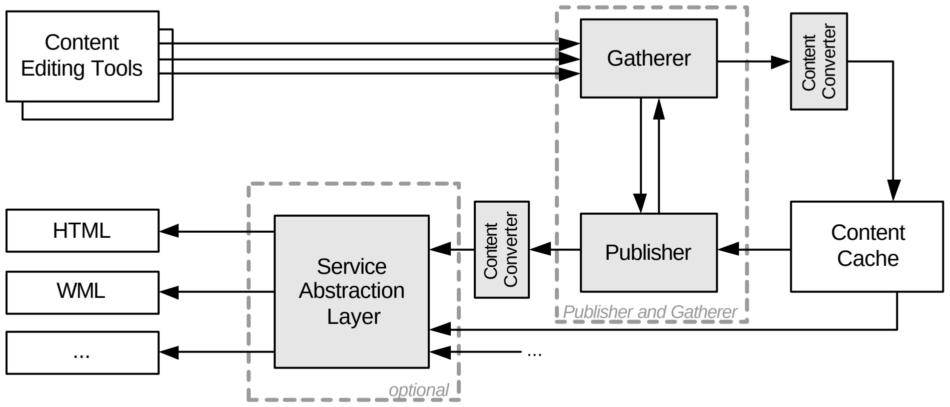

Figure 2. Content Converters, Publisher and Gatherer, Content Cache, and Service Abstraction Layer

The PUBLISHER AND GATHERER pattern offers a set of benefits: PUBLISHER AND GATHERER are *central* instances that enable service access from *different platforms* and with *different protocols*. Correct *content conversion and generation* is triggered automatically, and caching is handled. PUBLISHER AND GATHERER can be easily integrated with sophisticated service abstraction architectures.

The PUBLISHER AND GATHERER pattern can also incur the following liabilities: Using a central instance means that we have to care about *scalability and performance* issues. The converters are stateless, so they can be replicated. Only the caches must be shared. To enable automatic conversion means that *all converters have to be written and maintained*, whereas hand-built architectures can only rely on the relevant converters.

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PUBLISHERS AND GATHERERS can be implemented in different variants. First, we can decide whether PUBLISHER AND GATHERER are implemented as two separate entities or as one entity of the programming language. In many more advanced server architectures PUBLISHER AND GATHERER are separated. Often they can be forked or redirect to other servers to provide a higher scalability of the architecture. Often there is a central instance to receive requests, and multiple workers to handle individual requests. Of course, this is only an issue if they run in different threads or processes. This architecture is actually quite typical for PUBLISHERS AND GATHERERS in systems with high hit rates.

In SERVICE ABSTRACTION LAYERS [Vogel01] the publisher can either be used as a service or as a MESSAGE REDIRECTOR [GNZ01] for resolving URLs.

CONTENT CONVERTER

Content has to be represented in multiple different formats. Typical target formats for the web include XML, WML, HTML. Sometimes formats, such as PDF, are required as well. Often pictures in formats, such as GIF, JPEG, PNG, have to be generated. A PUBLISHER AND GATHERER requires content conversion facilities.

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How can we automatically convert content in one format to a different format, and/or update the content according to a set of change rules?

Content in different formats has to be generated for an interactive web application. Important consideration in this context are *performance* and *scalability* issues: for high-performance web applications (typically with high hit rates) generating all content on-the-fly is usually costly in terms of memory and performance, and this imposes severe requirements on the scalability of the application.

In the context of *migrating legacy applications* to the web (or other new media platforms), usually the original format has to be supported as well. Thus, we cannot change the legacy application to directly support web-enabled output as its primary output format. It is necessary to convert either the legacy format or the web format.

Converting one content format to another often means to reduce the expressiveness of the application to the *common denominator* of all target (and input) formats involved. Otherwise we have to live with *lossy conversions.*

Usually, conversions should take place either on request or upon certain *events*.

Therefore:

For each required conversion type, provide a CONTENT CONVERTER that has callback methods to be lazily called when a conversion should take place. In general, content conversion includes input processing of the input format, data conversion and manipulation, and output processing to the target format.

A CONTENT CONVERTER is constructed from three elements that are ordered in a CHAIN OF RESPONSIBILITY [GHJV94], each of them is optional:

1. *Input processing* creates a representation in memory from a given *input format*. As a result an intermediate representation is created. Usually, this is a representation in memory. In exceptional cases, such as operating on very large data sets (that do not fit into memory), we may use different intermediate representations. If the conversion is very simple, we can also directly operate on the input format.
2. *Data conversion and manipulation routines* on the intermediate representation (i.e. most often in memory) apply a set of change rules. The result is manipulated data in the intermediate format. Of course, this step can be repeated multiple times.
3. *Output processing* is used to create and convert the intermediate format to the target format.

The CHAIN OF RESPONSIBILITY and the produced data formats of a CONTENT CONVERTER are depicted in Figure 3. All parts of the CHAIN OF RESPONSIBILITY are optional, however, most often all parts are present. For instance, if steps 2 and 3 are performed on the input format, input processing is not required. If there is only a one-to-one conversion from one format to another one without any manipulations (e.g. to adapt the differences of the two formats) then step 2 is obsolete. If the intermediate format is equal to the target format then step 3 is not required.

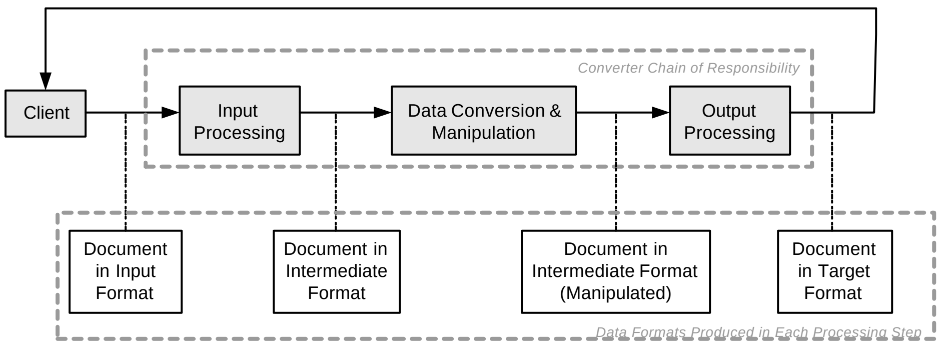
Converter Chain of Responsibility
Client
Input Processing
Data Conversion & Manipulation
Output Processing
Document in Input Format
Document in Intermediate Format
Document in Intermediate Format (Manipulated)
Document in Target Format
Data Formats Produced in Each Processing Step

Figure 3. CONTENT CONVERTERS: CHAIN OF RESPONSIBILITY and Produced Data Formats

There are different events that trigger CONTENT CONVERTERS. The CONTENT CONVERTER can be triggered on demand, say, when an HTTP request is coming in. The conversion can also be caused by events like content changes. Finally, the content can be pre-processed when the system is idle or has a low work-load.

The converter may be able to operate back and forth. It unifies all different conversions to and from the target format. Therefore, usually the converter has two TEMPLATE METHODS on an abstract converter class that call the three CHAIN OF RESPONSIBILITY methods for input processing, conversions, and output processing. One TEMPLATE METHOD handles conversion to the target format, and one handles conversion to the GENERIC CONTENT FORMAT such as XML. Special converter classes implement the hook methods for the target format that they represent (such as HTML). Figure 4 illustrates this design.

Often static and dynamic content FRAGMENTS have to be combined to create one page. CONTENT FORMAT TEMPLATES and FRAGMENTS can be used for specifying in a static page where dynamic parts have to be inserted. CONTENT FORMAT BUILDER can be used to build up content dynamically in a specific format using a generic interface. Thus, of course, it can be used to build up the target format processed by the CONTENT CONVERTER.

