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A TYPOLOGY OF ADAPTATION PATTERNS FOR EXPRESSING ADAPTIVE NAVIGATION IN ADAPTIVE HYPERMEDIA

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1 Introduction

Over the last decade, Adaptive hypermedia (AH) have been under development [8], and particularly in education [3], [9], where learners have access to personalized resources[1] according to their knowledge, preferences and goals.

The adaptation can be over the navigation, the presentation or the content of resources [1]. This acts on a defined set of resources, where their structure is known at the design time and is not going to evolve. Therefore, the author can augment the resources with additional data in order to exploit them by adaptation algorithms [**?**]. However, this particularity of AH makes that not all their possibilities can be proposed in AH using an open corpus[2], whose development is now increasing [4].

The adaptation of navigation is the adaptation which a priori does not exploit the additional data specified by the author on the available resources. Therefore, it can be defined in both adaptive hypermedia using close and open corpus. In this paper we focus on the adaptation of navigation, which is done through the definition of multiple adaptation strategies. By an adaptation strategy, we mean that *an author specifies which resources have to be proposed and how these resources will be proposed to a set of users who share the same characteristics*. We perceive an adaptation strategy as a combination of elementary parts [**?**]. Each part corresponds to an elementary adaptation and is bound to a user characteristic. A part can belong to different complex adaptation strategies depending on user characteristics. Our work takes up this idea. The notion of elementary adaptation patterns that we propose, is an abstraction of such elementary parts. Elementary adaptation patterns are independent from any application domain, but limited in a first time to express adaptive navigation. We propose a typology for the elementary adaptation patterns and a semi-automatic process to combine them (the most difficult part is done automatically).

In this paper, we present only the the typology of our elementary adaptation patterns, while the whole process of defining adaptation strategies for the adaptive navigation is described in [**?**]. The paper is organized as follows. In section **??**, we define the notion of elementary adaptation patterns that we propose. Afterwhat, in section **??** we present the syntax of the elementary adaptation patterns and followed in section **??** by the description of the associated semantic. In section **??**, we detail the typology of the elementary adaptation patterns. Finally, in section **??** we conclude the paper.

2 Definition of elementary adaptation patterns

We propose the following definition for elementary adaptation patterns, based on the definition of design patterns [7].

Definition 1: An elementary adaptation pattern describes a generic solution for a generic elementary adaptation problem.

This solution is independent from any language, and it exploits the characteristics of the domain model. We assume that a domain model may be any model composed of a set of classes, of properties and relations between classes.

Definition 2: A generic elementary adaptation problem describes a criterion to select resources to be proposed and a criterion to define in which order the selected resources are going to be proposed.

We define in the following the fundamental criteria on which the elementary adaotation patterns are based.

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1. A resource may be a document or a part of a document: XML, pdf etc

2. An AH using an open corpus, for example, can be a set of documents that is not known at design time and, moreover, can constantly change and expand [2]

2.1 Fundamental criteria for defining elementary adaptation patterns

As each part of the $S1$ strategy defined by Jane, an elementary adaptation pattern targets a set of resources of a particular type to be presented and also specifies the order in which they will be proposed. This Section presents exhaustive criteria to select resources (cf. Section 2.1.1) and to organize the selected resources (cf. Section 2.1.2).

2.1.1 Criteria used to select resources

Criteria used to select resources are based on the domain model, where resources are structured and described. We argue that the general description of a domain model includes the following elements:

- *a set of classes*. This set must contain the class representing all the resources to be proposed to users which we have called *Resource*, and the class representing all the domain concepts, which we have called *Concept*.
- *a set of relations between classes*. Each relation defines a graph on instances of classes on which it is defined. This graph can be navigated according to two different navigational paths in order to reach the goals: depth-first or breadth first.
- *a set of properties*.

Thereby, we have differentiated between criteria selecting resources and criteria defining a navigational path on relations. Our criteria for selecting resources are: their belonging to a class, the values of some properties, or the presence of a relation that defines a navigational path through the resources or the concepts graph. Furthermore, our criteria currently considered for defining a navigational path are either depth-first, breadth-first.

2.1.2 Criteria used to order the selected resources

We have looked over works defining adaptation methods, by giving a particular interest for adaptive navigation, without mattering if the methods are applied on a set of links to resources or resources themselves.

We have looked over the Brusilovsky typology (cf. Section **??**) excluding methods of the adaptive navigation support group which modify resources (e.g, hiding links belonging to content of resources). Only *direct guidance*, *adaptive ordering* and *adaptive link annotation* have been considered. We have grouped the *direct guidance* and *adaptive ordering* in one operation as both of them define a kind of order either on a link or on several links per time. Therefore, two operations are used from Brusilovsky typology.

We have also looked over the classification of external actions in AHS defined by Stash and al. [**?**]. The classification includes *actions on items* (e.g, selection, showing items or links to items), *actions on a set of items* (e.g, ordering), *hierarchical actions* (e.g, action on parent or child) and *actions on the overall environment* (e.g, changing the layout). We only consider the actions having impact on the navigation of users, this includes: *actions on items*, *actions on a set of items* and *hierarchical actions*. Furthermore, we distinguish between actions and elements on which the actions are performed. The elements can be an item, a set of items, parents or children. So, we only consider the *selection*, *show* and *order* actions. Note that, the *show* action cannot be used alone, it is necessarily combined to the other actions. But the combination of *order* and *show* actions is equivalent to the order operation defined by Brusilosvky. Therefore, we can neglect it, and retain only the combination of *select* and *show* actions,

On the other hand, we have looked over AHS implementing adaptive navigation like AHA! [**?**], WHURLE [**?**], GLAM [6] etc. We found that GLAM implements a kind of adaptation not mentioned elsewhere. This adaptation proposes alternative resources if the desired resources are not available. We find it interesting and have retained it in our own typology.

