An Approach to Personalization and Adaptivity in Hyperlink-Based Systems

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Acknowledgement

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Agenda

- **Part 1**: Motivation, Some Problems and Responses
- **Part 2**: Towards One Possible Solution
    1. A Model of Hyperlink-Based Interaction
    2. Adding Personalization
    3. Adding Adaptivity
- **Part 3**: Contrast, Limitations, Possibilities, Conclusions

Motivation

- The claim that making hyperlink-based systems (HLBS) personalizable and adaptive will increase their effectiveness in learning tasks needs backing:

  > *Linda Roberts, the director of the Office of Educational Technology in the [US] Department of Education, says there needs to be a serious effort to do research that will help determine whether computers and the Internet improve student achievement. "It's critical. [...] School districts will be called to task for 'What are you doing with your money and what difference does it make?"' (New York Times 27 Apr 98)*

- Research so far has followed the well-known pattern of ad-hoc, hands-on, system- and technology-driven activity.
- This makes it difficult to verify whether, in general, there are indeed gains to be made by making it possible for the material and its delivery to be tailored.

Some Problems and Responses

1. Why are tailoring actions required?
2. What is the purpose of tailoring actions?
3. Which tailoring actions could be made available?
4. Which tailoring actions should be made available?

The responses so far from the body of research on **adaptive hypermedia** (as this class of systems is being referred to) have been (roughly):

1. Tailoring actions are required to transfer ownership from the designers of a hyperdocument to its users.
2. Tailoring actions revise the decisions of the designers as to content, navigation and rendering.

There exist no answers to the other questions, relating to which tailoring actions could or should be made available.

The tailoring actions that <u>have been</u> made available are those that turn out to be feasible to implement in some system with whatever technologies are currently available and which intuition suggests would be useful.

The work presented in this talk concurs with those views in that:

1. Yes, tailoring actions are required for ownership transfer.
2. Yes, tailoring actions affect content, navigation and rendering.

However, it differs from them in that:

1. The choice of tailoring actions should not be system- and technology-driven.
2. It proposes defining an abstract model of personalizable, adaptive hyperlink-based interaction which can induce a rich set of tailoring actions that could be made available.
3. It postulates that then, and only then, empirical studies can determine which tailoring actions should be made available (because they increase the effectiveness of HLBSs as a platform for learning).

One step further, the following derived problems present themselves:

1. How to model the interaction with a hyperdocument?
2. How to transfer ownership of the process of interaction with a hyperdocument from the designers to its users?
3. How to make design decisions more explicit?
4. How to make design decisions revisable?
5. How to distinguish (and model (and implement)) tailorable hyperdocuments and non-tailorable ones?
6. How to distinguish (and model (and implement)) personalization and adaptivity?

The responses so far from the body of research on adaptive hypermedia have been characterized by a few shortcomings, e.g.:

