Network of Web services
Agenda

- Introduction
- The concept of Network of Services
- Network of Services - case study
- Model extension: Dynamic Network of Services
- Link prediction in Dynamic Networks of Services
- Conclusions
Introduction

• The SOA software paradigm leads to the creation of independently developed software components (services) which may be composed to build service applications.

• The services are composed on the basis of their functionality and the semantic compatibility of their inputs/outputs.

• For any service repository it is possible to create a graph, with nodes representing services and links representing compatibility relations.

• The network structural analysis (a prominent research topic in other areas) was recently proposed to be applied to such software networks.
Introduction

- Exemplary service description (XML – SSDL)

```xml
<?xml version="1.0" encoding="utf-8"?>
<ServiceDescription xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <physicalDescription>
    <serviceName>720p Video Encoding Service</serviceName>
  </physicalDescription>
  <functionalDescription>
    <serviceClasses>
      <serviceClass>Video Encoding</serviceClass>
    </serviceClasses>
    <description>Service compressing the video signal</description>
    <inputs>
      <input>
        <id>InputSignal</id>
        <label>input video signal</label>
        <dataType>signal</dataType>
        <class>video signal</class>
      </input>
    </inputs>
    <outputs>
      <output>
        <id>OutputSignal</id>
        <label>output video signal</label>
      </output>
    </outputs>
  </functionalDescription>
</ServiceDescription>
```
The concept of Networks of Services

- Network of Services (NoS) model – basic assumptions:
  - Network of Services is a directed graph
  - Network nodes are services
  - Semantic compatibility of inputs/outputs leads to directed relations

Exemplary network of services

First publication on the NoS:
Effective Web Service Composition in Diverse and Large-Scale Service Networks. Seog-Chan Oh, Dongwon Lee, Soundar R. T. Kumara
IEEE Transactions of Services Computing, 2008

Node degree distribution in network of services
The concept of Networks of Services

- Networks of Services – model properties and applications:
  - Networks of Services are typically scale-free networks with the structure similar to that of social networks
  - They may be analyzed using the same structural analysis methods
  - Network analysis was shown to be useful in clustering services, searching through service repositories and in the service discovery
  - Service composition may benefit from the NoS analysis as well (easing the search for services with compatible inputs/outputs)

- Typical NoS analysis approach:
  1. Create Networks of Services graph
  2. Perform structural network analysis using chosen algorithms
  3. Apply the results (in service selection, composition, optimization, ...)

PlaTel – *Platform for Planning and Monitoring of Teleinformatic Services* – is a software platform designed for service management, composition and execution:

- All PlaTel functionalities are provided *as services*
- PlaTel covers all aspects of planning, description, composition, execution and validation of services
- Configurable PlaTel applications are composite services themselves
- A native service description language is provided – Smart Service Description Language (SSDL)

PlaTel is one of the results of the research supported by the European Union within the European Regional Development Fund program no. POIG.01.03.01-00-008/08: *New SOA Information Technologies for Industry and Information Society*
NoS case study – PlaTel service repository

- One of the PlaTel’s service repositories was chosen for the NoS case study:
  - Repository contains 27 services composed to build service applications
  - Repository domain is monitoring and surveillance in an intelligent building
NoS case study – PlaTel service repository

- PlaTel offers a Web-based interface for complex service requirement definition and supports on-demand composition of services:
NoS case study – PlaTel service repository

NoS structural analysis shows that:

- Group detection algorithms may help to group services by functionalities
- Node betweenness centrality value helps to identify nodes which position in the network is important
- Node position may be used in risk assessment (for example: when service failure isolates other services from the network)

<table>
<thead>
<tr>
<th>Data Type</th>
<th>In Degree</th>
<th>Out Degree</th>
<th>Betweenness Centrality</th>
<th>Node Type</th>
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<tr>
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</table>
Model extension: Dynamic Network of Services

- There exist numerous methods and algorithms designed for the analysis of dynamic networks (where links are formed and disappear in time)
- The most known problem for dynamic networks is link prediction
- So far the dynamic network analysis was not applied to software networks
- NoS represents all possible service input-output compatibility relations
- In any time period only part of them is effectively used when the services are composed and executed
- If we create a NoS on the basis of the actual service usage, it will be dynamic, and the set of links will change in time
- This allows to apply dynamic network analysis to the NoS model
Dynamic NoS (DNoS) - model extension and application proposal:

1. Build Dynamic NoS – a series of networks created out of data from the actual service usage not only semantic compatibility (which is a static feature).
   - User queries trigger composition of complex service
   - Complex services are executed by the (PlaTel) engine
   - Temporal networks are created by relations corresponding to service input-output data flows recorded during time windows

2. Use link prediction methods to infer the future service usage and data flows

3. Relate predictions to measurable consumption of system resources (network and computational)
Model extension: Dynamic Network of Services

- Key research questions:
  - which prediction methods fit to the scenario (standard link prediction has strong social network background)?
  - how the Dynamic Network of Services may be used to reason about the dynamics of distributed service system?
  - is Dynamic Network of Services applicable to the prediction of resource consumption?
Dynamic Network of Services – link prediction experiment

Experimental setup:
PlaTel composition engine, monitoring services’ repository

- 5 users submitting service composition queries
- 9 types of service composition queries invoked ~200 times
- Queries served by the PlaTel composition engine with *exact match* semantic filter
- Link predictors used: Preferential Attachment (PA), Common Neighbors (CN), Triad Transition Matrix (TTM):
  - PA predicts new links on the premise that there is higher probability for a new link to be adjacent to a high-degree node
  - CN predicts new links on the premise that they will link nodes which have common neighbors
  - TTM uses statistical analysis of the structural changes in all three-node network subgraphs
  - The premises of PA and CN reflect network evolutionary schemes observed in social networks
- The experiment created a DNoS consisting of 50 networks corresponding to the 50 time windows, during which the data was collected
- Prediction evaluation was done using methodology proposed by Kleinberg in 2003
Dynamic Network of Services
- TTM on social networks

Prediction results for different methods on WUT dataset where time window has size 7 days

Prediction results for different methods on WUT dataset where time window has size 1 day

TTM containing the transition probabilities averaged for 9 time windows of size 7 days
Dynamic Network of Services – link prediction experiment

Predictor performance:
Conclusions

• TTM decisively outperforms the other predictors (which means that DNoS evolution is not driven by *social* evolutionary schemes)
• Methodology for choosing window timespan is needed
• There is a possibility of new approaches to the definition of network links (relations)—detailed information in WSDL and SSDL service descriptions allows to define other types of relations, different from input/output semantic compatibility
• Predictor performance:
  • TTM is promising due to domain independence
  • Social network-grounded approaches are probably useless for DNoS – our results suggest recommendation for predictors based on time series analysis, sub-graph statistics etc.
  • Computational cost is reduced for all predictors due to reduced link space: \( \sim O(n) \) instead of \( \sim O(n^2) \) – this is because in the DNoS new links may appear only between services with compatible inputs/outputs
• First experiments will be repeated on bigger DNoS of other PlaTel service repositories

→ This approach is quite novel. Related works show the *lack of papers discussing quantitative observations of working service composition frameworks* (!)
Thank you for Your attention