A Data Flow Modeling Language for WS Composition

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Outline

1. Introduction
   - Aim
   - State of the art

2. Data Flow Language
   - Syntax
   - Semantics
   - VTA Case Study

3. Future Works
Specify how messages sent to component services must be obtained from messages received from component services. e.g.:

- how several input messages must be combined to obtain an output message,
- whether an input message can be used several times or just once
- whether all messages received must be processed and sent or not
Language Aim

- Specify how messages sent to component services must be obtained from messages received from component services. 
  e.g.: 
  - how several input messages must be combined to obtain an output message, 
  - whether an input message can be used several times or just once 
  - whether all messages received must be processed and sent or not

- Specify message precedences and other requirements related to the order in which messages must be sent is not an issue of this language.
Existing Modeling Languages

Data Flow Diagrams

- ambiguous semantics
- several formalization attempts, e.g.
  - *Bruza et al., 1993*: DFD + activation possibilities $\rightarrow$ Petri Nets
  - *Larsen et al., 1993*: DFD + firing rules $\rightarrow$ VDM (Vienna Development Method)
Existing Modeling Languages

UML 2.0 Activity Diagrams

- control flow + data flow
- not clear and precise semantics
  - *Storrle et al.*, 2005:
    - AD → colored Petri-nets
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Language Components

Identity

**Syntax:** Has one input and one output channel of the same type.

**Intuitive Semantics:** It forwards data received from the input channel to the output channel.
Syntax: It is related to a function definition, has one input channel for each function parameter (the type of each channel is the same of the parameter) and only one output channel corresponding to the function result.

Intuitive Semantics: When it receives data on all the input channels, it computes the result and forwards it to the output channel.
Fork

Syntax: Has one input channel and as many output channels as necessary. All channels are of the same type.

Intuitive Semantics: It forwards data received on the input channel to all the output channels.
**Language Components**

**Syntax:** Has only one output channel and as many input channels as necessary. All channels are of the same type.

**Intuitive Semantics:** It forwards data received on some input channel to the output channel. It preserves the temporal order of data arriving on input channels (if it receives data on two or more input channels at the same time, the order is nondeterministic).
Cloner

**Syntax:** Has one input channel and one output channel and they are of the same type.

**Intuitive Semantics:** It forwards, once or more times, data received from the input channel to the output channel.
Filter

**Syntax:** Has one input channel and one output channel and they are of the same type.

**Intuitive Semantics:** When it receives data on the input channel it either forwards it to the output channel or discards it.
Syntax: Has only one output channel and as many input channels as necessary. All channels are of the same type.

Intuitive Semantics: It forwards to the output channel at most one data: the last data received on the input channels. It discards all other data received.
Language Components

Connection Node

Is used to compose different language components. Can be external or internal:

- an external connection node is associated to an output (or an input) external port and can be connected to an input (or an output) channel of the same type;
- an internal connection node connects an output channel to an input channel of the same type.
Examples

example1

example2

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Data Net

The diagram obtained by modeling the data flow requirements with the specified language is called data net.
Semantic Domain

Data Net

The diagram obtained by modeling the data flow requirements with the specified language is called data net.

Event

An event $e$ is a couple $(n, d)$, where $n$ is a connection node and $d$ is a data item, and models the fact that the data item $d$ passes through the connection node $n$;

- $node(e)$ denotes the node of event $e$
- $data(e)$ denotes the data of event $e$
Execution

An execution $\rho$ of a data net is a finite sequence of events $e_0, .. e_n$
An **execution** $\rho$ of a data net is a finite sequence of events $e_0, \ldots e_n$

- Given an execution $\rho$ we define it’s **projection** on a set of connection nodes $N$, and denote it with $\Pi_N(\rho)$, the ordered sequence $x_0, \ldots x_m$ representing the indexes in $\rho$ of all events whose node is in $N$. 
Semantic Domain

Execution

An execution $\rho$ of a data net is a finite sequence of events $e_0, .. e_n$

- Given an execution $\rho$ we define its projection on a set of connection nodes $N$, and denote it with $\Pi_N(\rho)$, the ordered sequence $x_0, .. x_m$ representing the indexes in $\rho$ of all events whose node is in $N$.