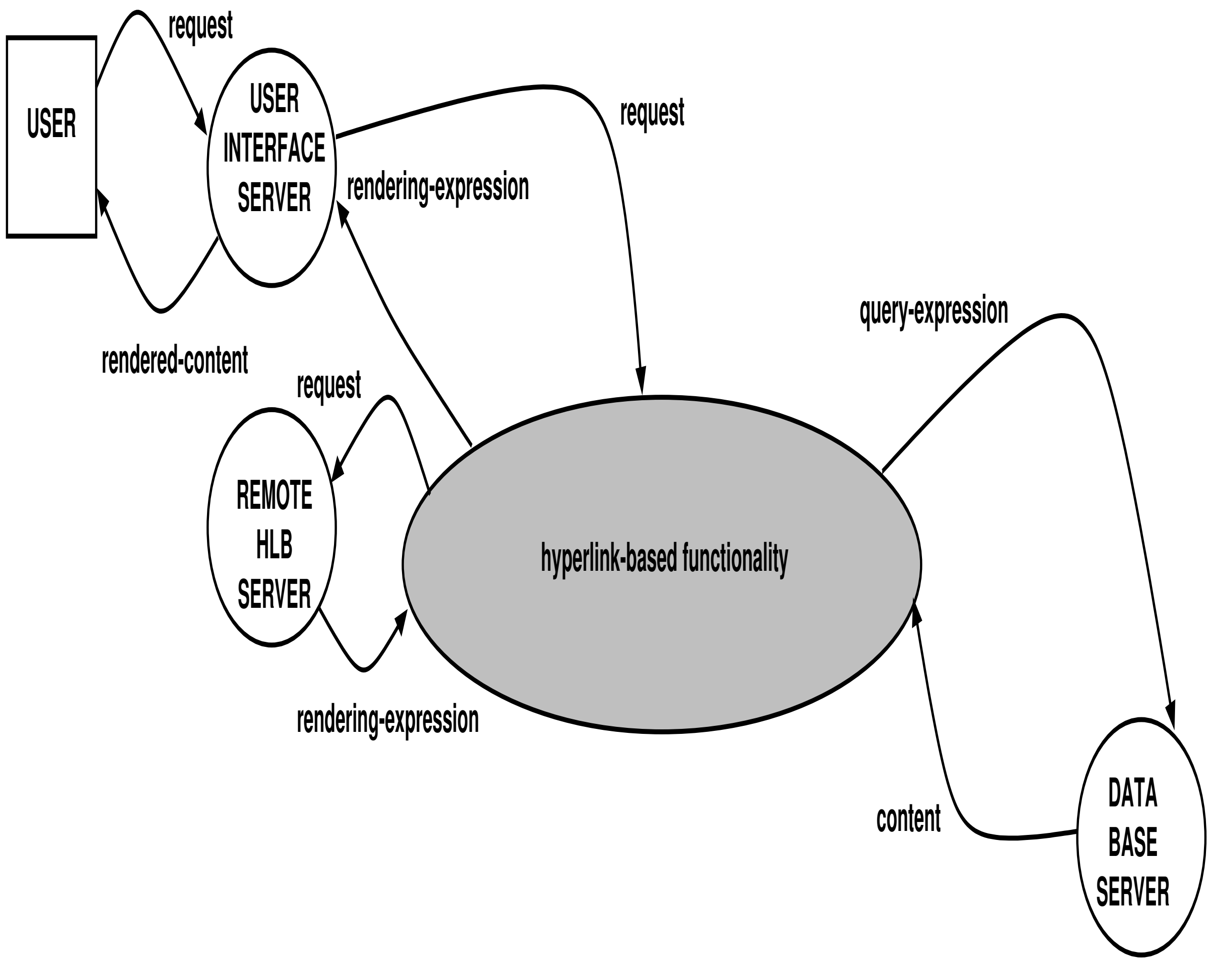
1. Choosing a tailoring action and simply coding it into an existing system means it is often difficult to generalize and share insights.
2. Design decisions are often difficult to parse, and therefore revise.
3. Personalization and adaptivity are not clearly distinguished, resulting in some degree of conceptual muddle.
4. This makes it is difficult to analyze and measure their (presumably distinct, independent) effects.

Towards One Possible Solution

The work presented in this talk aims at responding to these shortcomings via the following goals:

1. to characterize a core of hyperlink-based functionality viewed as a client technology;
2. to view tailoring actions as ranging over entities within this core and as effecting the transfer of ownership from designers to users;
3. to make design decisions explicit and therefore easier to revise;
4. to model **personalization** as *user-initiated tailoring* and **adaptivity** as *system-initiated personalization*;
5. to propose this distinction as a basis to analyze and measure their independent and compound effects.

Isolating Core Hyperlink Functionality



External Architectural Features

- The basic assumption is that user-interface and database services are available, and distinguishable from a core which is responsible for the way a hyperdocument is perceived and interacted with by users.
- User-interface servers (UISs) channel in requests.
- Database servers (DBSs) can be queried for the content of the hyperdocument and reply with refreshed data.
- The core realizes designer specifications as to content, navigation and rendering.
- The core accepts request from UISs, possibly queries DBSs for content, and composes a renderable hyperdocument that is returned to a UIS, as the response to the original request, for rendering.