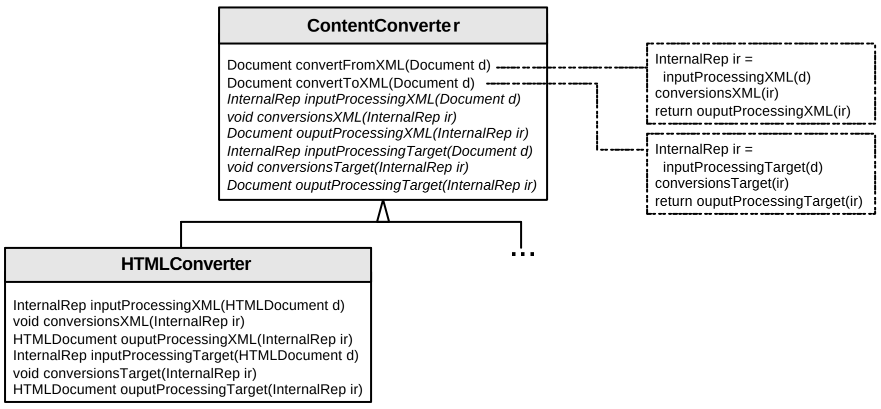
ContentConverter
Document convertFromXML(Document d)
Document convertToXML(Document d)
InternalRep inputProcessingXML(Document d)
void conversionsXML(InternalRep ir)
Document ouputProcessingXML(InternalRep ir)
InternalRep inputProcessingTarget(Document d)
void conversionsTarget(InternalRep ir)
Document ouputProcessingTarget(InternalRep ir)
InternalRep ir = inputProcessingXML(d)
conversionsXML(ir)
return ouputProcessingXML(ir)
InternalRep ir = inputProcessingTarget(d)
conversionsTarget(ir)
return ouputProcessingTarget(ir)
HTMLConverter
InternalRep inputProcessingXML(HTMLDocument d)
void conversionsXML(InternalRep ir)
HTMLDocument ouputProcessingXML(InternalRep ir)
InternalRep inputProcessingTarget(HTMLDocument d)
void conversionsTarget(InternalRep ir)
HTMLDocument ouputProcessingTarget(InternalRep ir)
...

Figure 4. Generic XML and Special HTML CONTENT CONVERTER Classes

The CONTENT CONVERTER pattern offers a set of benefits: It *unifies different APIs* for data transformation and manipulation to one abstract converter interface. Thus, in a content management environment different converters *can be applied in an automated fashion*. Automatic data conversion is required for automatically updating dynamic data in CONTENT

CACHES and for dynamically applying conversion in PUBLISHER AND GATHERER. Moreover, the pattern allows for *combining different content conversion approaches* such as the event-based, tree-based, and rule-based processing models. Content conversion is an *efficient* way to (re-)construct FRAGMENTS when new or changed input arrives.

The CONTENT CONVERTER pattern can also incur the following liabilities: content conversion offers only a *limited expressiblity* compared to fragments, templates, or builders. Therefore, higher-level manipulations of content should be implemented using these patterns. However, they can be triggered by a CONTENT CONVERTER. In many problem settings there are certain exceptional conversions that should be handled differently. Here, the CONTENT CONVERTER offers only *limited diversity of conversions* because it does not make much sense to produce a new converter for each exception. Better solutions are to provide a BEFORE/AFTER INTERCEPTOR [GZ01] or other callback mechanisms on the converter object for these cases.

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There are different CONTENT CONVERTER variants. Since all three parts of a CONTENT CONVERTER are optional all parts can be omitted. The internal creation of content can be hand-built, or it can use CONTENT FORMAT BUILDER, TEMPLATES, or FRAGMENTS.

In some variants, the CONTENT CONVERTER object is also used to store the internal (generic) and the target format (instead of using an external CONTENT CACHE). This especially makes sense in some automatic type conversion systems, such as the scripting language Tcl (with Tcl_Objs as CONTENT CONVERTERS) or some SOAP implementations. Here, the CONTENT CONVERTER object potentially "knows" the two representations in the two supported formats. However, at any time one of them may be undefined, if it is possible to create the content without loosing information in both directions. The conversion is performed when the typed or untyped object is requested the next time. When the information changes in one of the representations, the other representation is automatically invalidated. This variant is especially useful for integrating FRAGMENTS objects and a GENERIC CONTENT FORMAT. At any time, only one of the representations has to be valid, and the other one can be lazily created on demand. Lazy resource acquisition is also the focus of the LAZY ACQUISITION pattern [Kircher01].

CONTENT FORMAT BUILDER

In interactive web applications, dynamically generated content in HTML format and most often in multiple others formats is required. Sometimes the same application supports the same format in different variants. For instance, HTML may be delivered pretty-printed in a debugging version and compressed for optimizing file size in the released version. CONTENT CONVERTERS require a facility to build up a representation in a target format dynamically.

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How can we build up content in different content formats dynamically and reuse the same code for different content formats? How do we avoid hard-coding content format specifics in the business logic code?

Different content formats have *different characteristics and specialties*; however, the requirement for supporting multiple formats exists in many systems. As an example of this diversity, consider for instance classical widget sets and markup formats, such as HTML and XML. Moreover, format types are heterogeneous in different incarnations. For instance, some widget sets have highly static and monolithic programming interfaces (such as Swing, AWT, or MFC), whereas other interfaces are highly dynamic (such as TK). Some markup formats such as XML are well-formed and can be validated with a DTD or schema, whereas HTML, for instance, is only loosely defined.

Converting one content format to another often means to reduce the expressibility of the application to the *common denominator* of all target (and input) formats involved. Otherwise we have to live with *lossy conversions.*

Often, we have to create the same content in the *same format in different ways*. Consider, for instance, generation of HTML text. Ideally, we would like to have pretty printed and indented HTML output that is easily readable. However, for larger pages this may become problematic: pretty printing HTML text means to insert a lot of white space and carriage returns. Therefore, in such cases, we require a more compressed output. When different platforms have to be supported, often we want to leave away marked parts of the content, such as leaving away larger pictures in HTML text for supporting mobile devices. Another common example is stripping out comments.

Therefore:

Provide an abstract CONTENT FORMAT BUILDER class that determines the common denominator of the used interfaces. Build special classes that implement that interface for each supported content format, as well as special methods (e.g. callbacks) for required specialties.

The classes' instances enable the application to incrementally build up pages in the user interface and to retrieve the result. Usually for each user interface element we have methods for starting and ending the element, so that elements may be placed in between.

Sometimes, the CONTENT FORMAT BUILDER builds up a string, say, for generating XML or HTML directly. The CONTENT FORMAT BUILDER'S internal data representation can also be a COMPOSITE that is built up incrementally from the content format elements (which are then represented as objects). This variant has the advantage that the content representation in memory can be changed. That is, if the internal format of a CONTENT FORMAT BUILDER and a CONTENT CONVERTER are identical (e.g. a DOM tree), we do not have to perform input processing in the CONTENT CONVERTER after generating content on the CONTENT FORMAT BUILDER, but we can directly use the internal format generated. Those objects may also be of the internal FRAGMENTS structure.

CONTENT FORMAT BUILDERS let us abstract specialties and characteristics of different user interfaces. However, we have to "simulate" the more advanced formats in the less advanced ones, or reduce the output to the common denominator. Another variant is to live with lossy conversions.

Sometimes, living with lossy conversions is intended, say, if we want to provide a rich web interface, and reduced content for smaller mobile devices or settop boxes. In such cases, we can either leave certain parts of the content away during the building process or use different CONTENT FORMAT BUILDER objects as STRATEGIES [GHJV94]. Note that it is often easier and less memory and performance consuming to use CONTENT FORMAT TEMPLATES to create multiple different variants of the same content in the same format. Here, the content to be provided only on some platforms can be marked in the template definition.

In Figure 5 a typical design of a CONTENT FORMAT BUILDER is shown. An abstract CONTENT FORMAT BUILDER class determines the common interface for all derived builders. Here, four special Builder classes are derived: the GENERIC CONTENT FORMAT XML, HTML pages on the web, MMS pages for mobiles, and DVB-J Java classes that represent pages on interactive digital television platforms such as the Multimedia Home Platform.