From this study, we retained two operations from Brusilovsky typology and one combination of actions from the Stash classification and one adaptation from the GLAM platform. We conclude thus that there are four basic modes to select resources in a setting of adaptive navigation support, as described below:

1 - Selection only mode

- *Description:* it provides a set of resources, which are all proposed to the user, i.e, only the selected resources are proposed to users, the other resources are not proposed.
- *Example:* we may would like to propose only definitions.
- *Comparison with existing works:* it is equivalent to the combination of the *selection and show actions* described by Stash et al. In fact, Stash et al. propose to select and show selected resources in two separate processes, while in our approach implicitly all selected resources are shown. There is no equivalent in the Brusilovsky typology.

2 - Recommend selection mode

- *Description:* it provides multiple sets of resources (at least two) that include knowledge to specify which set should be recommended rather than the other (sets of) resources.
- *Example:* in e-learning, we may recommend definitions rather than examples. The user can access both types of resources, but a typographic indication enables the user to identify which resources are recommended.

- *Comparison with existing works:* it is equivalent to the *adaptive link annotation* described by Brusilovsky, but there is no equivalent in the actions described by Stash et al.

3 - Ordered selection mode

- *Description:* it provides multiple sets of resources (at least two), accompanied with knowledge to specify the order in which they must be presented. Only one set of resources is proposed at a time, and the resources of a particular set are not proposed until all the resources of all sets of higher priority have been viewed by the user.
- *Example:* in e-learning, concepts can be selected and ordered using the prerequisite relation defined between concepts.
- *Comparison with existing works:* it is equivalent to the *adaptive ordering* and to the *direct guidance* described by Brusilovsky when the returned result includes only one resource in each set. It is also equivalent to the combination of the *order and show* actions described by Stash et al.

4 - Alternate selection mode

- *Description:* it provides multiple sets of resources (at least two), accompanied with data that specifies the order in which they must be presented, knowing that only one set is presented to the user.
- *Example:* we propose textual resources when they are available, and audio resources in the absence of textual resources.
- *Comparison with existing works:* neither Brusilosvky or Stash et al. has considered this selection mode.

3 Syntax of elementary adaptation patterns

In this section, we first describe informally the elementary adaptation patterns in the Table 1. After what, we describe the most formal characteristic, named *Solution* using the Extended Backus-Naur Form (EBNF) [11] grammar in the Table 2. The grammar includes a set of non-terminal elements expressed between brackets, and a set of terminal elements expressed between coats. For people not familiar with EBNF syntax.

Characteristic	Informal description of the characateristic
Name	the name of the elementary adaptation pattern described.
Intent	the intent is a short statement about an elementary adaptation problem. It answers the following questions: what is the elementary adaptation pattern supposed to do? i.e. what is its goal? Indeed, it indicates the way the resources are selected and the way they are presented.
Solution	the solution includes two elements: • *Expressions*: denote a set of resources to be proposed to the user, and the conditions which have to be satisfied. These conditions can be represented in one or more logical expressions. Those to be considered simultaneously are gathered in the same expression, while excluded conditions are expressed in different expressions. The formal description of expressions may be accompanied by an informal description. • *Meta-expressions*: a binary relation between two expressions. Indeed, when using multiple expressions, we specify the way they have to be considered by using meta-expressions. The formal description of meta-expressions may be accompanied by an informal description.
Constituents	describe the elements of the domain model used in the expressions described in the solution pattern.

TABLE 1: Description of elementary adaptation patterns

⟨*Solution*⟩ ::= ⟨*Expressions*⟩ ⟨*Meta-Expressions*⟩.

⟨*Expressions*⟩ ::= (⟨$Expression_{rel}$⟩)*| (⟨$Expression_{prop}$⟩)*| (⟨$Expression_{cls}$⟩)*.
⟨*Meta-expressions*⟩ ::= (⟨*Id*⟩ "$\prec$" ⟨*Id*⟩)* | (⟨*Id*⟩ "$\uplus$" ⟨*Id*⟩)* | (⟨*Id*⟩ "|" ⟨*Id*⟩)*.

⟨$Expression_{rel}$⟩ ::= ⟨*Id*⟩ ":"⟨Exp_{rel}⟩ ("$\wedge$" ⟨Exp_{rel}⟩)*.
⟨$Expression_{prop}$⟩ ::= ⟨*Id*⟩ ":"⟨Exp_{prop}⟩.
⟨$Expression_{cls}$⟩ ::= ⟨*Id*⟩ ":"⟨Exp_{cls}⟩.

⟨Exp_{rel}⟩ ::= linked "("⟨*Inst*⟩","⟨*Inst*⟩","⟨*Rel*⟩")" |
linked-transitive "("⟨*Inst*⟩","⟨*Inst*⟩","⟨*Rel*⟩")" |
distance "("⟨*Inst*⟩","⟨*Inst*⟩","⟨*Rel*⟩","⟨*Number*⟩")".

⟨Exp_{prop}⟩ ::= characteristicOf "("⟨*Res*⟩","⟨*Prop*⟩","⟨*Operator*⟩","⟨*Val*⟩")" .
⟨*Operator*⟩ ::= "=" |"$\neq$" | "$\leq$" | "$\geq$".

⟨Exp_{cls}⟩ ::= instanceOf "(" ⟨*Res*⟩","⟨*Cls*⟩")" .

⟨*Id*⟩ ::= ⟨*String*⟩.

⟨*Cls*⟩ ::= "c"⟨*Number*⟩ .
⟨*Inst*⟩ ::= "concept"⟨*Number*⟩ | ⟨*Res*⟩.

⟨*Res*⟩ ::= "resource"⟨*Number*⟩ .

⟨*Rel*⟩ ::= "r"⟨*Number*⟩ .
⟨*Prop*⟩ ::= "p"⟨*Number*⟩ .
⟨*Val*⟩ ::= (⟨*String*⟩ | ⟨*Number*⟩)+.
⟨*String*⟩ ::= ["a"-"z"] ⟨*String*⟩ * .
⟨*Number*⟩ ::= ["0"-"9"] ⟨*Number*⟩ * .