- Given an execution $\rho$, we denote with $\text{event}(\rho)[i]$ the function that returns the $i$-th event in execution $\rho$. 
Accepting execution

An execution \( \rho = e_0, \ldots, e_n \) is accepted by a data net if it satisfies all the following properties:
Semantic Mapping

Accepting execution

An execution $\rho = e_0, .., e_n$ is accepted by a data net if it satisfies all the following properties:

**Property 1**

for each Identity element in the data net

![Diagram](image)

where $\Pi\{a\}(\rho) = x_0, .., x_k$ and $\Pi\{b\}(\rho) = y_0, .., y_m$,

- $k = m$
- $data(e_{x_i}) = data(e_{y_i}), 0 \leq i \leq k$
- $y_i > x_i, 0 \leq i \leq k$
Semantic Mapping

Accepting execution

An execution $\rho = e_0, .., e_n$ is accepted by a data net if it satisfies all the following properties:

Property 1

for each Identity element in the data net

$\Pi\{a\}(\rho) = x_0, .. x_k$ and $\Pi\{b\}(\rho) = y_0, .. y_m,$

- $k = m$
- $\text{data}(e_{x_i}) = \text{data}(e_{y_i}), 0 \leq i \leq k$
- $y_i > x_i, 0 \leq i \leq k$

Accepting
- (a,1),(b,1),(a,2),(b,2)
- (a,1),(a,2),(b,1),(b,2)
- (a,1),(a,1),(b,1),(a,2),(b,1),(b,2)

NON-accepting
- (a,1),(a,2),(b,1)
- (a,1),(b,1),(a,2),(b,1)
- (a,1),(a,1),(b,1),(a,2),(b,2),(b,1)
Semantic Mapping

Accepting execution

An execution $\rho = e_0, .., e_n$ is accepted by a data net if it satisfies all the following properties:

Property 2

for each Operation element in the data net

```
  a  f  c
  b
```

where $\Pi_{\{a\}}(\rho) = x_0, .., x_m$, $\Pi_{\{b\}}(\rho) = y_0, .., y_k$, and $\Pi_{\{c\}}(\rho) = z_0, .., z_p$,

- $p = \min(m, k)$
- $data(e_{z_i}) = f(data(e_{x_i}), data(e_{y_i})), 0 \leq i \leq p$
- $z_i > \max(x_i, y_i), 0 \leq i \leq p$
Semantic Mapping

Accepting execution

An execution $\rho = e_0, \ldots, e_n$ is accepted by a data net if it satisfies all the following properties:

Property 2

for each Operation element in the data net

where $\Pi\{a\}(\rho) = x_0, \ldots x_m$, $\Pi\{b\}(\rho) = y_0, \ldots y_k$, and $\Pi\{c\}(\rho) = z_0, \ldots z_p$,

- $p = \min(m, k)$
- $\text{data}(e_{zi}) = f(\text{data}(e_{xi}), \text{data}(e_{yi})), 0 \leq i \leq p$
- $z_i > \max(x_i, y_i), 0 \leq i \leq p$

Accepting ($f=\text{sum}(x,y)$)
- (a,1),(a,2),(b,1),(b,2),(c,2),(c,4)
- (a,1),(a,2),(b,1),(c,2),(b,0),(c,2)
- (a,1),(a,2),(b,2),(c,3)

NON-accepting
- (a,1),(c,2),(b,1)
- (a,1),(a,0),(b,1),(b,2),(c,1),(c,3)
- (a,1),(b,1),(c,2),(a,2),(b,0)
Semantic Mapping

Accepting execution

An execution $\rho = e_0, \ldots, e_n$ is accepted by a data net if it satisfies all the following properties:

Property 3

for each Fork element in the data net

\[
\begin{align*}
&\text{where } \Pi_{\{a\}}(\rho) = x_0, \ldots, x_m, \quad \Pi_{\{b\}}(\rho) = y_0, \ldots, y_k, \text{ and} \\
&\Pi_{\{c\}}(\rho) = z_0, \ldots, z_p,
\end{align*}
\]

- $p = m = k$
- $\text{data}(e_{z_i}) = \text{data}(e_{x_i}) = \text{data}(e_{y_i}), \ 0 \leq i \leq p$
- $y_i, z_i > x_i, \ 0 \leq i \leq p$
Accepting execution

An execution $\rho = e_0, .., e_n$ is accepted by a data net if it satisfies all the following properties:

Property 3

for each Fork element in the data net

\[ a \to \begin{array}{c} \bullet \\ \bullet \\ \bullet \end{array} b \\
\]
\[ \bullet \to \begin{array}{c} \bullet \\ \bullet \\ \bullet \end{array} c \]

where $\Pi_{\{a\}}(\rho) = x_0, ..x_m$, $\Pi_{\{b\}}(\rho) = y_0, ..y_k$, and $\Pi_{\{c\}}(\rho) = z_0, ..z_p$,

- $p = m = k$
- $data(e_{zi}) = data(e_{xi}) = data(e_{yi})$, $0 \leq i \leq p$
- $y_i, z_i > x_i$, $0 \leq i \leq p$
Semantic Mapping

Accepting execution

An execution $\rho = e_0, \ldots, e_n$ is accepted by a data net if it satisfies all the following properties:

Property 4

for each $\textbf{Merge}$ element in the data net

where $\Pi_{\{a,b\}}(\rho) = x_0, \ldots, x_m$ and $\Pi_{\{c\}}(\rho) = y_0, \ldots, y_k$,

- $m = k$
- $data(e_{x_i}) = data(e_{y_i}), 0 \leq i \leq p$
- $y_i > x_i, 0 \leq i \leq p$
Accepting execution

An execution $\rho = e_0, \ldots, e_n$ is accepted by a data net if it satisfies all the following properties:

**Property 4**

for each **Merge** element in the data net

where $\Pi_{\{a,b\}}(\rho) = x_0, \ldots, x_m$ and $\Pi_{\{c\}}(\rho) = y_0, \ldots, y_k$,

1. $m = k$
2. $\text{data}(e_x) = \text{data}(e_y)$, $0 \leq i \leq p$
3. $y_i > x_i$, $0 \leq i \leq p$

Accepting
- (a,1),(a,2),(c,1),(b,1),(c,2),(c,1)
- (a,1),(b,0),(c,1),(a,2),(c,0),(c,2)

NON-accepting
- (a,1),(b,0),(c,1)
- (a,1),(b,0),(c,0),(c,1)
- (c,1)
Accepting execution

An execution $\rho = e_0, \ldots, e_n$ is accepted by a data net if it satisfies all the following properties:

Property 5

for each Cloner element in the data net

\[
\begin{array}{c}
\vdots \\
\bullet \\
\vdots \\
\end{array}
\]

where $\Pi_{\{a\}}(\rho) = x_0, \ldots, x_m$ and $\Pi_{\{b\}}(\rho) = y_0, \ldots, y_p$,

- $p \geq m$
- there exist $j^0, \ldots, j^{m+1}$ s.t. $j^0 = 0$, $j^{m+1} = p + 1$, $j^i > j^{i-1}$ and $\text{data}(e_{x_i}) = \text{data}(e_{y_k})$, $j^i \leq k < j^{i+1}$
Semantic Mapping

Accepting execution

An execution $\rho = e_0, .., e_n$ is accepted by a data net if it satisfies all the following properties:

Property 5

for each Cloner element in the data net

\[
\begin{align*}
&\text{where } \Pi_{\{a\}}(\rho) = x_0, ..x_m \text{ and } \Pi_{\{b\}}(\rho) = y_0, ..y_p, \\
&p \geq m \\
&\text{there exist } j^0, ..j^{m+1} \text{ s.t. } j^0 = 0, j^{m+1} = p + 1, \\
&j^i > j^{i-1} \text{ and } data(e_{x_i}) = data(e_{y_k}), j^i \leq k < j^{i+1}
\end{align*}
\]
Semantic Mapping

Accepting execution

An execution \( \rho = e_0, .., e_n \) is accepted by a data net if it satisfies all the following properties:

**Property 6**

for each Filter element in the data net

\[
\begin{align*}
& \quad \quad \quad \quad \quad a \quad ? \quad b \\
\end{align*}
\]

where \( \Pi_{\{a\}}(\rho) = x_0, .. x_m \) and \( \Pi_{\{b\}}(\rho) = y_0, .. y_p \),

- \( p \leq m \)
- there exist \( j^0, .. j^p \) s.t. \( j^i > j^{i-1} \) and \( data(e_{x_{j^i}}) = data(e_{y_i}), 0 \leq i \leq p \)
Semantic Mapping

Accepting execution

An execution $\rho = e_0, .., e_n$ is accepted by a data net if it satisfies all the following properties:

Property 6

for each Filter element in the data net

\[
\begin{array}{cc}
\text{a} & \text{?} & \text{b} \\
\end{array}
\]

where $\Pi_{\{a\}}(\rho) = x_0, .. x_m$ and $\Pi_{\{b\}}(\rho) = y_0, .. y_p$,

- $p \leq m$
- there exist $j^0, .. j^p$ s.t. $j^i > j^{i-1}$ and $data(e_{x_{j^i}}) = data(e_{y_{j^i}})$, $0 \leq i \leq p$

Accepting

- (a,1),(a,2),(b,1),(b,2)
- (a,1),(a,2),(b,1)
- (a,1),(a,0),(a,2),(b,2)

NON-accepting

- (a,1),(a,2),(b,1),(b,1)
- (a,1),(b,0),(a,0)

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A Data Flow Modeling Language for WS Composition
Semantic Mapping

Accepting execution

An execution $\rho = e_0, .., e_n$ is accepted by a data net if it satisfies all the following properties:

**Property 7**

for each Last element in the data net

where $\Pi_{\{a,b\}}(\rho) = x_0, ..x_m$ and $\Pi_{\{c\}}(\rho) = y_0, ..y_k$,

- $k = 0$
- $y_0 > x_m$
- $data(e_{y_0}) = data(e_{x_m})$
Semantic Mapping

Accepting execution

An execution $\rho = e_0, .., e_n$ is accepted by a data net if it satisfies all the following properties:

Property 7

for each Last element in the data net

Accepting

- $(a,1),(a,0),(b,1),(b,2),(c,2)$
- $(a,1),(a,2),(b,1),(c,1)$

NON-accepting

- $(a,1),(c,1),(b,1),(c,1)$
- $(a,1),(a,0),(b,1)$
- $(a,1),(b,0),(c,1)$

where $\Pi_{\{a,b\}}(\rho) = x_0, ..x_m$ and $\Pi_{\{c\}}(\rho) = y_0, ..y_k$,

- $k = 0$
- $y_0 > x_m$
- $\text{data}(e_{y_0}) = \text{data}(e_{x_m})$
### WS Composition Model

#### State Transition System (STS)

A state transition system $\Sigma$ is a tuple $\langle S, S^0, I, O, R, L \rangle$ where:

- $S$ is the finite set of states;
- $S^0 \subseteq S$ is the set of initial states;
- $I$ is the finite set of input actions;
- $O$ is the finite set of output actions;
- $R \subseteq S \times (I \cup O \cup \{\tau\}) \times S$ is the transition relation;
- $L : S \rightarrow 2^{Prop}$ is the labeling function.

