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Identifying Optimal Service Compositions by Decomposing the Service Composition Problem

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Web Service Composition

Given:
- Repository of Web services
- Functional requirement (FR) specification θ
- Preferences over non-functional properties (NFPs)

Choose services to form a WS composition that is *most preferred* (w.r.t. NFPs) among those that satisfy FR θ

Overview of Our Solution

Central theme: Functional requirements are decomposable to simpler requirements that can be expressed in at least one existing formalism.

1. Decompose service composition problem [ECOWS 2010]
   - *atomic properties* represent discrete parts of functionality
   - total functionality is a Boolean combination of all atomic properties
2. then identify optimal composite services by:
   - eliciting and modeling preferences over NFPs
   - reasoning over preferences to find *non-dominated* composite services

Benefits

- Identifies optimal solution(s) w.r.t. non-functional properties
- More efficient than existing global search methods
- Works with any requirement specification formalism(s) and any quantitative/qualitative preference formalism(s)
- Assuming all services in repository R are compatible:
  - Algorithm is sound and weakly complete
  - Relative efficiency improves as problems grow more complex

Comparing Our Method to Others

- Alrifai and Risse [WWW 2009]
  - Decompose global NFP constraints into local constraints
  - Use mixed integer programming (MIP) to find optimal composition
- LOEM [Qi *et al.*, ICWS 2010]
  - Identify several promising services for each subtask (local optimization)
  - Enumerate all possible compositions, use MIP to make optimal choice

Alrifai & Risse, LOEM	Our Method
Focus on QoS properties only	Handles any type of NFP
Quantitative valuations only	Qualitative or quantitative valuations