TABLE 2: Syntax of the *Solution* characteristic

4 SEMANTIC OF ELEMENTARY ADAPTATION PATTERNS

We give an informal description of the semantic of the language defined by the grammar and some associated constraints. In order to do so, we consider a domain model *DM*, composed of:

- *Cls* = {c/ c is a class}
- *Rel* = {rel/ rel is a relation}
- *Prop* = {p/ p is a property}
- Val_p = {v/ v is a value of the property p}
- *Res* = {r/ r is a resource}

We defined general elements, which we describe below.

- <*Number*>: any integer number
- <*String*>: any string
- <*Id*>: identifiers. Identifiers belonging to the same solution part have to be different
- <*Res*>: a resource
- <*Inst*>: either a concept or a resource
- <*Cls*>: a class of *DM*
- <*Rel*>: a relation of *DM*
- <*Prop*>: a property of *DM*
- <*Val*>: a value among the allowed values for the used property

We also defined predicates facilitating the selection of either resources or concepts. The predicate are:

- *instanceOf*: *instanceOf(r, c)* is true, for all resources *r* that are instances of the class *c*.

- *characteristicOf*: *characteristicOf(r, p, op, v)* is true, for all resources *r* having the property *p* and satisfying the comparison test using the operator *op* and the value *v*.
- *linked*: *linked(i1, i2, rel)* is true, for all instances *i1* that are linked directly to the instance *i2* by the relation *rel*.
- *linked-transitive*: *linked-transitive(i1, i2, rel)* is true, for all instances *i1* that are linked directly or indirectly to the instance *i2* by the relation *rel*.
- *distance*: *distance(i1, i2, rel, n)* is true, for all instances *i1* that are distant from the instance *i2* by *n* instances using the relation *rel*.

These predicates compose 3 types of expressions:

- $<Exp_{cls}>$ for expressions on classes.
- $<Exp_{prop}>$ for expressions on properties. Expressions belonging to the same solution part have to be expressed on the same property.
- $<Exp_{rel}>$ for expressions on relations. When the expression includes multiple selections, the variables indicating the selected resources have to be the same.

When more than one expression is defined in a solution, meta-expressions must be defined between all expressions of the solution. This is done using the expression identifiers. Each identifier used in the definition of a meta-expression must correspond to an expression identifier. Three types of meta-expressions are proposed. They are:

- $<Id1> \prec <Id2>$ means that the set of resources selected with the expression identified by *Id1* is proposed before the set of resources selected with the expression identified by *Id2*.
- $<Id1> \uplus <Id2>$ means that the set of resources selected with the expression identified by *Id1* is recommended rather than the set of resources selected with the expression identified by *Id2*. A typographic indication can be used to differentiate between the set of resources recommended from those they are not.
- $<Id1> \mid <Id2>$ means that the set of resources selected with the expression identified by *Id2* is an alternative of the set of resources selected with the expression identified by *Id1*.

5 Typology of elementary adaptation patterns

We have defined a library of 22 elementary adaptation patterns using the criteria defined ???. An elementary adaptation pattern is based simultaneously on (1) one of the 4 selection modes of resources to be proposed, (2) one of the 3 elements of the domain model involved in the selection process and when the element is a relation, we consider also (3) one of the 2 types of navigation through the resources or the concepts graph. The two navigation modes are applied for all the selection modes except for the *selection only* mode, which proposes a set of resources according to a particular criterion.

In order to be able to look easily over the defined elementary adaptation patterns, we have organized them in a tree where each leaf is an elementary adaptation pattern (cf. Figure 1). The tree represents our typology.