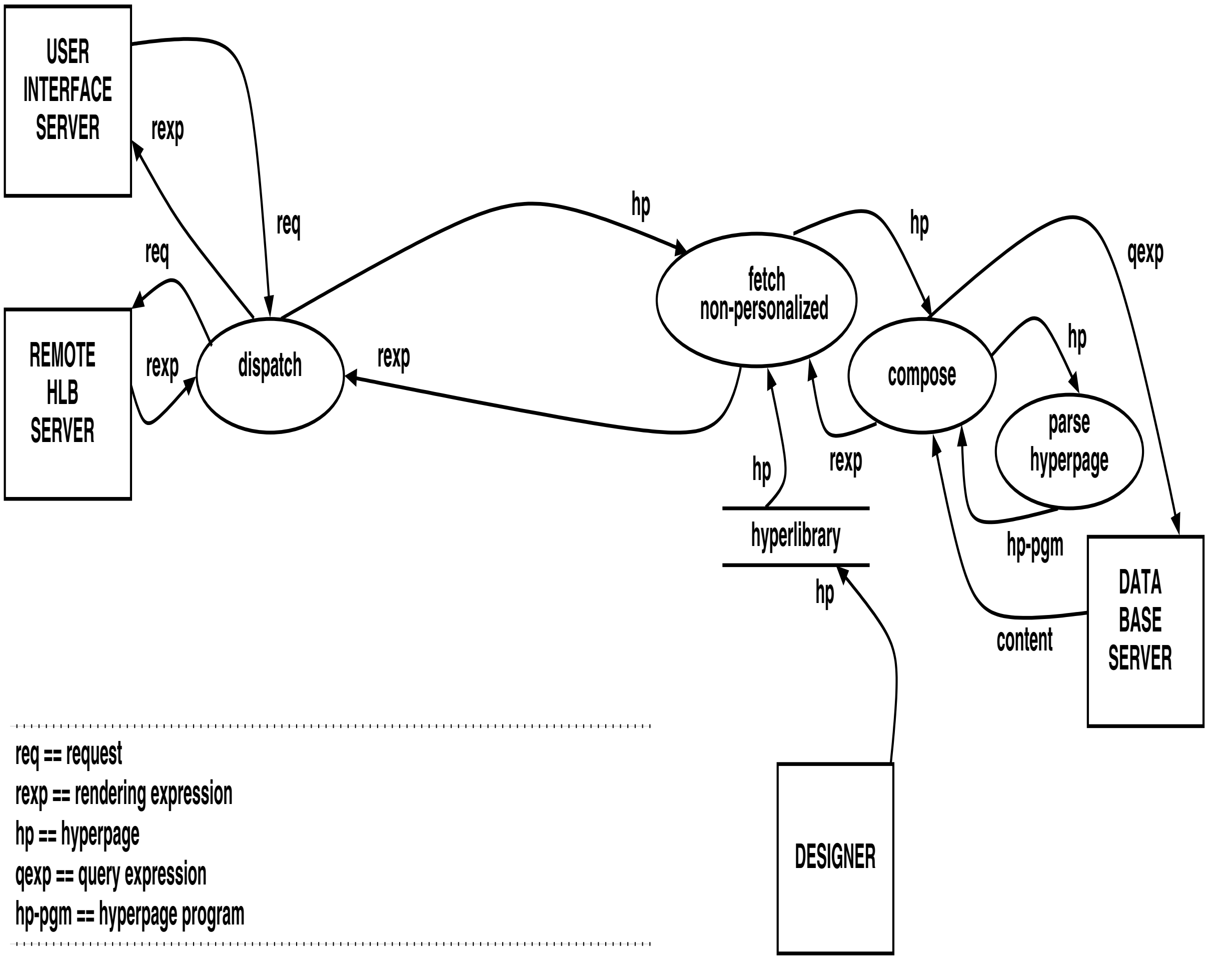
Internal Architectural Features

- The core contains at least one group of functions, which is referred to, here, as the **H-region**.
- The H-region models interaction with non-tailorable hyperdocuments.
- Two other groups of functions can be added, non-disruptively, viz., the **P-region** and the **A-region**.
- The P-region models tailoring actions initiated and specified by users. These are referred to as **personalization requests**. The P-region presupposes, but requires no modification of, the H-region.
- The A-region models personalization requestss initiated and specified by the system itself. These are referred to as **adaptivity actions**. The A-region presupposes, but requires no modification of, the P-region (and hence, not of the H-region either).