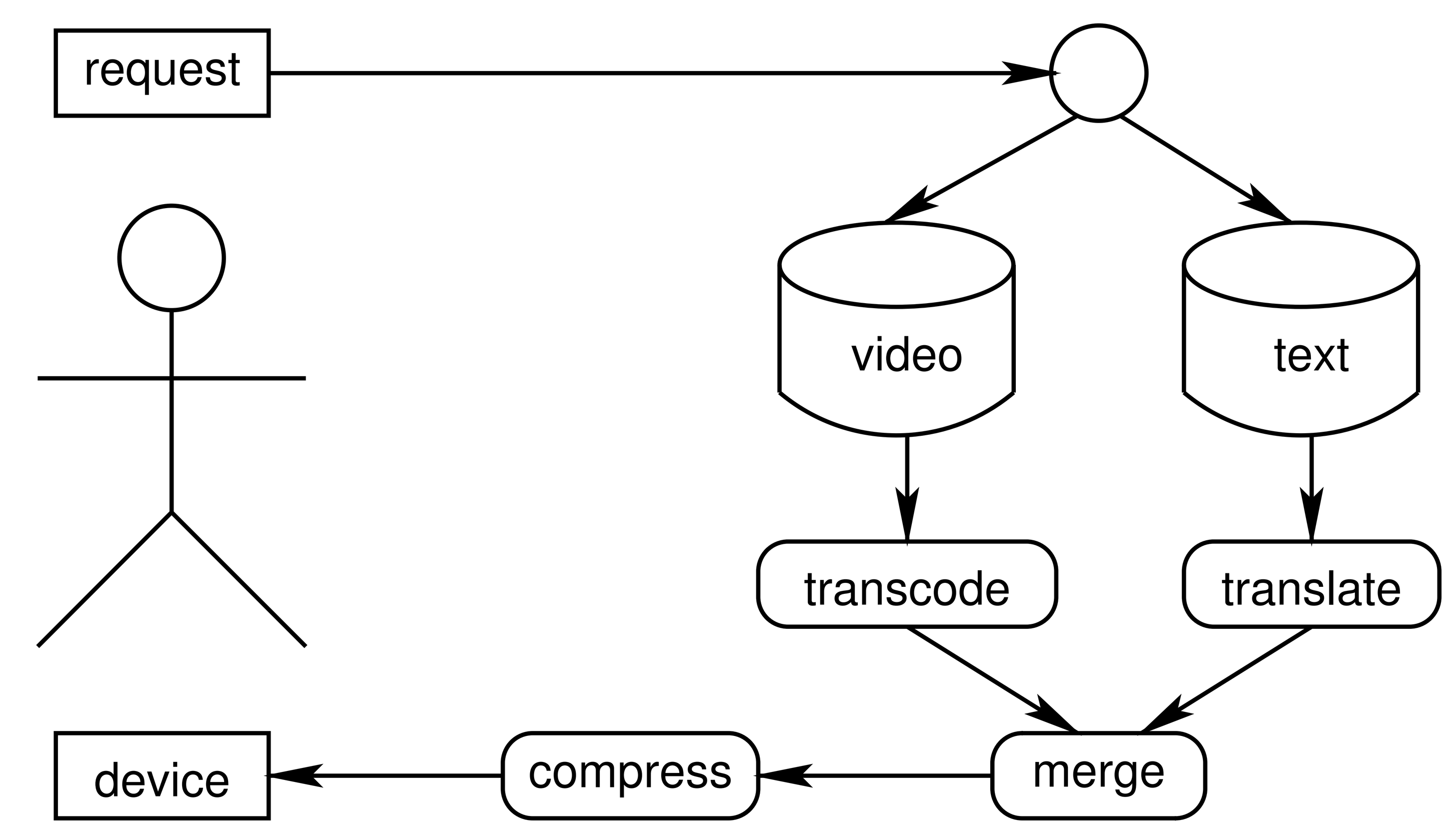
Future Directions

- Implement simulation framework for our method
- Apply our method to substitution and adaptation problems
- Experiment with different dominance relations for preference reasoning, different AND-OR tree configurations
- Generalize framework for any requirements engineering problem (softgoal preferences often determine best design)

Example: Online Multimedia Delivery [Wagner & Kellerer, ACM Multimedia 2004]

Goal: Use a Web service composition to deliver multimedia content to electronic devices over the Web