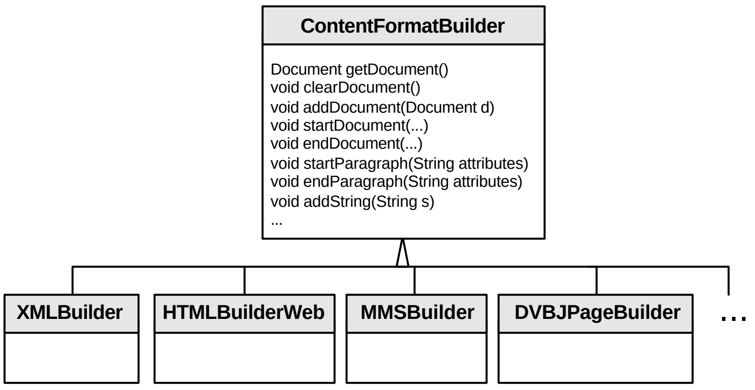


Figure 5. Abstract Content Builder CONTENT BUILDER and Special BUILDERS

The CONTENT FORMAT BUILDERS pattern offers a set of benefits: The CONTENT FORMAT BUILDER allows for abstracting *multiple target formats*. Compared to implementing each target format by hand, the CONTENT FORMAT BUILDER result in *shorter code* that is *easier to maintain*, say in cases of changing web standards, new features, etc. CONTENT FORMAT BUILDER *avoid scattering format specifics throughout the business logic code*. In comparison to template or fragment approaches, the constructive approach of the CONTENT FORMAT BUILDER is more *flexible*. *Syntax errors in the target format can be detected a priori*, say, the builder can raise an error, if a content element is opened but not closed.

The CONTENT FORMAT BUILDERS pattern can also incur the following liabilities: In comparison to template or fragment approaches, the constructive approach of the CONTENT FORMAT BUILDER is rather *slow*. Problems of *lossy conversions* and reducing all inputs to the *common denominator* of the target formats can only be avoided by programming specialties of target formats for all other formats by hand. CONTENT FORMAT BUILDERS require programming efforts to create and customize content; thus, they are hardly applicable at the end-user level without tool support.

♦ ♦ ♦

CONTENT FORMAT BUILDERS let us generically program how to build up the content format; thus, they are a generic constructive approach. In contrast, CONTENT FORMAT TEMPLATES and FRAGMENTS are template-based approaches for the same problem (but both have a different set of forces in focus).

CONTENT FORMAT BUILDERS can be structured as class hierarchies with methods for each content element, as discussed above, or as alternative variants other descriptive structures can be chosen. As a runtime structure an object can be created for each content element. Sometimes simpler list structures are appropriate as well.

CONTENT FORMAT TEMPLATE

In interactive web applications, content in HTML format and most often in multiple others formats has to be dynamically generated. CONTENT CONVERTERS need a facility to build up a representation in a target format dynamically.

♦ ♦ ♦

How can we build up content in a target content format and allow the content editor to add highly dynamic content parts in a simple way that yields a high performance?

An important limitation of CONTENT FORMAT BUILDER is that it requires programming to create and customize the content created. *End-user-level customizability*, however, is important for many web applications since web developers are easier to hire (and less costly) than qualified programmers.

Compared to static HTML content, CONTENT FORMAT BUILDERS are rather slow. For high-performance systems a *performance* closer to using static content is required. Most often only small parts of a page are dynamic, and others are given statically. In suitable cases, we should not build up the whole page dynamically, but use static content where possible.

The same content in the same format may be *presented in different ways*. For example, when different platforms are supported, often we want to leave away marked parts of the content, such as leaving away larger pictures in HTML text for supporting mobile devices.

FRAGMENTS solve both of these issues to a certain extent. However, for highly dynamic content elements we still have to create these Fragments e.g. using CONTENT FORMAT BUILDERS. Therefore, in such cases the problems appear again during construction of the FRAGMENTS.

Therefore:

Provide a template written in the content format that contains special code in a template language to be substituted by a template engine.

A CONTENT FORMAT TEMPLATE enriches the content with meta-information. A (little) language is needed for specifying the substitutions to be performed by the template engine. In some variants this is a whole scripting language.

A typical example structure are AOLServer's ADP templates that are using Tcl. For instance, in the following example a web page is created dynamically in which the user's browser type and the time is displayed:

```
<%
  set header [ns_conn headers]
  set browser [ns_set iget $headers User-Agent]
  set time [clock seconds]
%>
<html>
  <body>
    Time: <%= $time %>
    Browser: <%= $browser %>
  </body>
</html>
```

The template engine replaces the embedded Tcl code and produces proper HTML output.

The CONTENT FORMAT TEMPLATE pattern offers a set of benefits: For simple scenarios, template production is *very simple and straightforward*. That is, web page design can be separated from program development, and it is possible for web designers to create dynamic pages. In general, the approach is more *efficient* then purely constructive approaches on top of CONTENT FORMAT BUILDERS. In contrast to FRAGMENTS more high-level *dynamic interactions* can be supported in the content format. Simple *behavioral customizations can be performed by the end-user*.

The CONTENT FORMAT TEMPLATE pattern can also incur the following liabilities: In many approaches such as JSP and ASP the *promise to be simple and straightforward turns out to be unrealistic in practice,* because complex programming language elements have to be understood by the web designers. Real applications have complex interdependencies. Since templates only act at the *local level of a single document* they can hardly cope with these issues. A second liability results from this problem: recurring elements often have to be recoded for every use in a template; that is, there is only *limited reuse* of template code. The *page design and business logic of the application are usually not separated.*

♦ ♦ ♦

CONTENT FORMAT BUILDERS operate in the same context as CONTENT FORMAT TEMPLATE. But they build up the content in a programmatic and constructive approach. In some domains, this can lead to significant liabilities regarding end-user customizability and performance compared to static HTML content.

The CONTENT FORMAT TEMPLATE can internally be realized using CONTENT FORMAT BUILDERS. Other combinations of the patterns are also possible. For instance, templates may be embedded in CONTENT FORMAT BUILDER'S client code. It is also useful to reference FRAGMENTS or CONTENT FORMAT BUILDERS directly from the embedded template code written in the content format.

A FRAGMENT is another template-based approach. It codes only the fragment ID into the document, but it does not include the dynamic content itself. Thus, dynamic behavioral aspects of content that can be coded into the documents themselves is limited.

There are many CONTENT FORMAT TEMPLATE variants based on popular programming languages that are embedded in HTML code. We can generally distinguish between approaches aiming at the end-user and web designer level, and more complex approaches. Another aspect to distinguish the approaches is caching and interpretation. Some approaches always compile pages, some approaches cache pages once they are created, and other approaches always interpret the pages.

FRAGMENTS

You are developing a web application serving web pages containing various dynamic content. The different parts of your web page can have a different life time, can be highly personalized, and can depend on other parts of your web page.

♦ ♦ ♦

Instead of providing static web pages only, today's web sites offer dynamically generated web pages, enriched with real time information like stock quotes in a sometimes highly personalized manner. Examples of such web sites are financial, news and sports sites. You have to assure that the content presented is consistent. Moreover, you must provide these dynamic web pages in a highly efficient manner.

Generating web pages from dynamic content is an expensive task as *content has to be fetched from data stores* like RDBMS, XMLDBMS or even from other web systems by accessing web services. This leads to *increased I/O operations* and often *network overhead* as backend systems are incorporated over the intranet or even the internet.

Furthermore, assembling of the retrieved content to web pages results in a *processing overhead*. Content might have to be converted into a GENERIC CONTENT FORMAT and web pages are regenerated completely as no means are available to determine which parts of a web page have changed. Often web pages as a whole are the most fine grained building blocks of web systems. Therefore, web pages cannot be served in an *efficient* manner if the whole web page is regenerated.

The *consistency of the content* displayed on the web page is another key challenge. Different parts of a web page should be consistent. Consider a web page showing stock quotes belonging to the user's portfolio. To get more detailed information on a specific stock the user can click on a hyperlink bringing up a details page. The information on that page may not be older or inconsistent with the one displayed on the former page. To assure that web pages are generated consistently, intelligent means must be available to identify that underlying content has changed. This enforces a *flexible and intelligent information architecture*.

Therefore:

Provide an information architecture which represents web pages from smaller building blocks called FRAGMENTS. Connect these FRAGMENTS so that updates and changes can be propagated along a FRAGMENTS chain.

FRAGMENTS are pieces of information that have an independent meaning and identity. A single stock quote, news, or user profile information are examples of FRAGMENTS. These independent parts can be assembled to compound parts like whole web pages. Thus FRAGMENTS can contain other FRAGMENTS and reference others. FRAGMENTS can thereby build a dependency chain or object dependency graph. If FRAGMENTS lower in the chain change, the higher FRAGMENTS have to be revalidated and regenerated. Thus, only the parts of a web page which have actually changed are regenerated leading to a decreased processing overhead.