H-Region: Requests

- With only the H-region, all that users can request is for hyperpages to be rendered.
- Designers' decisions as to the content, navigation and rendering features of a hyperdocument cannot be revised.
- Hence, the H-region offers *non-tailorable interaction*.

H-Region: Design



H-Region: Features

- A hyperlibrary stores hyperpage specifications.
- Upon a request arriving from a UIS, a composition function parses the hyperpage specification into a series of actions that, when executed, realize the specified hyperpage as a renderable text.
- In the present version, these actions involve textual substitution of content (possibly retrieved from DBSs) into pieces of renderable text interspersed with template variables.
- The renderable text is returned to a UIS for rendering.

H-Region: A Hyperpage Specification

```
page{
  chunk {
    entry     { [<A NAME="welcome">]
              }
    content   { X := 'hello',
                Y1 := ', world'
              }
    rendering { [<B>] X [</B>]
                [<B> <I>] Y1 [</I> </B>]
              }
        }
  chunk {
    content   { X := [SELECT * FROM welcome]
              }
    rendering { [<I> <B>] X [</B> </I>]
              }
    exit      { [<A HREF="http://www.gold.ac.uk/"> next </A>]
              }
        }
    }
```

H-Region: Grammar for Hyperpage Specs

```
hyperpage              ::=   page {
                                 chunk*
                             }

chunk                  ::=   chunk {
                                 entry-point*
                                 C-spec
                                 R-spec
                                 exit-point*
                             }

entry-point            ::=   entry {
                                 USER-INTERFACE-SERVER-STRING+
                             }

C-spec                 ::=   content {
                                 content-assignment*,
                             }

R-spec                 ::=   rendering {
                                 rendering-template*
                             }

exit-point             ::=   exit {
                                 USER-INTERFACE-SERVER-STRING+
                             }

rendering-template     ::=   USER-INTERFACE-SERVER-STRING* template-variable*

content-assignment     ::=   template-variable := content-expression

template-variable      ::=   IDENTIFIER

content-expression     ::=   VALUE
                         |   DATABASE-SERVER-STRING
```

H-Region: An Example Composition

```
compose('<a NAME="Welcome">')                              →  L1
bind(X1')                                                  →  L2
bind(Y1')                                                  →  L3
evaluate('hello')                                          →  L2
evaluate(', world')                                        →  L3
compose('<B> L2* </B> <B> <I> L3* </I> </B>')              →  L4
replace(L2,L4)                                             →  L5
replace(L3,L5)                                             →  L6
bind(X2')                                                  →  L7
evaluate('SELECT * FROM welcome')                          →  L7
compose('<B> <I> L7* </I> </B>')                           →  L8
replace(L7,L8)                                             →  L9
compose('<A HREF="http://www.gold.ac.uk/"> next </A>')     →  L10
append(L1,L6)                                              →  L11
append(L11,L9)                                             →  L12
append(L12,L10)                                            →  L13
return(L13)
```

H-Region: Abstract Machine

bind	:	IDENTIFIER' $\times$ *location*
evaluate	:	content-expression' $\times$ *location*
compose	:	rendering-expression' $\times$ *location*
replace	:	IDENTIFIER' $\times$ $location_1$ $\times$ $location_2$
append	:	$location_1$ $\times$ $location_2$ $\times$ $location_3$
return	:	*location*

- *bind* allocates memory space at *location* to the template variable whose denotation is IDENTIFIER';
- *evaluate* writes onto *location* the value of content-expression' (which may originate from a database server to which the abstract machine, in the role of client, submits a retrieval request);
- *compose* writes rendering-expression' onto *location*;
- *replace* moves the contents of $location_1$ onto $location_2$, replacing each occurrence of IDENTIFIER' in $location_1$ with the contents of the memory space bound to IDENTIFIER' in $location_2$;
- *append* moves onto $location_3$ the concatenation of $location_1$ and $location_2$;
- *return* passes back *location*, which contains the expression to be rendered, to the user interface server.