Functional Requirements



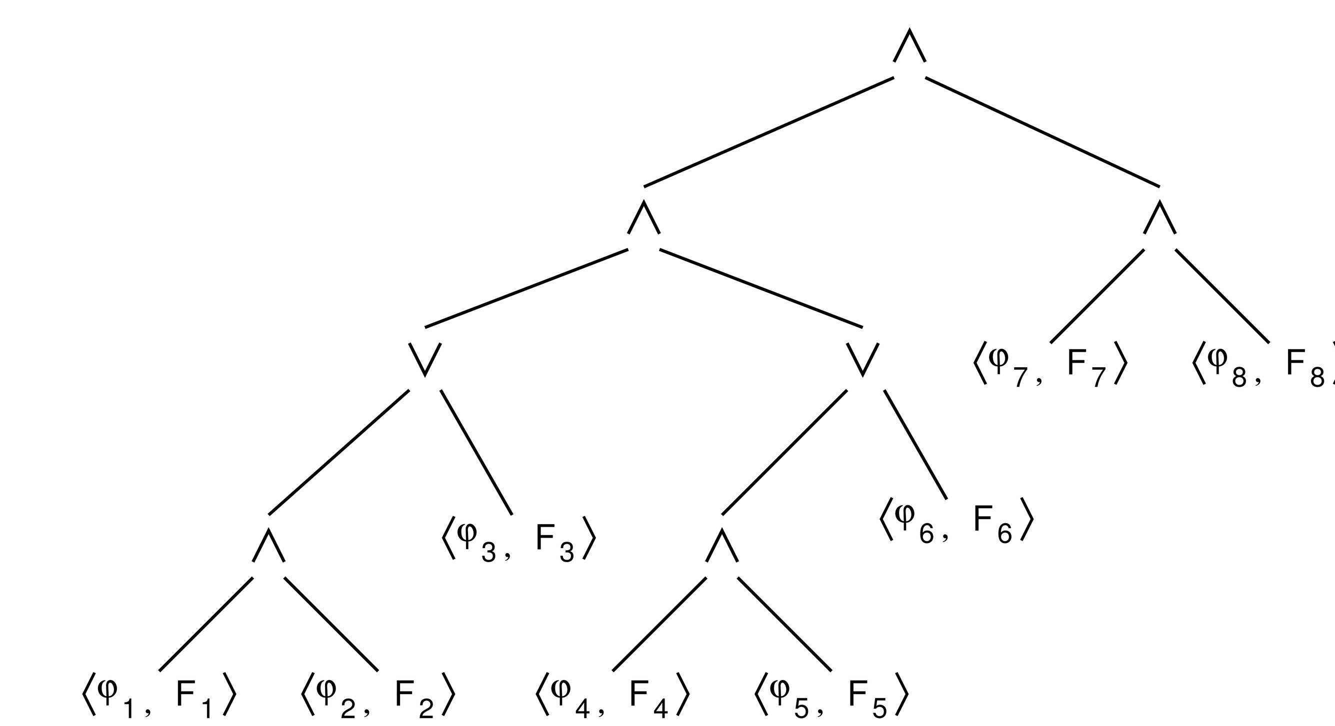
decompose into

Property	Subtask Name	Meaning
φ_1	`video`	Retrieve video content (if any) from provider
φ_2	`transcode`	Transcode content for appropriate device/network
φ_3	`video, transcode`	Retrieve *pre-transcoded* video from provider
φ_4	`text`	Retrieve text content (if any) from provider
φ_5	`translate`	Translate text content into requested language
φ_6	`text, translate`	Retrieve *pre-translated* text from provider
φ_7	`merge`	Merge video and text content into one stream
φ_8	`compress`	Compress stream in correct format for device

Boolean combinations of φ_is that satisfy overall FR θ:

$$\underbrace{(\varphi_1 \wedge \varphi_2 \wedge \varphi_4 \wedge \varphi_5 \wedge \varphi_7 \wedge \varphi_8)}_{\text{option 1}} \vee \underbrace{(\varphi_1 \wedge \varphi_2 \wedge \varphi_6 \wedge \varphi_7 \wedge \varphi_8)}_{\text{option 2}}$$

transform options into AND–OR tree



- *Atomic Property:* $\psi \doteq \langle \varphi, F \rangle$, where φ is an expression interpreted according to a formalism F, e.g., $\langle \varphi_8, F_8 \rangle = \langle A(\neg\texttt{send}\ U\ \texttt{compress}), CTL \rangle$
- *Overall FR:* Boolean combination of all atomic properties
- Can specify FRs using multiple (incompatible) formalisms

Non-Functional Properties

Attribute (Abbrev.)	Type	Domain
Cost (C)	Quantitative	Positive real numbers
Throughput (T)	Qualitative	{*Low, Medium, High*}
Reliability (R)	Qualitative	{*Low, Medium, High*}

Intra-attribute preferences between NFP valuations:
- Cost: lower preferred to higher
- Throughput/reliability: *High* preferred to *Medium*, both preferred to *Low*

Service w_i *(Pareto-)dominates* service w_j ($w_i \succ w_j$) if both:
1. w_i's valuations for every NFP are *preferred to or equal to* w_j's
2. for some NFP, w_i's valuation is *strictly preferred* to that of w_j

(other preference semantics also work with our approach)