As FRAGMENTS have an independent meaning in the user's conceptual model they can build the basic entities for caching strategies. It is important to understand that FRAGMENTS are a concept of the used information architecture and are completely independent of base technologies like J2EE or .NET. Therefore the same information architecture can be used on different technology platforms [Kriha01]. A FRAGMENTS based information architecture fits nicely into the overall software architecture of a web application system as they can be represented by conventional means like classes.

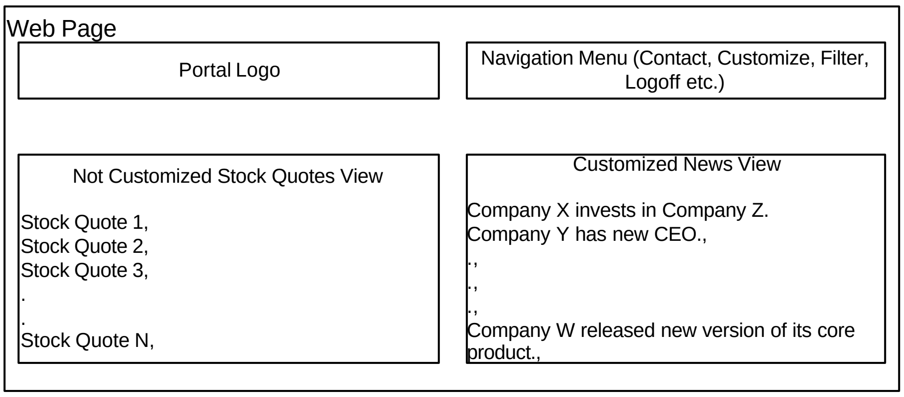

Web Page
Portal Logo
Navigation Menu (Contact, Customize, Filter, Logoff etc.)
Not Customized Stock Quotes View
Stock Quote 1,
Stock Quote 2,
Stock Quote 3,
.
.
Stock Quote N,
Customized News View
Company X invests in Company Z.
Company Y has new CEO.,
.,
.,
.,
Company W released new version of its core product.,

Figure 6. An Example Web Page Containing Personalized and Non-Personalized Parts

The illustration in Figure 6 shows a web page of a financial portal site constructed from smaller building blocks. The portal logo and the navigation menu are user independent and thus appear on every portal page. The uncustomized stock quotes view is build upon dynamic content but not personalized. Therefore, it can be reused across different portal pages.

In contrast, the customized news view is personalized by the user and is specifically generated for that particular user. However, several users could have the very same configuration; or different news items could appear on different web pages as well. Thus, there is a reuse potential for the news view and news items. Furthermore the stock quotes view and the news view are themselves build from smaller building blocks, namely stock quotes or news items respectively.

Using the FRAGMENTS concept the web page is a compound FRAGMENT containing the portal logo FRAGMENT, the navigation menu FRAGMENT, the stock quotes FRAGMENT and the news FRAGMENT. The stock quotes and news FRAGMENT are compound FRAGMENTS as well build from stock quote and news item FRAGMENTS. Like the GENERIC CONTENT FORMAT a FRAGMENTS architecture can be designed using the COMPOSITE pattern.

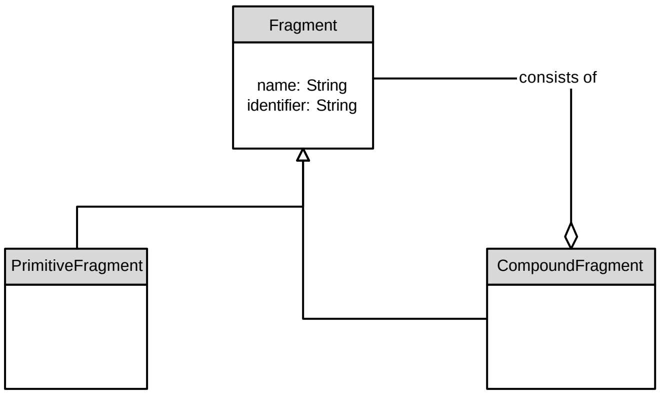


Figure 7. Generic Fragments Structure Using the COMPOSITE Pattern

Using the COMPOSITE pattern arbitrary FRAGMENT trees can be assembled. In order to tell which FRAGMENTS make up which other FRAGMENT'S FRAGMENT Definition Sets (FDS) are used. FRAGMENT Definition Sets are FRAGMENTS themselves and build an object dependency graph necessary to invalidate FRAGMENTS and to detect which parts of a FRAGMENT have to be regenerated. The FRAGMENT Definition Sets can themselves be modeled using the COMPOSITE pattern (see Figure 8).

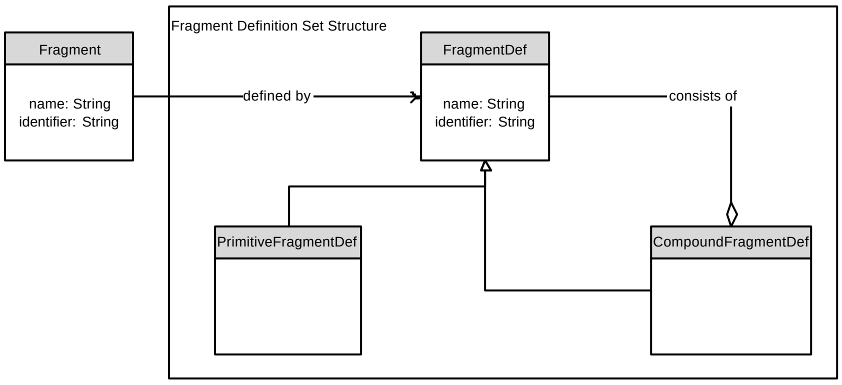
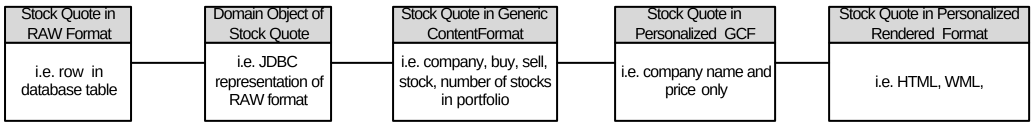


Figure 8. Generic Structure of a FRAGMENT Definition Set

FRAGMENTS are defined by FRAGMENT definitions. Combining the definition and the instance level of the information architecture leads to a dynamic object model system as described in [RTJ00].

Besides using FRAGMENTS to structure web pages, FRAGMENTS are also ideal candidates to model dependencies between different formats of the same content.



Stock Quote in RAW Format
i.e. row in database table
Domain Object of Stock Quote
i.e. JDBC representation of RAW format
Stock Quote in Generic ContentFormat
i.e. company, buy, sell, stock, number of stocks in portfolio
Stock Quote in Personalized GCF
i.e. company name and price only
Stock Quote in Personalized Rendered Format
i.e. HTML, WML,

Figure 9. FRAGMENTS Chain of the same Content

In Figure 9 we can see a typical FRAGMENTS chain. If any part of the FRAGMENTS chain changes, its successor has to be revalidated and regenerated. The upper part in the chain, the rendered FRAGMENT, is usually part of a web page chain triggering the revalidation of the affected parts of the web page after its regeneration. To detect and to propagate fragment changes special algorithms can be used. For example, a Data Update Propagation (DUP) algorithm can be used to propagate changes along the FRAGMENT chain by assuring consistent updates as described in [CIW00]. Another approach is to include special validator objects containing the logic necessary to determine if FRAGMENTS have become invalid and therefore have to be updated. The validators can either be configured using a rule based approach or be created programmatically [Kriha01]. Moreover, caching can be integrated within the FRAGMENTS architecture as explained in CONTENT CACHE.

The FRAGMENTS pattern offers a set of benefits: Compared to the other content generation patterns, FRAGMENTS potentially offer the highest *performance*. Fragment elements are highly *personalizable*, and offer a *good integration with a layered CONTENT CACHE*. The other content generation patterns can be combined with the FRAGMENT approach.