P-Region: Requests

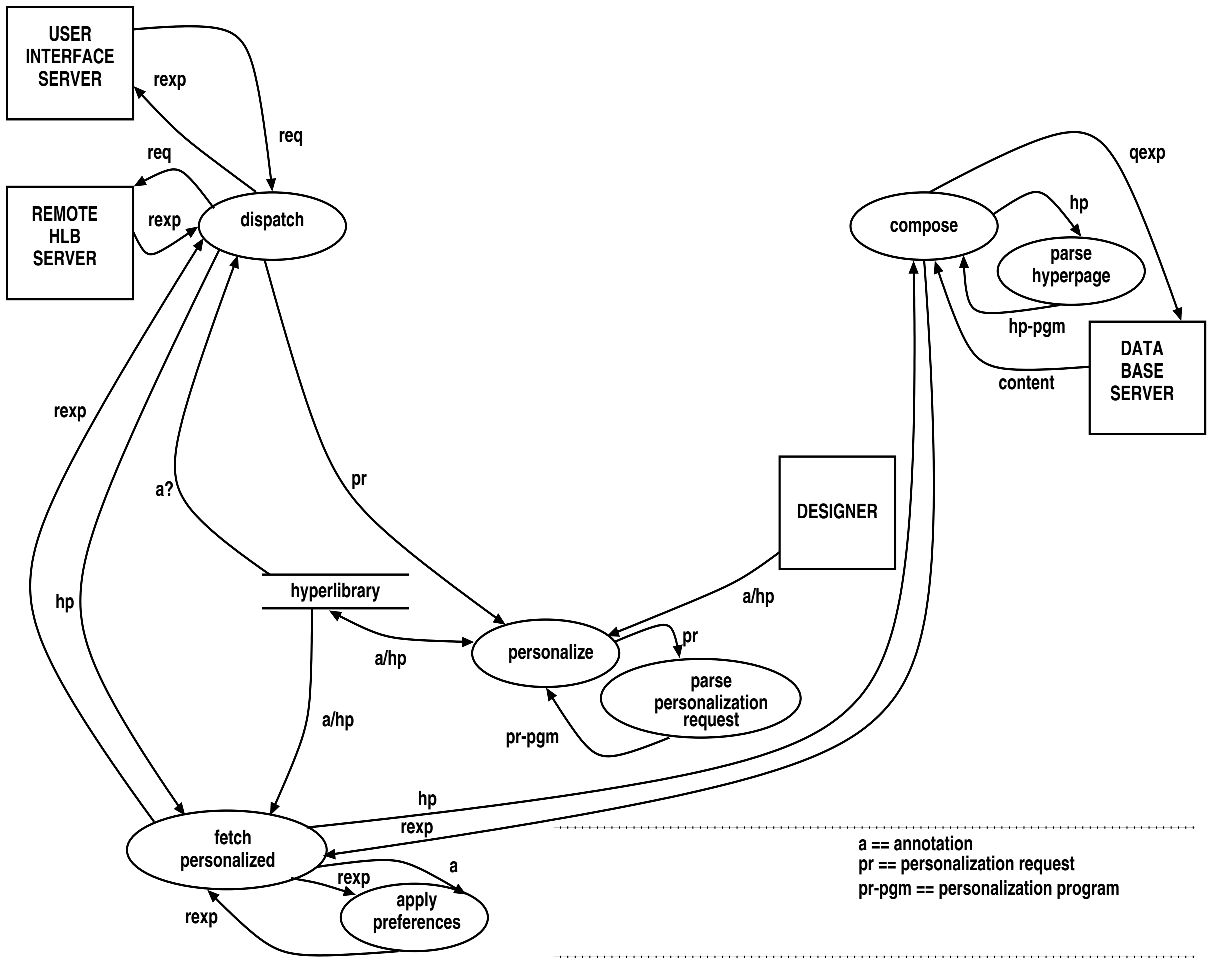
Adding the P-region allows users to create their own version of a hyperpage specification by the following initiatives:

1. **annotation**, allowing a user to pair a hyperpage specification with their own preferences as to:
   (a) **attribute assignment**, for a range of attributes which qualify designer decisions as to contents and navigation, and
   (b) **post-composition rewrite**, which enforces user preferences by rewriting the renderable text before it is returned for rendering; and
2. **personalization**, allowing a user to version a hyperpage specification by rewriting the designer specification, entirely if need be.