Generating Optimal Compositions from the Decomposed Problem

Leaf Nodes: Choose Components

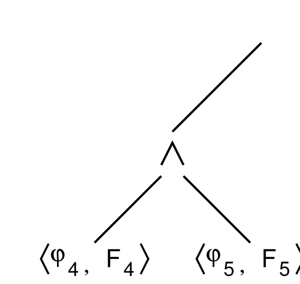
Property	Service	C	T	R
$\langle \varphi_1, F_1 \rangle$	w_{11}	0.064	H	M
	w_{12}	0.048	L	H
$\langle \varphi_2, F_2 \rangle$	w_{21}	0.060	H	H
	w_{22}	0.036	M	M
$\langle \varphi_3, F_3 \rangle$	w_{31}	0.155	M	H
	w_{32}	0.095	H	L
$\langle \varphi_4, F_4 \rangle$	w_{41}	0.010	M	M
	w_{42}	0.015	L	H
$\langle \varphi_5, F_5 \rangle$	w_{51}	0.030	M	M
	w_{52}	0.045	H	M
$\langle \varphi_6, F_6 \rangle$	w_{61}	0.082	M	H
	w_{62}	0.070	L	H
$\langle \varphi_7, F_7 \rangle$	w_{71}	0	H	H
$\langle \varphi_8, F_8 \rangle$	w_{81}	0.010	M	H
	w_{82}	0.005	H	M

For $\langle \varphi_5, F_5 \rangle$:
- Cost: $w_{51} \succ w_{52}$
- Throughput: $w_{51} \prec w_{52}$
- Reliability: $w_{51} = w_{52}$

Neither w_{51} nor w_{52} dominates; return both.

AND Nodes: Create Compositions

- Identify compositions that can be created by choosing a service from each child



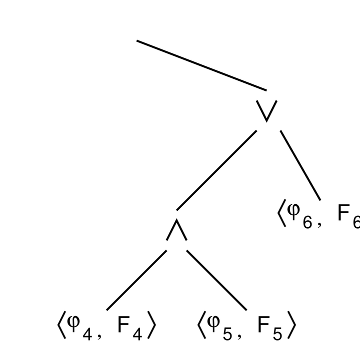
- Aggregate NFP valuations by *worst-frontier aggregation* (or other method)
- Compute non-dominated composition set, pass to parent (or return if root)

Compositions satisfying $\langle \varphi_4, F_4 \rangle \wedge \langle \varphi_5, F_5 \rangle$:

ID	Structure	C	T	R
w_{a1}	$w_{41} \otimes w_{51}$	0.040	M	M
w_{a2}	$w_{41} \otimes w_{52}$	0.055	M	M
w_{a3}	$w_{42} \otimes w_{51}$	0.045	L	M
w_{a4}	$w_{42} \otimes w_{52}$	0.060	L	M

OR Nodes: Combine Options

Service	C	T	R
$w_{a2} \doteq w_{41} \otimes w_{51}$	0.040	M	M
w_{61}	0.082	M	H
w_{62}	0.070	L	H



- Cost: $w_{a2} \succ w_{62} \succ w_{61}$
- Throughput: $w_{a2} = w_{61} \succ w_{62}$
- Reliability: $w_{62} = w_{61} \succ w_{a2}$

No service is dominated by any other service. Return all three.

Results

ID	Structure	C	T	R
w_{c1}	$w_{11} \otimes w_{22} \otimes w_{41} \otimes w_{51} \otimes w_{71} \otimes w_{82}$	0.145	M	M
w_{c2}	$w_{12} \otimes w_{21} \otimes w_{62} \otimes w_{71} \otimes w_{81}$	0.188	L	H
w_{c3}	$w_{12} \otimes w_{22} \otimes w_{41} \otimes w_{51} \otimes w_{71} \otimes w_{82}$	0.129	L	M
w_{c4}	$w_{31} \otimes w_{61} \otimes w_{71} \otimes w_{81}$	0.247	M	H
w_{c5}	$w_{32} \otimes w_{41} \otimes w_{51} \otimes w_{71} \otimes w_{82}$	0.140	M	L

These compositions are *optimal* or *most preferred*, i.e., not dominated by any other composition.

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