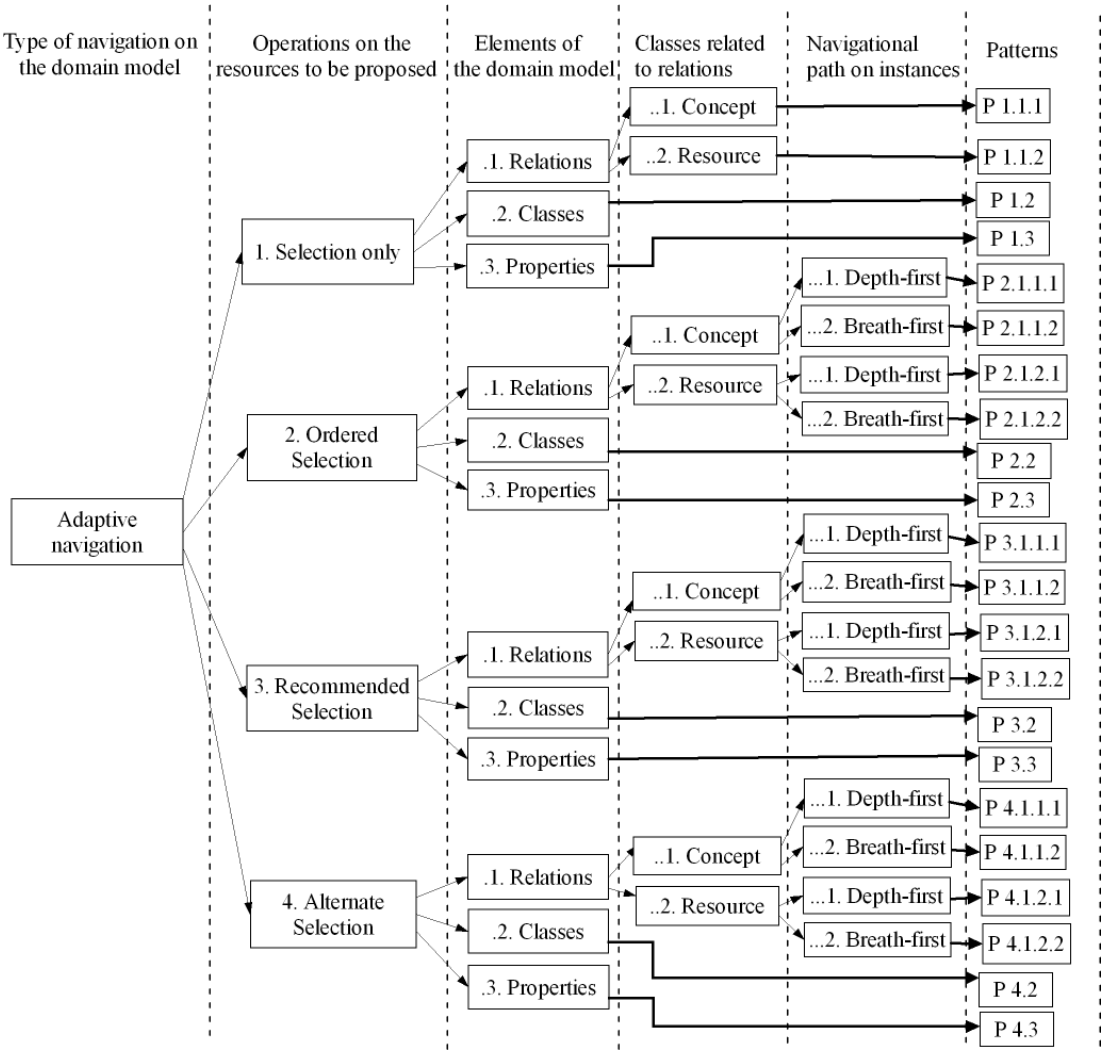

Fig. 1. Typology of elementary adaptation patterns

In the following, we describe the elementary adaptation patterns per selection mode. The Section 5.0.3, Section 5.0.4, Section 5.0.5, and Section 5.0.6 describe successively the elementary adaptation patterns that use the simple selection, ordered, recommended and alternate mode.

5.0.3 Elementary adaptation patterns using selection only mode

In the Table 3, we describe the elementary adaptation patterns using the selection only mode. It includes the elementary adaptation patterns P1.1.1, P1.1.2, P1.2 and P1.3 (cf. Figure 1).

Pattern 1.1.1
Name: Selection Only - Relation - Concept **Intent**: This pattern proposes resources that are linked to concepts by $abstraction$, and where each concept can reach the concept named *goal* directly or indirectly using $relation_i$.

Solution:

- Expression
  - *E_1: linked-transitive(concept, goal, $relation_i$) $\wedge$ linked(r, concept, $abstraction$)*

  According to E_1: selected resources are linked to concepts using $abstraction$, and these concepts are linked directly or indirectly to the $goal$ using $relation_i$.

Constituents:

- concept: a variable representing an instance of the class *Concept*.
- goal: a variable representing the goal to reach, which is an instance of the class *Concept*.
- r: a variable representing an instance of the class *Resource* or of one of its specializations.
- relation$_i$: a variable representing a relation defined between instances of the class *Concept*.
- abstraction: a variable representing a relation defined between an instance of the class *Concept* and one or more instances of the class *Resource* or of one of its specializations.

Pattern 1.1.2

Name: Selection Only - Relation - Resource
Intent: This pattern proposes resources that can reach the resource named *goal* directly or indirectly using $relation_i$.
Solution:

- Expression
  - *E_1: linked-transitive(r, goal, $relation_i$)*

  According to E_1: selected resources are linked directly or indirectly to the $goal$ using $relation_i$.

Constituents:

- goal: a variable representing the goal to reach, which is an instance of the class *Concept*.
- r: a variable representing an instance of the class *Resource* or of one of its specializations.
- relation$_i$: a variable representing a relation defined between instances of the class *Concept*.

Pattern 1.2

Name: Selection only - Classes
Intent: This pattern allows to select all resources of a specific type.
Solution:

- Expressions
  - *E_1: instanceOf (r, $Class_1$)*

  According to E_1: resources proposed to the user must be instances of the class $Class_i$

Constituents:

- r: a variable representing an instance of the class *Resource* or of one of its specializations.
- Class$_i$: a variable representing a subclass of the class *Resource*.

Pattern 1.3

Name: Selection only- particular value of a property
Intent: This pattern allows to select resources according to some values of a property.
Solution:

- Expressions
  - *E_1: characteristicOf(r, $property_i$, op, val)*

  According to E_1: selected resources must have the property $property_i$ and their value must satisfy the comparison test.

Constituents:

- r: a variable representing an instance of the class *Resource* or of one of its specializations.
- property$_i$: a variable representing a property of the class *Resource*.
- val: a variable representing a possible value for the property $property_i$.

TABLE 3: Elementary adaptation patterns using the simple selection mode

5.0.4 Elementary adaptation patterns using ordered selection mode

In the Table 4, we describe the elementary adaptation patterns using the odrdered selection mode. It includes the elementary adaptation patterns P2.1.1.1, P2.1.1.2, P2.1.2.1, P2.1.2.2, P2.2 and P2.3 (cf. Figure 1).

Pattern 2.1.1.1

Name: Ordered Selection - Depth first- Relation - Concept
Intent: This pattern proposes resources according to a depth first navigational path on concepts.

Solution:

- Expression
  - E_1: *linked(currentR, concept', $abstraction$) $\wedge$ linked-transitive(concept, goal, $relation_i$) $\wedge$ linked(r, concept, $abstraction$) $\wedge$ linked(concept, concept', $relation_i$)*
  - E_2: *linked-transitive(concept, goal, $relation_i$) $\wedge$ linked(r, concept, $abstraction$)*

  According to E_1: selected resources are linked to concepts using $abstraction$. these concepts can reach the $goal$ using $relation_i$ and are directly linked to the current concept. According to E_2: selected resources are linked to concepts using $abstraction$, these concepts can reach the $goal$ using $relation_i$.
- Meta-expressions
  - $E_1 \prec E_2$

  According to this meta-expression, the set of resources selected by E_1 is proposed before the ones selected by E_2.