The existence of annotations on hyperpage specifications also allows requests for:

1. **alternatives** to a specified hyperpage;
2. **comparable** hyperpages to a specified one; and
3. **information** about a hyperpage specification (i.e., the current values of attributes set by previous annotations).

P-Region: Design



P-Region: Features

- An annotation causes a hyperpage spec to be versioned and paired with that annotation.
- The hyperpage spec/annotation pair is bound to the user who defined it.
- A personalization request that rewrites the hyperpage spec also causes versioning and binding to the user who requested it.
- If a hyperpage spec is versioned because it has been annotated, then, if a post-composition rewrite is requested, this is effected after the H-region has composed the renderable text.
- It is also open to designers to annotate hyperpage specs.

P-Region: An Example Annotation

```
annotation{
  page                          : level := 1;
  [any, chunk                  ]: keyword := 'dynamic content';
  [1, chunk                    ]: keyword := 'introduction';
  [2, chunk (C-spec)           ]: keyword := 'clusters', keyword := 'galaxies';
  [2, chunk (1, exit-point)    ]: level := 1;
  [2, chunk (any, exit-point)]: level := 5;
  [2, chunk (R-spec)           ]: keyword := 'JPEG', keyword := 'greyscale';
  [3, chunk (C-spec)           ]: keyword := 'planets', level := 5;
  [4, chunk (C-spec)           ]: level := 1;
  page                          : "center" -> "centre"
}
```

P-Region: Annotation Grammar

annotation	::=	`annotation {`
		`note`*;
		`}`

note	::=	scope attribute-assignment*,
	|	rewrite
	|	QUERY-ON-ENVIRONMENT rewrite
scope	::=	`: page` | `: [` page-part `]`
page-part	::=	relevant-chunk
	|	relevant-chunk (relevant-single-part)
	|	relevant-chunk (relevant-multi-part)
relevant-chunk	::=	shift `, chunk`
relevant-single-part	::=	`entry-point`
	|	`C-spec`
	|	`R-spec`
relevant-multi-part	::=	shift `, exit-point`
shift	::=	`any` | signed-integer
signed-integer	::=	INTEGER | sign INTEGER
sign	::=	`+` | `-`
attribute-assignment	::=	attribute := value
attribute	::=	`description` | `keyword` | `level`
	|	`see-as-well` | `see-instead`
	|	`wherefrom` | `whereto`
	|	`status`
value	::=	VALUE | entry-point* | exit-point*
rewrite	::=	scope from -> to
from	::=	*from-regular-expression*
to	::=	*to-regular-expression*

P-Region: PR Examples

```
select-page-if [any, chunk (entry-point)] contains "www.cs.gold.ac.uk"
then-do {
   [any, chunk (entry-point)]: "cs" -> "cis"
   }

select-page-if true
then-do {
   retain-if [any, chunk] contains "1998"
   }

select-page-if true
then-do {
   insert [1, chunk]: level := 1;
   }

select-page-if [any, chunk] contains "Goldsmiths"
then-do {
   insert page: keyword := "Goldsmiths College";
   }
```


```
select-page-if [any, chunk (entry-point)] contains "www.cs.gold.ac.uk"
then-do {
   [any, chunk (entry-point)]: "cs" -> "cis"
   }

select-page-if true
then-do {
   retain-if [any, chunk] contains "1998"
   }

select-page-if true
then-do {
   insert [1, chunk]: level := 1;
   }

select-page-if [any, chunk] contains "Goldsmiths"
then-do {
   insert page: keyword := "Goldsmiths College";
   }
```

P-Region: PR Grammar (1)

personalization-request	::=	transformation-scope transformation*
transformation-scope	::=	`select-page-if` cond
cond	::=	atomic-cond
	|	`not` cond
	|	cond `and` cond
	|	cond `or` cond
atomic-cond	::=	`true`
	|	atomic-cond-on-page
	|	atomic-cond-on-page-part
	|	atomic-cond-on-note
atomic-cond-on-page	::=	`page` containment-expression
atomic-cond-on-page-part	::=	page-part containment-expression
atomic-cond-on-note	::=	`note` containment-expression
containment-expression	::=	`contains` REGULAR-EXPRESSION
transformation	::=	`then-do` { annotation-transformation }
	|	`then-do` { hp-transformation }
annotation-transformation	::=	update-operator persistency-condition note
	|	note-projection
	|	attribute-assignment-set-operation
update-operator	::=	`insert` | `delete`
persistency-condition	::=	`until` QUERY-ON-ENVIRONMENT
	|	`while` QUERY-ON-ENVIRONMENT
note-projection	::=	projection-operator cond-on-note
projection-operator	::=	`drop-if` | `retain-if`
attribute-assignment-set-operation	::=	page-part set-operator page-part