The FRAGMENTS pattern can also incur the following liabilities: FRAGMENTS only *assemble pre-built parts*. They are *not highly programmable* and do not offer *behavioral abstractions.* However, these problems can be eliminate by combining them with the other content generation patterns. In pre-built FRAGMENTS content changes have to be detected and propagated to ensure *content consistency.*

♦ ♦ ♦

In their internal structure, FRAGMENTS can be atomic, chained, COMPOSITES, or cascaded COMPOSITES. Fragments can only have an object representation or they can also cache the GENERIC CONTENT FORMAT representation that corresponds to their internal representation. Then only one of these representations has to be valid, and the other one can be computed lazily.

CONTENT CACHE

You are developing a web application system targeting many users that has to support dynamic content in an efficient way. You are using FRAGMENTS to structure your content. The processing time required to render web pages should be reduced.

♦ ♦ ♦

How can you increase the performance of web page delivery and thereby increase efficiency of the web architecture.

Dynamic web application systems often lack in providing web pages in an *efficient way.* A FRAGMENTS architecture can be used to reduce the amount of parts of a web page having to be *regenerated* every time a new request enters the system. However, the performance of the overall web architecture might still be insufficient.

Content changes that affect already created content have to be detected and propagated to *avoid content inconsistencies*.

Therefore:

Provide a central CONTENT CACHE for caching already created dynamic content. Consider the life-time of pre-created dynamic content and cache it as long as it is still valid in the application's context.

The main reason for caching is to increase throughput and thereby performance. According to a report by Yahoo [MPR00], 80% of all users do not customize their homepage. This means that besides the welcome message, everything appearing on the individual's portal page stays the same. Caching these parts truly increases the performance of the overall web site tremendously.

However, enabling caching in a consistent way is challenging as accurate cache invalidation algorithms have to be applied. Moreover, client and server side caching has to be considered. Whereas server side caching enables cache invalidation by introducing validator objects containing the knowledge when a cached piece of content becomes invalid, client side caching is often quite cumbersome.

First of all, clients, in most cases web browsers, must adhere to a protocol supporting the control of client side caching from the server side. Although, the common protocol HTTP allows for setting certain caching parameters most popular web browsers still do not implement the HTTP specification accurately. This makes caching of dynamic content on the client side unreliable as it is not clear how the client's browser implements the specification. One can limit access to web sites to certain, tested browsers only. But the next version or the same version on another platform might still behave differently. Thus, often the only choice is to turn off client side caching completely leading to a decrease of performance.

Server side caching is an effective means to speed up overall request satisfaction. To support efficient server side caching an information architecture must be in place which decomposes the information space along the dimensions time and personalization and which distinguishes clearly between global pieces, individual selections of global pieces and really individual pieces [Kriha01]. An information architecture based on FRAGMENTS can be used to classify content. Moreover validator objects can be applied to determine, if a piece of information is still valid according to time and personalization constraints. The validator objects can either be configured using a rule-based approach or implemented programmatically. Different validator algorithms can be supplied using the STRATEGY pattern.

Assuming that hundreds of requests for the same stock quote are entering the system, the same number of requests to the backend system, requesting the same information, would be required. Thus, system performance would heavily reduced. Only the first request should trigger the retrieval of the information all subsequent request should receive the information from the server side cache as long as it is valid. For most types of information an accuracy of a few seconds is acceptable. Therefore, every request should go through a CONTENT CACHE. The CONTENT CACHE checks if the requested piece of information is in the cache and if it is valid. If not, the content is loaded from the backend system and stored in the cache. Afterwards it is returned to the client. This applies for whole web pages as well for parts of web pages.

Content can be gathered and published by using the PUBLISHER AND GATHERER pattern. Typically CONTENT CONVERTERS are triggered before and/or after the content is placed in the CONTENT CACHE. The PUBLISHER AND GATHERER checks whether the CONTENT CACHE contains a valid entry before it re-creates content dynamically.

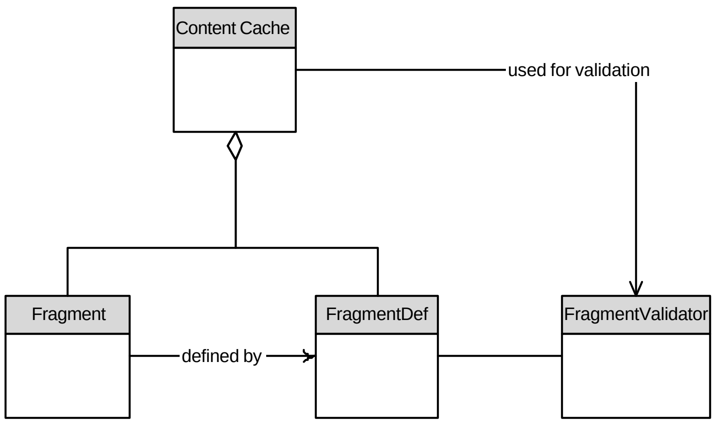


Figure 10. Internal Structure of Content Cache

The *ContentCache* itself contains *Fragments* as well as *FragmentDefs* and uses associated *FragmentValidators* to validate *Fragments* of certain types (see Figure 10).

Chains of FRAGMENTS, representing the same content in different formats, can be cached in the *ContentCache* too. Because of the behavior of *FragmentChains,* the *ContentCache* is not the only active component within the caching process. FRAGMENTS within a chain automatically notify its successors upon content change triggering their revalidation and probably leading to the invalidation of the *ContentCache*. Thus, FRAGMENTS play an active role in the caching process as well.

The CONTENT CACHE pattern offers a set of benefits: In combination with FRAGMENTS the patterns allows for a highly *efficient* information architectures. Together with a PUBLISHER AND GATHERER it *integrates well* with CONTENT CONVERTERS.

The CONTENT CACHE pattern can also incur the following liabilities: Possible *inconsistencies* in the CONTENT CACHE have to be resolved. In exceptional cases change detection and propagation can be more costly than the performance gain of caching. In multi-threaded environments a CONTENT CACHE requires mutex locks which can result in *lock contention*. Therefore, it is important to *monitor hit rates and contention* closely.

♦ ♦ ♦

There are different variants of CONTENT CACHES. A cache can be supplied as one central instance. As a variant, there can also be multiple caching instances, one for each content element. For instance, in Tcl, Tcl_Objs use this style of caching: each Tcl_Obj is one cached element plus a CONTENT CONVERTER to/from a generic, string-based representation.

A CONTENT CACHE can support automatic invalidation of all dependent objects, or invalidation has to be handled by hand. Moreover, CONTENT CACHES can also support more advanced forms of content change detection and propagation such as object dependency graphs [CIW00].

If personalized FRAGMENTS are supported, an important variant is a layered CONTENT CACHE. Each caching layer than reflects one personalization layer in the FRAGMENTS.

3 Pattern Interactions in the Language

Figure 11 illustrates the most important pattern dependencies in the language. GENERIC CONTENT FORMAT is the most general pattern in the language. It is used to represent content from any supported content source. Usually, the pattern language is applied incrementally. Typically, at first, an initial GENERIC CONTENT FORMAT is defined to start off, and it is refined as the application evolves.