Constituents:

- concept: a variable describing an instance of the class *Concept*.
- currentR: a variable describing the current instance proposed to users of the class *Resource* or of one of its specializations.
- goal: a variable describing the goal to reach, which is an instance of the class *Concept*.
- r: a variable describing an instance of the class *Resource* or of one of its specializations.
- relation$_i$: a variable describing a relation defined between instances of the class *Concept*.
- abstraction: a variable describing a relation defined between an instance of the class *Concept* and one or more instances of the class *Resource* or of one of its specializations.

Pattern 2.1.1.2

Name: Ordered Selection - Relation - Concept - breadth first
Intent: This pattern proposes resources that are linked to concepts by $abstraction$, and where each concept can reach the concept named *goal* directly or indirectly using $relation_i$ according to a depth first navigational path.
Solution:

- Expression
  - E_1: *linked-transitive(concept2, goal, $relation_i$) $\wedge$ linked(r, concept2, $abstraction$) $\wedge$ distance(concept2, origin, $relation_i$) $\wedge$ distance(concept, origin, $relation_i$) $\wedge$ linked(currentR, concept, $abstraction$)*
  - E_2: *linked-transitive(concept, goal, $relation_i$) $\wedge$ linked(r, concept, $abstraction$)*

  According to E_1: selected resources are linked to concepts using $abstraction$, these concepts are linked directly or indirectly to the $goal$ using $relation_i$ and they have the same distance of the concept which is an abstraction of the current resource from the first resource proposed to the user. According to E_2: selected resources linked to concepts using $abstraction$, and these concepts are linked directly or indirectly to the $goal$ using $relation_i$.
- Meta-expressions
  - $E_1 \prec E_2$

  According to this meta-expression, the set of resources selected by the criterion specified by E_1 is proposed before the ones selected by the criterion specified by E_2.

Constituents:

- concept: a variable representing an instance of the class *Concept*.
- goal: a variable representing the goal to reach, which is an instance of the class *Concept*.
- origin: a variable representing the first resources proposed to the user.
- r: a variable representing an instance of the class *Resource* or of one of its specializations.
- currentR: a variable representing an instance of the current resource proposed to the user.
- relation$_i$: a variable representing a relation defined between instances of the class *Concept*.
- abstraction: a variable representing a relation defined between an instance of the class *Concept* and one or more instances of the class *Resource* or of one of its specializations.

Pattern 2.1.2.1

Name: Ordered Selection - Relation - Resource - Depth-first
Intent: This pattern proposes resources that can reach the resource named *goal* directly or indirectly using $relation_i$ according to a depth first navigational path.

Solution:

- Expression
  - E_1: *linked-transitive(resource, goal,* $relation_i$*)* $\wedge$ *linked(currentR, resource,* $relation_i$*)*
  - E_2: *linked-transitive(r, goal,* $relation_i$*)*

  According to E_1: selected resources are linked directly or indirectly to the $goal$ using $relation_i$ and they are linked directly to the current resource using $relation_i$. According to E_2: selected resources are linked directly or indirectly to the $goal$ using $relation_i$.
- Meta-expressions
  - $E_1 \prec E_2$

  According to this meta-expression, the set of resources selected by the criterion specified by E_1 is proposed before the ones selected by the criterion specified by E_2.

Constituents:

- goal: a variable representing the goal to reach, which is an instance of the class *Concept*.
- r: a variable representing an instance of the class *Resource* or of one of its specializations.
- currentR: a variable representing an instance of the current resource proposed to the user.
- relation$_i$: a variable representing a relation defined between instances of the class *Concept*.

Pattern 2.1.2.2

Name: Ordered Selection - Relation - Resource - Breadth-first
Intent: This pattern proposes resources that can reach the resource named *goal* directly or indirectly using $relation_i$ according to a breadth first navigational path.
Solution:

- Expression
  - E_1: *linked-transitive(resource, goal,* $relation_i$*)* $\wedge$ *distance(resource, origin,* $relation_i$*)* $\wedge$ *distance(currentR, origin,* $relation_i$*)*
  - E_2: *linked-transitive(r, goal,* $relation_i$*)*

  According to E_1: selected resources linked directly or indirectly to the $goal$ using $relation_i$ and they have the same distance of the current resource from the first resource proposed to the user. According to E_2: selected resources linked directly or indirectly to the $goal$ using $relation_i$.
- Meta-expressions
  - $E_1 \prec E_2$

  According to this meta-expression, the set of resources selected by the criterion specified by E_1 is proposed before the ones selected by the criterion specified by E_2.

Constituents:

- goal: a variable representing the goal to reach, which is an instance of the class *Concept*.
- r: a variable representing an instance of the class *Resource* or of one of its specializations.
- currentR: a variable representing an instance of the current resource proposed to the user.
- relation$_i$: a variable representing a relation defined between instances of the class *Concept*.

Pattern 2.2

Name: Ordered Selection - Classes
Intent: This pattern proposes ordered resources belonging only to subclasses of the class Resource.
Solution:

- Expressions
  - E_1: *instanceOf (r,* $Class_1$*)*
  - ...
  - E_n: *instanceOf (r,* $Class_n$*)*

  According to Ei:selected resources are instances of the class $Class_i$
- Meta-expressions
  - $E_i \prec E_j$, i = j, i = 1..n and j = 1..n.

  According to this meta-expression, the set of resources selected by the criterion specified by E_i is proposed before the ones selected by the criterion specified by E_j (i $<$ j).

Constituents:

- r: a variable representing an instance of the class *Resource* or of one of its specializations.
- Class$_i$: a variable representing a subclass of the class *Resource*.