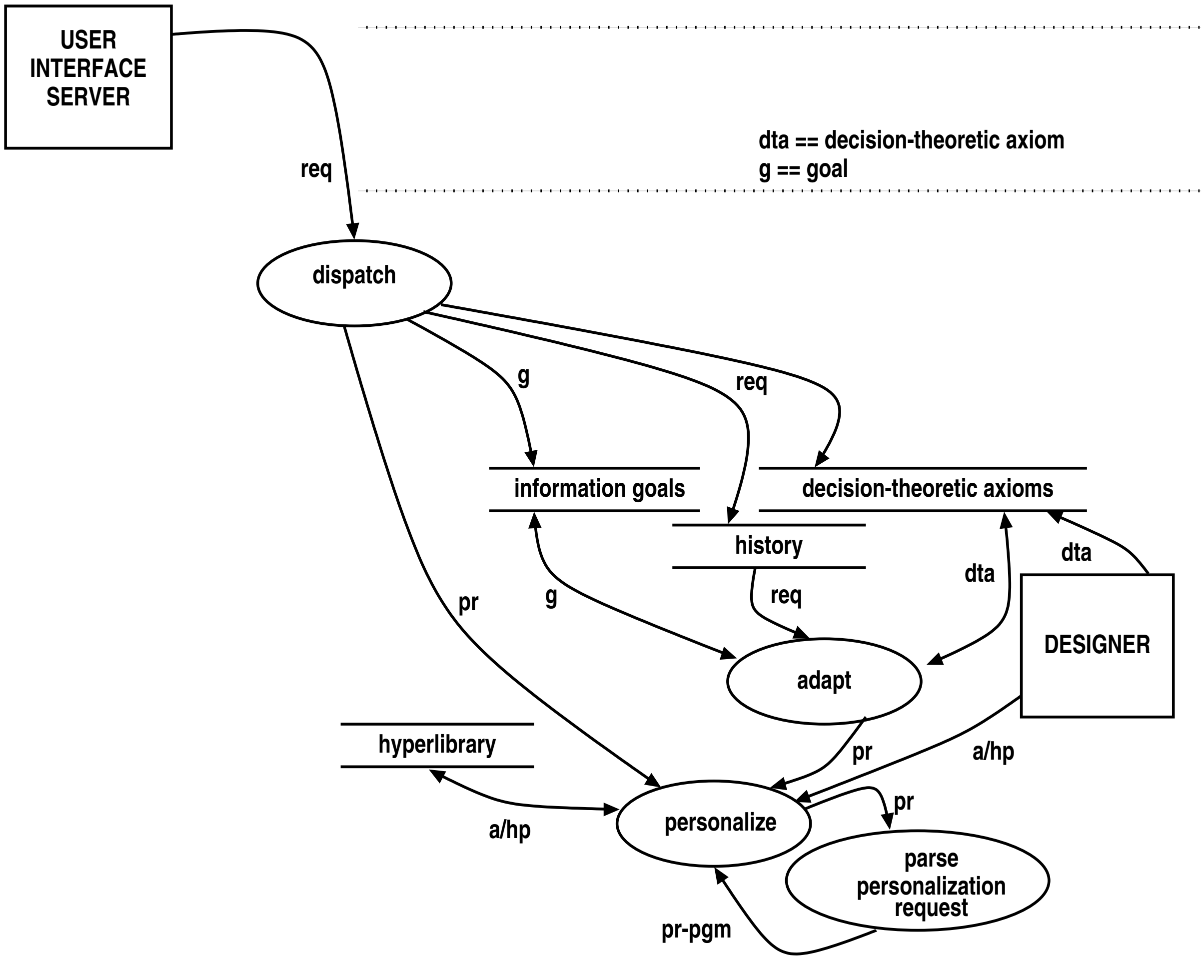
P-Region: PR Grammar (2)