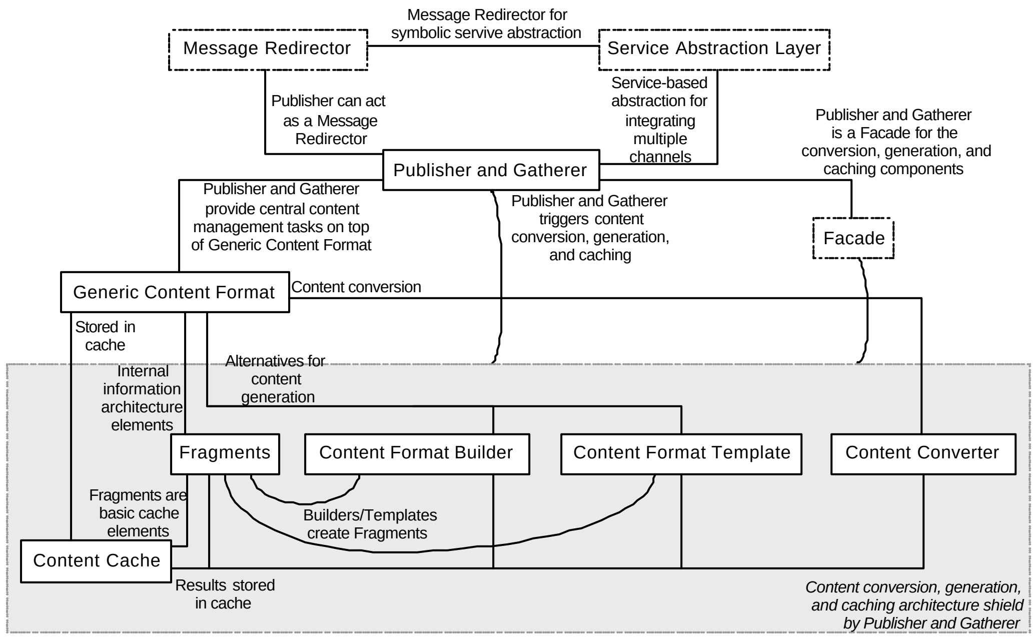

Message Redirector for symbolic servive abstraction
Message Redirector
Service Abstraction Layer
Publisher can act as a Message Redirector
Service-based abstraction for integrating multiple channels
Publisher and Gatherer is a Facade for the conversion, generation, and caching components
Publisher and Gatherer
Publisher and Gatherer provide central content management tasks on top of Generic Content Format
Publisher and Gatherer triggers content conversion, generation, and caching
Facade
Generic Content Format
Content conversion
Stored in cache
Internal information architecture elements
Alternatives for content generation
Fragments
Content Format Builder
Content Format Template
Content Converter
Fragments are basic cache elements
Builders/Templates create Fragments
Content Cache
Results stored in cache
Content conversion, generation, and caching architecture shield by Publisher and Gatherer

Figure 11. Pattern Language Overview

PUBLISHER AND GATHERER are central instances to convert to and from the GENERIC CONTENT FORMAT, and to handle other central content management tasks. Therefore, it is quite usual to design and build PUBLISHER AND GATHERER very early in a project. Usually, PUBLISHER AND GATHERER have to integrated with the mapping of URLs (or other document/service IDs) to service implementations. This task is often handled by the MESSAGE REDIRECTOR pattern [GNZ01]. If multiple channels have to be served, often the PUBLISHER AND GATHERER is integrated with a SERVICE ABSTRACTION LAYER [Vogel01] as well. Usually, PUBLISHER AND GATHERER trigger the content conversion, generation, and caching components, and they are FACADES to this subsystem.

Conversions are performed by CONTENT CONVERTERS. Converters are triggered by PUBLISHER AND GATHERER. For each supported content format, one converter has to be written for conversion to and from the GENERIC CONTENT FORMAT. These may be hand-built or use one of the patterns for content generation.

Concerning the patterns CONTENT FORMAT BUILDERS, FRAGMENTS, and CONTENT FORMAT TEMPLATES, we want to introduce a major distinction of content generation models into template-based approaches, generating pages by substituting certain elements in template files, and constructive approaches, constructing a web page on the fly. CONTENT FORMAT BUILDERS are implementing the constructive approach. They are highly flexible and programmable, but not the fastest alternative and not well-suited for end-user customization. FRAGMENTS and CONTENT FORMAT TEMPLATES are template-based approaches. Potentially, FRAGMENTS offer a very high performance but can only assemble pre-built parts. A compromise are CONTENT FORMAT TEMPLATES that integrate program elements in the content source. Thus they are customizable with behavior and offer a sufficient performance, but they are less flexible and less well-integrated with the programming model than CONTENT FORMAT BUILDERS. Of course, there are several systems supporting more than one of the approaches in different combinations.

FRAGMENTS, CONTENT FORMAT BUILDERS, and CONTENT FORMAT TEMPLATES can be seen alternatives for implementing dynamic content generation. However, FRAGMENTS are acting at a different abstraction level than the other two patterns, because they used as elements of the content cache. Therefore, often the patterns are integrated. For instance, CONTENT FORMAT BUILDERS and CONTENT FORMAT TEMPLATES create FRAGMENTS as results that are stored in the cache. The information architecture part of the GENERIC CONTENT FORMAT pattern can be implemented with FRAGMENTS.

A CONTENT CACHE is used to store and retrieve the content in a central repository. Content caching is a central document management task, therefore, the CONTENT CACHE is usually triggered by the PUBLISHER AND GATHERER. Besides complete documents, FRAGMENTS are the primary information elements stored in the cache.

4 Implementation Example in Java

In this section, we provide a few Java code examples to illustrate the practical use of the patterns. In the pattern language, the PUBLISHER AND GATHERER pattern is used as the central pattern for architecturally integrating the other patterns of the language. Let us consider PUBLISHER AND GATHERER realized as two separate Java classes with methods for each type of source content. In a simple publisher class methods for retrieving each individual content type are provided. A document in the GENERIC CONTENT FORMAT (here: XML) can directly be delivered with `getXml`, if it is found in the cache. Each document has a unique document ID, for instance denoted by an URL. We would have to trigger building a page from FRAGMENTS here as well, if this functionality is supported. Internally, the document FRAGMENTS consist of an object tree corresponding with the GENERIC CONTENT FORMAT'S information architecture. XML and HTML text are just views on this generic representation; however, the XML view has a one-to-one correspondence.

Other formats, such as HTML, are either already converted and stored in the generic cache, or they have to be converted from XML. If a conversion took place, we can put the generated HTML document into the cache.

```
class Publisher {
  CacheHandler xmlCache;
  CacheHandler htmlCache;
  ContentConverter htmlConverter;
  ...
  public XmlDocument getXml (DocumentID docID) {
    return xmlCache.get(docID);
  }
  public HtmlDocument getHtml (DocumentID docID) {
    HtmlDocument htmlDoc = htmlCache.get(docID)
    if (htmlDoc == null) {
      XmlDocument xmlDoc = getXml(docID);
      htmlDoc = htmlConverter.convertFromXml(xmlDoc);
      if (htmlDoc != null)
        htmlCache.enter(docID, htmlDoc);
    }
    return htmlDoc;
    }
    ...
  }
```

Similarly, a gatherer can directly store XML input into the document cache (or on any other storage device), and entries for the document in depending caches, such as the HTML cache, are invalidated. If HTML input is received, the XML and HTML cache entries are invalidated, and the new document is converted to XML.

```
  class Gatherer {
    CacheHandler xmlCache;
    CacheHandler htmlCache;
    ContentConverter htmlConverter;
    ...
    public void storeXml (DocumentID docID, XmlDocument xmlDoc) {
      xmlCache.store(xmlDoc);
      xmlCache.propagateChangeToDependingCaches(xmlDoc);
    }
    public void storeHtmlAsXml (HtmlDocument htmlDoc) {
      invalidateAllCaches(docID);
      xmlCache.store(docID, htmlConverter.convertToXml(htmlDoc));
    }
    ...
  }
```

CONTENT CONVERTERS are triggered by the PUBLISHER AND GATHERER. We will now discuss code examples for input processing with the tree-based model on basis of the Document Object Model (DOM). The CONTENT CONVERTER has to wrap and trigger a DOM BUILDER. Before parsing, we have to instantiate a document tree builder object first. Then we have to parse the file as well:

```
DocumentBuilderFactory factory = DocumentBuilderFactory.newInstance();
factory.setValidating(false);
DocumentBuilder builder = factory.newDocumentBuilder();
...
Document document = builder.parse(file);
```

A tree structure is generated in memory. DOM provides a low-level API to traverse this tree as an intermediate format in memory, e.g.:

```
NodeList nodes_i = document.getDocumentElement().getChildNodes();
for (int i = 0; i < nodes_i.getLength(); i++) {
  Node node_i = nodes_i.item(i);
  if (node_i.getNodeType() == Node.ELEMENT_NODE &&
      ((Element) node_i).getTagName().equals("A")) {
   handleElementA();
  }
  ...
}
```

A Content Converter wraps these low-level details of XML processing and generates the appropriate GENERIC CONTENT FORMAT with its corresponding information architecture. Usually, only the Java FRAGMENT objects are created from the DOM tree and the corresponding XML text and other content formats are created lazily on demand.

Alternatively, we can use event-based XML processing models, such as SAX or Expat, or rule-based processing models, such as XSLT.