Pattern 2.3

Name: Ordered Selection - Properties
Intent: This pattern proposes ordered resources that satisfy some values of the property $property_i$.

Solution:

- Expressions
  - E_1: *characteristicOf(r, $property_i$, op, val_1)*
  - ....
  - E_n: *characteristicOf(r, $property_i$, op, val_n)*

  According to Ei: selected resources must have the property $property_i$ and their value must satisfy the comparison test.
- Meta-expressions
  - $E_i \prec E_j$, i < j, i = 1..n and j = 1..n.

  According to this meta-expression, the set of resources selected by the criterion specified by E_i is proposed before the ones selected by the criterion specified by E_j (i < j).

Constituents:

- r: a variable representing an instance of the class *Resource* or of one of its specializations.
- property$_i$: a variable representing a property of the class *Resource*.
- val: a variable representing a possible value for the property $property_i$.

TABLE 4: Elementary adaptation patterns using the ordered selection mode

5.0.5 Elementary adaptation patterns using recommended selection mode

In the Table 5, we describe the elementary adaptation patterns using the recommended selection mode. It includes the elementary adaptation patterns P3.1.1.1, P3.1.1.2, P3.1.2.1, P3.1.2.2, P3.2 and P3.3 (cf. Figure 1).

Pattern 3.1.1.1

Name: Recommended Selection - Relation - Concept- Depth first

Intent: This pattern proposes recommended resources that are linked to concepts by $abstraction$, and where each concept can reach the concept named *goal* directly or indirectly using $relation_i$ according to a depth-first navigational.

Solution:

- Expression
  - E_1: *linked-transitive(concept2, goal, $relation_i$) $\wedge$ linked(r, concept2, $abstraction$) $\wedge$ linked(concept, concept2, $relation_i$) $\wedge$ linked(currentResource, concept, $abstraction$)*
  - E_2: *linked-transitive(concept, goal, $relation_i$) $\wedge$ linked(r, concept, $abstraction$)*

  According to E_1: the selected resources are linked to concepts using $abstraction$, these concepts are linked directly to a concept that is an abstraction of the current resource and they are linked directly or indirectly to the *goal* using $relation_i$. According to E_2: the selected resources are linked to concepts using $abstraction$, and these concepts are linked directly or indirectly to the *goal* using $relation_i$.
- Meta-expressions
  - $E_1 \uplus E_2$

  According to this meta-expression, the set of resources selected by the criterion specified by E_1 is recommended rather than the ones selected by the criterion specified by E_2.

Constituents:

- concept: a variable representing an instance of the class *Concept*.
- goal: a variable representing the goal to reach, which is an instance of the class *Concept*.
- r: a variable representing an instance of the class *Resource* or of one of its specializations.
- currentResource: a variable representing an instance of the current resource proposed to the user.
- relation$_i$: a variable representing a relation defined between instances of the class *Concept*.
- abstraction: a variable representing a relation defined between an instance of the class *Concept* and one or more instances of the class *Resource* or of one of its specializations.

Pattern 3.1.1.2

Name: Recommended Selection - Relation - Concept - breadth first

Intent: This pattern proposes recommended resources that are linked to concepts by $abstraction$, and where each concept can reach the concept named *goal* directly or indirectly using $relation_i$ according to a depth first navigational path.

Solution:

- Expression
  - E_1: *linked-transitive(concept2, goal,* $relation_i$*)* $\wedge$ *linked(r, concept2,* $abstraction$*)* $\wedge$ *distance(concept2, origin,* $relation_i$*)* $\wedge$ *distance(concept, origin,* $relation_i$*)* $\wedge$ *linked(currentResource, concept,* $abstraction$*)*
  - E_2: *linked-transitive(concept, goal,* $relation_i$*)* $\wedge$ *linked(r, concept,* $abstraction$*)*

  According to E_1: the selected resources are linked to concepts using $abstraction$, these are linked directly or indirectly to the $goal$ using $relation_i$ and they have the same distance of the concept which is an abstraction of the current resource from the first resource proposed to the user. According to E_2: the selected resources are linked to concepts using $abstraction$, and these concepts are linked directly or indirectly to the $goal$ using $relation_i$.
- Meta-expressions
  - $E_1 \uplus E_2$

  According to this meta-expression, the set of resources selected by the criterion specified by E_1 is recommended rather than the ones selected by the criterion specified by E_2.

Constituents:

- concept: a variable representing an instance of the class *Concept*.
- goal: a variable representing the goal to reach, which is an instance of the class *Concept*.
- origin: a variable representing the first resources proposed to the user.
- r: a variable representing an instance of the class *Resource* or of one of its specializations.
- currentResource: a variable representing an instance of the current resource proposed to the user.
- relation$_i$: a variable representing a relation defined between instances of the class *Concept*.
- abstraction: a variable representing a relation defined between an instance of the class *Concept* and one or more instances of the class *Resource* or of one of its specializations.

Pattern 3.1.2.1

Name: Recommended Selection - Relation - Resource - Depth-first

Intent: This pattern proposes recommended resources that can reach the resource named *goal* directly or indirectly using $relation_i$ according to a depth first navigational path.

Solution:

- Expression
  - E_1: *linked-transitive(resource, goal,* $relation_i$*)* $\wedge$ *linked(currentResource, resource,* $relation_i$*)*
  - E_2: *linked-transitive(r, goal,* $relation_i$*)*

  According to E_1: the selected resources are linked directly or indirectly to the $goal$ using $relation_i$ and they are linked directly to the current resource using $relation_i$. According to E_2: the selected resources are linked directly or indirectly to the $goal$ using $relation_i$.
- Meta-expressions
  - $E_1 \uplus E_2$

  According to this meta-expression, the set of resources selected by the criterion specified by E_1 is recommended rather than the ones selected by the criterion specified by E_2.