set-operator	::=	`union` | `intersection` | `complement`
cond-on-note	::=	atomic-cond-on-note | `not` cond-on-note
	|	cond-on-note `and` cond-on-note
	|	cond-on-note `or` cond-on-note
hp-transformation	::=	hp-structure-transformation
	|	hp-terminal-transformation
hp-structure-transformation	::=	`insert` page-part hp-constr
	|	`delete` page-part
	|	projection-operator cond-on-hp-constr
hp-constr	::=	hyperpage | chunk | entry-point
	|	C-spec | R-spec | exit-point
cond-on-hp-constr	::=	atomic-cond-on-hp-constr |
	|	`not` cond-on-hp-constr
	|	cond-on-hp-constr `and` cond-on-hp-constr
	|	cond-on-hp-constr `or` cond-on-hp-constr
atomic-cond-on-hp-constr	::=	atomic-cond-on-chunk
	|	atomic-cond-on-chunk-part
hp-terminal-transformation	::=	rewrite

Work is in progress to give a formal semantics to personalization requests.

The approach is to formalize the meaning of a personalization request in terms of a relational algebraic expression over a relational model of the hyperlibrary.

A-Region: Design



A-Region: Features

Adding the A-region will allow [– *this is future work* —] the system to take the initiative and launch personalization requests on behalf of a user.

For this to be possible, reasoning processes are envisaged that use (at least):

1. users' **information goals** (both explicitly stated and inferred);
2. the **history** of user requests; and
3. a **decision theory** that expresses background knowledge about cause and effect relationships, strategies towards achieving information goals, etc.

Using an inductive rule engine one could infer a model of users' knowledge state, goals, preferences, etc.

Using a deductive rule engine one could decide on which courses of action offer the best learning prospects for a user.

Using an active rule engine one could then monitor opportunities for intervention, validate them against the user model, and act to personalize the interaction for the benefit of the user.

Contrasts

- Whereas most related work on adaptive hypermedia has been aimed at implementing and experimenting, the work described here is aimed at an abstract, general model of the possibilities that arise in ownership transfer.
- Whereas most implemented systems have concentrated in one application area, the work described here (although inspired by learning) can inform the development of general systems.
- Whereas most proposals ignore the problem of making design decisions explicit so as to specify when and how they can be revised, the work described here suggests how the above can be achieved.
- Whereas personalization and adaptivity have often been too loosely defined, the work described here suggests a clear, principled distinction.
- Whereas it is difficult to test the gains in effectiveness by deploying systems whose

functionality is both constrained and difficult to generalize, the work described here provides a foundation for principled exploration of the potential effectiveness of HLBSs in learning tasks.

See [Brusilovsky, Peter, *Adaptive hypermedia, an attempt to analyze and generalize.*, LNCS 1077, pp. 288-304, 1996.] for a good survey.

Limitations

Many limitations, of course, among which a few important ones are:

- the still rather low-level formalization (e.g., imperative, state-based);
- there has been no thorough investigation of a principled, well-motivated attribute set;
- personalization requests quite probably admit a more elegant expression;
- deliberately keeping an eye on the WWW (and hence, on HTML), which is perhaps not the best of models;
- deliberately no built-in knowledge of UIS and DBS languages, which means that the scope for more high-level tailoring actions is blocked.

Possibilities

A few possibilities that suggest themselves from existing limitations are:

- to move on to more modern architectures for hyperlink-based systems (e.g., those that handle link servers);
- to explore how entry and exit points can be defined by rules or constraints (approximating, e.g., the idea of generic links and anchors);
- to embed more knowledge of UIS and DBS languages into the composition function so as to open the way for more high-level tailoring actions.

Conclusions

In conclusion, this work is a first step towards:

- providing a foundation for the systematic exploration of the nature, the scope and the effect of a range of very expressive personalization and adaptivity actions in hyperlink-based systems;
- achieving greater conceptual clarity in describing personalization and adaptivity;
- preparing the ground for implemented systems that, it is hoped, will be both more expressive and more effective in achieving the objectives that led to the emergence of this research area.