CONTENT FORMAT BUILDERS can be used in this architecture to generate XML and HTML text from the FRAGMENTS that are created after input processing. Here, the FRAGMENTS are ordered hierarchically in a COMPOSITE structure. For each element of the content format, the CONTENT FORMAT BUILDER has methods for starting the element and ending it. For instance, a paragraph in an HTML builder may have children; thus, it has to be started and ended:

```
void startParagraph(String attributes) {
  addStringIncr(“<P ”);
  addString(parseArguments(attributes));
  addStringIncr(“>\n”);
}
void endParagraph() {
  addStringDecr(“</P>”);
}
```

Leafs, such as strings, have only a method for adding the leaf. In `startParagraph` and `endParagraph` we have used the methods `addStringIncr`, `addString`, and `addStringDecr` for adding the leafs that markup the paragraph. Only `addString` is a method supported by the abstract CONTENT FORMAT BUILDER. `addStringIncr` and `addStringDecr` are methods for increasing and decreasing the indent level of HTML text before adding a string. Thus, they represent a specialty of the HTML format.

An XML CONTENT FORMAT BUILDER usually has a one-to-one mapping of content FRAGMENTS and CONTENT FORMAT BUILDER methods, as there is a one-to-one correspondence between those elements in the GENERIC CONTENT FORMAT pattern. A mapping method for each FRAGMENT type defines the correspondence between the semantic content in the FRAGMENTS and basic content layout, such as HTML or WML. Further layout refinements can be added with different means, such as Cascading Style Sheets and XSLT processing.

As an alternative, we can enhance given content with CONTENT FORMAT TEMPLATES. A simple example of CONTENT FORMAT TEMPLATE are JSPs that contain Java code to be substituted. The substitution rules can also be applied with XML. The template engine finds special tags containing the Java code and executes this code before delivering the pages. Here the data for date and time is computed dynamically:

```
<%@page import="java.util.*" %>
<HTML>
...
<BODY>
<H2>Date and Time</H2>
  Today’s date is: <%= new Date() %>
</BODY>
</HTML>
```

Of course, CONTENT FORMAT TEMPLATES are especially valuable if they are combined with the other patterns in the language. For instance, the called methods can refer to FRAGMENTS that are dynamically computed and/or cached. This computation can be done with CONTENT FORMAT BUILDERS.

5 Known Uses and Related Work

There are different commercial web service and portal architectures that are based on parts of the pattern language. For instance, BEA WebLogic Integration uses a GENERIC CONTENT FORMAT to receive and send data from and to clients connected to its integration platform. ORACLE’s PortalToGo uses a SimpleResult data structure to represent content in a device independent manner. It generates device-specific pages based on the content represented in the GENERIC CONTENT FORMAT. The Java Connector Architecture (JCA) provides ResultSets, MapResultsSets and other generic formats to represent data coming from different backend systems.

Different web standards and their implementations are also based on parts of the pattern language: SOAP [BEK+00] is an XML-based remote procedure call (RPC) protocol. SOAP envelopes are a typed GENERIC CONTENT FORMAT. RDF [LS99] is a graph-based GENERIC CONTENT FORMAT for providing meta-data on the web.

Servers that allow for putting and retrieving data (and programs) are simplistic implementation variants of the PUBLISHER AND GATHERER pattern with one entity: examples are FTP servers and HTTP PUT/POST-enabled HTTP servers.

There are numerous XML-based CONTENT CONVERTERS, based on the different processing standards: SAX [Megginson99] parsers and Expat are the basics for numerous event-based parsing architectures, DOM [W3C00] is the basics for numerous tree-based parsing architectures, and XSLT [Clark99] is the basics for numerous rule-based parsing architectures.

xoComm [NZ00] is a extensible web server architecture that has a worker object for each request, and a central server for handling incoming and outgoing HTTP requests. Thus, this web server architecture is also a PUBLISHER AND GATHERER variant. xoComm provides a CONTENT CACHE structure on the client side. Actiweb [NZ01] is a web object and mobile code system based on xoComm. It uses the "events" generated by the corresponding worker of the web server. It translates the URLs in an invoker component. Depending on the URL, either normal web pages are delivered, an agent immigration or RPC invocation is handled, or a web object is triggered. In this framework, xoRDF [NZ02] is a tree-based CONTENT CONVERTER architecture for RDF data that is extensible with multiple other interpretations using a VISITOR framework. Antti Salonen's Htmllib is a CONTENT FORMAT BUILDER written in XOTcl for the HTML target format that is integrated in Actiweb. It builds up a Tcl list dynamically on the builder object and supports the most important parts of HTML's functionality. The conference management system, described in [Zdun02a], uses these HTML builder objects extensively.

The Credit Control Platform has been developed for a leading Swiss bank. The platform stores credit control information coming from different credit control systems in GENERIC CONTENT FORMAT and uses it to render HTML pages. Credit Control Platform uses efficient, format specific, code generated CONTENT CONVERTERS to convert credit reports from different credit control systems into a GENERIC CONTENT FORMAT [Vogel00]. A modeling tool can be used to describe the schema of the input format. Based on the schema-specific CONTENT CONVERTERS are created. Credit Control Platform supports different CONTENT FORMAT TEMPLATES. Data Visualizers can be specified on a meta level using a special modeling tool [BIV00]. Concrete CONTENT FORMAT TEMPLATES can be generated for different technologies like JSP, ASP and XSLT.

The document archiving system in [GZ01] provides a GENERIC CONTENT FORMAT in form of a data capsule format for document archiving. The capsules contain the document plus metadata. In future system versions, the capsule format should be XML. The system provides central GATHERER entities for archiving of different content formats, and a document retrieval handler. All handlers are daemons that are provided for initial access only. Upon a request, a PUBLISHER handler is forked from the central instance and handles the request. The system supports CONTENT CONVERTERS for converting all inputs into an archive capsule format.

In the document management system DocMe a central `gatherd` and `publishd` are provided. Internally, all gathered information is converted. Here, different constructive CONTENT CONVERTERS are provided, e.g. from MS Word format and similar formats used by end users as content editors. The system approximates how the documents should look like in different formats, such as HTML, TV broadcasted data, etc. Using the central PUBLISHER AND GATHERER the system caches the information, handles multiple document versions in the CONTENT CACHE, change detection and propagation, user and rights management, and document classification issues.

AOL Digital City, based on AOL Server [Davidson00], has an architecture with a central *Pub* server and multiple front end servers as a variant of PUBLISHER AND GATHERER. A switch server multiplexes a client onto one of the front end servers. AOL Server's SOB (small objects) is an interface for dynamic publishing editorial content. SOBs can be placed as FRAGMENTS in templates. They are aggressively cached in a CONTENT CACHE, e.g. in AOL Movie Guide. AOL Server implements a CONTENT CACHE in a multi-threaded environment. Here, the cached data has to be mutex-protected during writing. AOL Digital City and Movie Guide use this functionality for central content caching servers. AOLServer's ADP templates are CONTENT FORMAT TEMPLATES that integrate HTML, Tcl, and the AOL Server interfaces. They are used on numerous high-performance web sites, including AOL Digital City and Movie Guide.

The Olympic Games 2000 Web Site [CIW00] is build by IBM using a FRAGMENTS-based system for dynamic creation of web content. It uses a server side CONTENT CACHE to cache dynamic content [CIW00].

Edge Side Includes are a new evolving FRAGMENT technology used to describe cacheable and non-cacheable Web page components. These components can be aggregated, assembled, and delivered at runtime [ESI02].

WebShell [Vckovski01] uses Tcl procedure to implement each part of the construction of a web page as a CONTENT FORMAT BUILDER. These are combined in a special method that assembles and delivers the web page. The code of this procedure already resembles the document to be created, but actually Tcl commands and lists are used.

In the EC project TPMHP we are building a Java-based CONTENT FORMAT BUILDER for the Multimedia Home Platform which should support DVB-J, HTML, and MMS pages.