Constituents:

- goal: a variable representing the goal to reach, which is an instance of the class *Concept*.
- r: a variable representing an instance of the class *Resource* or of one of its specializations.
- currentResource: a variable representing an instance of the current resource proposed to the user.
- relation$_i$: a variable representing a relation defined between instances of the class *Concept*.

Pattern 3.1.2.2

Name: Recommended Selection - Relation - Resource - Breadth-first

Intent: This pattern proposes recommended resources that can reach the resource named *goal* directly or indirectly using $relation_i$ according to a breadth first navigational path.

Solution:

- Expression
  - E_1: *linked-transitive(resource, goal,* $relation_i$*)* $\wedge$ *distance(resource, origin,* $relation_i$*)* $\wedge$ *distance(currentResource, origin,* $relation_i$*)*
  - E_2: *linked-transitive(r, goal,* $relation_i$*)*

  According to E_1: the selected resources are linked directly or indirectly to the $goal$ using $relation_i$ and they have the same distance of the current resource from the first resource proposed to the user. According to E_2: the selected resources are linked directly or indirectly to the $goal$ using $relation_i$.
- Meta-expressions
  - $E_1 \uplus E_2$

  According to this meta-expression, the set of resources selected by the criterion specified by E_1 is recommended rather than the ones selected by the criterion specified by E_2.

Constituents:

- goal: a variable representing the goal to reach, which is an instance of the class *Concept*.
- origin: a variable representing the first resources proposed to the user.
- r: a variable representing an instance of the class *Resource* or of one of its specializations.
- currentResource: a variable representing an instance of the current resource proposed to the user.
- relation$_i$: a variable representing a relation defined between instances of the class *Concept*.

Pattern 3.2

Name: Recommended Selection - Classes
Intent: This patterns proposes recommended resources according to their type.
Solution:

- Expressions
  - E_1: *instanceOf (r,* $Class_1$*)*
  - ...
  - E_n: *instanceOf (r,* $Class_n$*)*

  According to Ei: the selected resources are instances of the class $Class_i$
- Meta-expressions
  - $E_i \uplus E_j$, i < j, i = 1..n and j = 1..n.

  According to this meta-expression, the set of resources selected by the criterion specified by E_i is recommended rather than the ones selected by the criterion specified by E_j (i < j).

Constituents:

- r: a variable representing an instance of the class *Resource* or of one of its specializations.
- Class$_i$: a variable representing a subclass of the class *Resource*.

Pattern 3.3

Name: Recommended Selection - Properties
Intent: This pattern proposes resources that satisfy some values of the property $property_i$.
Solution:

- Expressions
  - E_1: *characteristicOf(r,* $property_i$ *, op,* val_1*)*
  - ....
  - E_n: *characteristicOf(r,* $property_i$ *, op,* val_n*)*

  According to Ei: The selected resources must have the property $property_i$ and their value must satisfy the comparison test.
- Meta-expressions
  - $E_i \uplus E_j$, i < j, i = 1..n and j = 1..n.

  According to this meta-expression, the set of resources selected by the criterion specified by E_i is recommended rather than the ones selected by the criterion specified by E_j (i < j).

Constituents:

- r: a variable representing an instance of the class *Resource* or of one of its specializations.
- property$_i$: a variable representing a property of the class *Resource*.
- val: a variable representing a possible value for the property $property_i$.

TABLE 5: Elementary adaptation patterns using the recommended selection mode

5.0.6 Elementary adaptation patterns using alternate selection mode

In the Table 6, we describe the elementary adaptation patterns using the alternate selection mode. It includes the elementary adaptation patterns P4.1.1.1, P4.1.1.2, P4.1.2.1, P4.1.2.2, P4.2 and P4.3 (cf. Figure 1).

Pattern 4.1.1.2

Name: Alternate Selection - Relation - Concept- Depth first
Intent: This pattern proposes alternate resources that are linked to concepts by $abstraction$, and where each concept can reach the concept named *goal* directly or indirectly using $relation_i$ according to a depth-first navigational.
Solution:

- Expression
  - E_1: *linked-transitive(concept2, goal,* $relation_i$*)* $\wedge$ *linked(r, concept2,* $abstraction$*)* $\wedge$ *linked(concept, concept2,* $relation_i$*)* $\wedge$ *linked(currentResource, concept,* $abstraction$*)*
  - E_2: *linked-transitive(concept, goal,* $relation_i$*)* $\wedge$ *linked(r, concept,* $abstraction$*)*

  According to E_1: selected resources are linked to concepts using $abstraction$, these concepts are linked directly to a concept that is an abstraction of the current resource and they are linked directly or indirectly to the $goal$ using $relation_i$. According to E_2: selected resources are linked to concepts using $abstraction$, and these concepts are linked directly or indirectly to the $goal$ using $relation_i$.
- Meta-expressions
  - $E_1 \mid E_2$

  According to this meta-expression, the set of resources selected by the criterion specified by E_1 is alternate of the ones selected by the criterion specified by E_2.

Constituents:

- concept: a variable representing an instance of the class *Concept*.
- goal: a variable representing the goal to reach, which is an instance of the class *Concept*.
- r: a variable representing an instance of the class *Resource* or of one of its specializations.
- currentResource: a variable representing an instance of the current resource.
- relation$_i$: a variable representing a relation defined between instances of the class *Concept*.
- abstraction: a variable representing a relation defined between an instance of the class *Concept* and one or more instances of the class *Resource* or of one of its specializations.