There are several different languages and platforms that support CONTENT FORMAT TEMPLATES natively. ASP and JSP are approaches that use tags to allow embedded code in an HTML page. ASP pages are written in Visual Basic, and JSP pages are written in Java. ASPs offer a CONTENT CACHE for all created pages. As a disadvantage, both approaches require "low-level" programming and are therefore hardly applicable at the end-user level. Scripting approaches for building templates on the web are often easy to customize. PHP introduces a new language for web page templates. It is small, light-weight, efficient, and easy to use for non-programmers. However, as a disadvantage the language is only created for one use: on the web. The Apache modules mod_perl, mod_tcl, and WebShell [Vckovski01] allow for combining templates, written in Tcl and Perl, with the Apache web server. Zope is a rather complex and powerful system for integrated web development that resides on the Python language, and also allows for templates.

Some approaches provide combinations of CONTENT FORMAT TEMPLATES and CONTENT FORMAT BUILDERS: WebShell [Vckovski01], ActiWeb [NZ01], and Brent Welch's TclHttpd can construct pages dynamically, and embedded template elements in the HTML code used to construct an HTML page.

6 Conclusion

In this paper we have presented patterns for dynamic content conversion and generation on the web. The patterns are used in many different web architectures, and, to a certain extent, different available technological instances can be exchanged. For instance, different models of CONTENT CONVERTERS or different content generation techniques can easily be exchanged. However, the base-line architecture stays the same, despite such important technological decisions. Since most basic technologies are based on XML, and since components, such as parsers and processors, are widely available for many different programming languages, we can assert that the patterns can be used for architectural decisions apart from concrete technological realizations. Therefore, they provide a good communication means with different stakeholders of the system in focus.

In our experience, the patterns yield architectures with a set of benefits and liabilities that vary slightly for different used implementation technologies, for different combinations of the patterns, for different sequences through the language, and for different variants of the patterns.

The patterns strongly encourage architectures that provide a separation of concerns between content, styles, formats, and channels. That is the reason, why different technological choices can relatively easily be exchanged against each other. MESSAGE REDIRECTORS [GNZ01] can be used to implement the indirection to the channels, and add-ons for the channels can be transparently provided, such as logging or authentication.

With a SERVICE ABSTRACTION LAYER [Vogel01] multiple representation channels may be supported. CONTENT FORMAT BUILDER and CONTENT FORMAT TEMPLATE can be used to abstract from different content formats. Thus, a common denominator can be implemented with minimal programming effort. Both patterns provide a programmable alternative to using FRAGMENTS alone, and both can be integrated with FRAGMENT approaches.

Generational aspects in the pattern language can be handled at runtime. Therefore, introducing changes into a running program is natively supported by many architectures based on the pattern language. However, since generation is always more performance-intensive than delivering static HTML pages (e.g. stored in files or in a database), performance may be influenced negatively. Therefore, the balance between CONTENT FORMAT BUILDERS, CONTENT FORMAT TEMPLATES, and static content often has to be considered very carefully. In different applications, performance impacts may significantly vary. Thus often combinations of the patterns and caching architectures are necessary to reach acceptable results. These forces are primarily resolved by the FRAGMENT and CONTENT CACHE patterns.

If CONTENT FORMAT BUILDERS are used exclusively, the user interfaces are reduced to the common denominator defined in the abstract builder. Of course, certain CONTENT FORMAT BUILDERS may also ignore certain formatting instructions, say, like a WML CONTENT FORMAT BUILDER that does not fully support the HTML subset.

On first sight, the complexity of architectures based on the pattern language is higher then simple architectures, such as template-based approaches or CGI scripts. However, for larger tasks, the complexity of the simpler models usually grows exponentially, say, because of cut-and-paste code and missing integration models. Therefore, in our experience, in real-world, large-scale web applications the complexity, and thus the maintainability and understandability, is rather influenced positively by applying the pattern language.

Acknowledgements

We wish to thank our EuroPLoP shepherd Markus Voelter for his valuable comments during the shepherding process.

References

[AIS+77] C. Alexander, S. Ishikawa, M. Silverstein, M. Jakobson, I. Fiksdahl-King, and S. Angel. A Pattern Language – Towns, Buildings, Construction. Oxford Univ. Press, 1977.

[BEK+00] D. Box, D. Ehnebuske, G. Kakivaya, A. Layman, N. Mendelsohn, H. F. Nielsen, S. Thatte, and D. Winer. Simple object access protocol (SOAP) 1.1. http://www.w3.org/TR/SOAP/, 2000.

[BIV00] A. Bredenfeld, E. Ihler, O. Vogel, GENVIS, Model Based Generation Of Data Visualizers, In Proceedings of Technology of Object Oriented Languages and Systems Conference, France, 2000, http://www.ovogel.de/publications/GENVIS.pdf

[CIW00] J. Challenger, A. Iyengar, K. Witting, C. Ferstat, P. Reed. A Publishing System for Efficiently Creating Dynamic Web Content, In Proceedings of IEEE INFOCOM 2000, Tel Aviv, Israel, March 2000.

[Clark99] J. Clark. XSL transformations (XSLT). http://www.w3.org/TR/xslt, 1999.

[Davidson00] J. Davidson. Tcl in AOL digital city the architecture of a multithreaded high-performance web site. In Keynote at Tcl2k: The 7th USENIX Tcl/Tk Conference, Austin, Texas, USA, February 2000. http://www.aolserver.com/docs/intro/tcl2k/.

[ESI02] Edge Side Includes (ESI) Overview, http://www.esi.org, 2002.

[GHJV94] E. Gamma, R. Helm, R. Johnson, and J. Vlissides. Design Patterns: Elements of Reusable Object-Oriented Software. Addison-Wesley, 1994.

[GZ01] M. Goedicke and U. Zdun. Piecemeal Legacy Migrating with an Architectural Pattern Language: A Case Study. In: Journal of Software Maintenance and Evolution: Research and Practice, 14:1-30, 2002.

[GNZ01] M. Goedicke, G. Neumann, and U. Zdun. Message redirector. In Proceedings of EuroPlop 2001, Irsee, Germany, July 2001.

[Kircher01] M. Kircher. Lazy Acquisition. In Proceedings of EuroPlop 2001, Irsee, Germany, July 2001.

[Kriha01] W. Kriha. Advanced Enterprise Portals, http://www.kriha.org, 2001.

[MPR00] U. Manber, A. Patel, and J. Robison. Experience with Personalization on Yahoo!. Communication of ACM, Aug.2000, Vol.43 (8), pages 107-111.

[LS99] O. Lassila and R. R. Swick. Resource Description Framework (RDF) Model and Syntax Specification. http://wwww3.org/RDF.

[Megginson99] D. Megginson. SAX 2.0: The simple API for XML. http://www.megginson.com/SAX/index.html, 1999.

[NZ00] G. Neumann and U. Zdun. High-level design and architecture of an http-based infrastructure for web applications. World Wide Web Journal, 3(1), 2000.

[NZ01] G. Neumann and U. Zdun. Distributed web application development with active web objects. In Proceedings of The 2nd International Conference on Internet Computing (IC'2001), Las Vegas, Nevada, USA, June 2001.

[NZ02] G. Neumann and U. Zdun. Pattern based design and implementation of a XML and RDF parser and interpreter: A case study. Accepted for ECOOP 2002, 2002.

[RTJ00] D. Riehle, M. Tilman, and R. Johnson. Dynamic object model. In Proceedings of 7th. Pattern Languages of Programs Conference (Plop 2000), Monticello, Illinois, USA, August 2000.

[Vckovski01] Andrej Vckovski. TclWeb. In Proceedings of 2nd European Tcl User Meeting, Hamburg, Germany, June 2001.

[Vogel00] O. Vogel, Usability of XML, Generation of efficient XML Content Converters, Speech at XML for Business, Switzerland, Zuerich / Regensdorf, 2000, http://www.ovogel.de/publications/XML4Business.pdf

[Vogel01] O. Vogel. Service abstraction layer. In Proceedings of EuroPlop 2001, Irsee, Germany, July 2001. http://www.ovogel.de/publications/ServiceAbstractionLayer.pdf

[W3C00] W3C. Document object model. http://www.w3.org/DOM/, 2000.

[Zdun02a] U. Zdun. Dynamically generating web application fragments from page templates. In Proceedings of Symposium of Applied Computing (SAC 2002), Madrid, Spain, 2002.

[Zdun02b] U. Zdun. Reenginering to the Web: Towards a Reference Architecture. In Proceedings of 6th European Conference on Software Maintenance and Reengineering, Budapest, Hungary, 2002

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