Pattern 4.1.1.2

Name: Alternate Selection - Relation - Concept - breadth first
Intent: This pattern proposes alternate resources that are linked to concepts by $abstraction$, and where each concept can reach the concept named *goal* directly or indirectly using $relation_i$ according to a depth first navigational path.
Solution:

- Expression
  - E_1: *linked-transitive(concept2, goal,* $relation_i$*)* $\wedge$ *linked(r, concept2,* $abstraction$*)* $\wedge$ *distance(concept2, origin,* $relation_i$*)* $\wedge$ *distance(concept, origin,* $relation_i$*)* $\wedge$ *linked(currentResource, concept,* $abstraction$*)*
  - E_2: *linked-transitive(concept, goal,* $relation_i$*)* $\wedge$ *linked(r, concept,* $abstraction$*)*

  According to E_1: selected resources are linked to concepts using $abstraction$, these concepts are linked directly or indirectly to the $goal$ using $relation_i$ and they have the same distance of the concept which is an abstraction of the current resource from the first resource proposed to the user. According to E_2: selected resources are linked to concepts using $abstraction$, and these concepts are linked directly or indirectly to the $goal$ using $relation_i$.
- Meta-expressions
  - $E_1 \mid E_2$

  According to this meta-expression, the set of resources selected by the criterion specified by E_1 is alternate of the ones selected by the criterion specified by E_2.

Constituents:

- concept: a variable representing an instance of the class *Concept*.
- goal: a variable representing the goal to reach, which is an instance of the class *Concept*.
- origin: a variable representing the first resources proposed to the user.
- r: a variable representing an instance of the class *Resource* or of one of its specializations.
- currentResource: a variable representing an instance of the current resource.
- relation$_i$: a variable representing a relation defined between instances of the class *Concept*.
- abstraction: a variable representing a relation defined between an instance of the class *Concept* and one or more instances of the class *Resource* or of one of its specializations.

Pattern 4.1.2.1

Name: Alternate Selection - Relation - Resource - Depth-first
Intent: This pattern proposes alternate resources that can reach the resource named *goal* directly or indirectly using $relation_i$ according to a depth first navigational path.

Solution:

- Expression
  - E_1: *linked-transitive(resource, goal,* $relation_i$*)* $\wedge$ *linked(currentResource, resource,* $relation_i$*)*
  - E_2: *linked-transitive(r, goal,* $relation_i$*)*

  According to E_1: selected resources have to be linked directly or indirectly to the $goal$ using $relation_i$ and they are linked directly to the current resource using $relation_i$. According to E_2: selected resources have to be linked directly or indirectly to the $goal$ using $relation_i$.
- Meta-expressions
  - $E_1 \mid E_2$

  According to this meta-expression, the set of resources selected by the criterion specified by E_1 is alternate of the ones selected by the criterion specified by E_2.

Constituents:

- goal: a variable representing the goal to reach, which is an instance of the class *Concept*.
- r: a variable representing an instance of the class *Resource* or of one of its specializations.
- currentResource: a variable representing an instance of the current resource.
- relation$_i$: a variable representing a relation defined between instances of the class *Concept*.

Pattern 4.1.2.2

Name: Alternate Selection - Relation - Resource - Breadth-first
Intent: This pattern proposes alternate resources that can reach the resource named *goal* directly or indirectly using $relation_i$ according to a breadth first navigational path.
Solution:

- Expression
  - E_1: *linked-transitive(resource, goal,* $relation_i$*)* $\wedge$ *distance(resource, origin,* $relation_i$*)* $\wedge$ *distance(currentResource, origin,* $relation_i$*)*
  - E_2: *linked-transitive(r, goal,* $relation_i$*)*

  According to E_1: the selected resources are linked directly or indirectly to the $goal$ using $relation_i$ and they have the same distance of the current resource from the first resource proposed to the user. According to E_2: the selected resources are linked directly or indirectly to the $goal$ using $relation_i$.
- Meta-expressions
  - $E_1 \mid E_2$

  According to this meta-expression, the set of resources selected by the criterion specified by E_1 is alternate of the ones selected by the criterion specified by E_2.

Constituents:

- goal: a variable representing the goal to reach, which is an instance of the class *Concept*.
- r: a variable representing an instance of the class *Resource* or of one of its specializations.
- currentResource: a variable representing an instance of the current resource.
- relation$_i$: a variable representing a relation defined between instances of the class *Concept*.

Pattern 4.2

Name: Alternate Selection - Classes
Intent: This patterns proposes alternative resources according to their type.
Solution:

- Expressions
  - E_1: *instanceOf (r,* $Class_1$*)*
  - ...
  - E_n: *instanceOf (r,* $Class_n$*)*

  According to Ei: selected resources must be instances of the class $Class_i$
- Meta-expressions
  - $E_i \mid E_j$, i = 1..n and j = 1..n.

  According to this meta-expression, the set of resources selected by the criterion specified by E_i is an alternative of the ones selected by the criterion specified by E_j (i $<$ j).

Constituents:

- r: a variable representing an instance of the class *Resource* or of one of its specializations.
- Class$_i$: a variable representing a subclass of the class *Resource*.

Pattern 4.3

Name: Alternate Selection - Properties
Intent: This pattern proposes alternate resources that satisfy some values of the property $property_i$.

Solution:

- Expressions
  - E_1: *characteristicOf(r, $property_i$, op, val_1)*
  - ....
  - E_n: *characteristicOf(r, $property_i$, op, val_n)*

  According to Ei: selected resources must have the property $property_i$ and their value must satisfy the comparison test.
- Meta-expressions
  - $E_i \mid E_j$, i < j, i = 1..n and j = 1..n.

  According to this meta-expression, the set of resources selected by the criterion specified by E_i is alternate of the ones selected by the criterion specified by E_j (i < j).

Constituents:

- r: a variable representing an instance of the class *Resource* or of one of its specializations.
- property$_i$: a variable representing a property of the class *Resource*.
- val: a variable representing a possible value for the property $property_i$.

TABLE 6: Elementary adaptation patterns using the alternate selection mode

6 Conclusion

In this paper, we have presented the different elementary adaptation patterns that we propose to define adaptation strategies for the adaptive navigation. They were organized in a typology in order to make easier their use and their understanding. In fact, each elementary adaptation pattern is defined according to a criteria selecting a set of resources and a criteria defining how the selected resources are going to be proposed.

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