- $P_{in} \times V$ and $P_{out} \times V$;
- $P_{in} i$ and $P_{out} i$;
- $a = (p, v)$ models the receiving/sending of a value $v$ on a particular service port $p$ if $a = (p, v) \in I \cup O$, then we write $\text{port}(a)$ for the port component $p$, and $\text{value}(a)$ for the value component $v$, of $a$.

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State Transition System (STS)

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- $S$ is the finite set of states;
- $S^0 \subseteq S$ is the set of initial states;
- $I$ is the finite set of input actions;
- $O$ is the finite set of output actions;
- $R \subseteq S \times (I \cup O \cup \{\tau\}) \times S$ is the transition relation;
- $L : S \rightarrow 2^{Prop}$ is the labeling function.

- $I = P^{in} \times V$ and $O = P^{out} \times V$;
  - $P^{in} = \bigcup P^{in}_i$ and $P^{out} = \bigcup P^{out}_i$
  - $a = (p, v)$ models the receiving/sending of a value $v$ on a particular service port $p$
  - if $a = (p, v) \in I \cup O$, then we write $\text{port}(a)$ for the port component $p$, and $\text{value}(a)$ for the value component $v$, of $a$
Recall some def..

1. $a \in (\mathcal{I} \cup \mathcal{O} \cup \{\tau\})$ is applicable on a state $s \in S$ if there exists a state $s' \in S$ s.t. $(s, a, s') \in R$;
2. $s \in S$ is final if no action $a \in (\mathcal{I} \cup \mathcal{O} \cup \{\tau\})$ is applicable in $s$;
3. a (finite) word $w$ is an element of $(\mathcal{I} \cup \mathcal{O} \cup \{\tau\})^*$, i.e., a finite sequence $a^0, \ldots, a^n$ of actions.
4. a run $\sigma$ of $\Sigma$ on a (finite) word $w=a^0, \ldots, a^{n-1}$ is a sequence $s^0, \ldots, s^n$ of states in $S$ such that, $s^0 \in S^0$, and $\langle s^i, a^i, s^{i+1} \rangle \in R$, $0 \leq i < n$; the run $\sigma$ is accepting if $s^n$ is a final state.
5. $w$ is accepted by $\Sigma$ if $\Sigma$ has an accepting run on $w$. 

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A Data Flow Modeling Language for WS Composition
Data Net Satisfiability

Let $\Sigma$ be a STS and $\mathcal{D}$ a data net. We say that $\Sigma$ satisfies $\mathcal{D}$, denoted with $\Sigma \models \mathcal{D}$, when for each word $w$ accepted by $\Sigma$, there exists an execution $\rho$ accepted by $\mathcal{D}$ such that:

- $n \leq m$;
- there exist $j^0, ..j^n, j^i > j^{i-1}$, s.t. $data(e_{j^i}) = value(a_i)$ and $extport(node(e_i)) = port(a_i)$;
- the number of output actions in $w$ is equal to the number of events in $event(\rho)[\Pi_{NO}(\rho)]$;

where $a_0, ..a_n = w|I\cup O$ and $e_0, ..e_m = event(\rho)[\Pi_{Next}(\rho)]$.
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3 Future Works
The VTA Case Study

Flight Service Protocol

Flight Input Ports
- f.request.date
- f.request.loc

Flight Output Ports
- f.offer.cost
- f.offer.schedule
- f.booked.info
The VTA Case Study

Hotel Service Protocol

Hotel Input Ports
- h.request.date
- h.request.loc

Hotel Output Ports
- h.offer.cost
- h.offer.hotel_info

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The VTA Case Study

AllMaps Service Protocol

START

? request(from_loc, to_loc)

! info(map)

SUCCESS

AllMaps Input Ports

m.request.from_loc
m.request.to_loc

AllMaps Output Ports

m.info.map

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A Data Flow Modeling Language for WS Composition
The VTA Case Study

Customer Service Protocol

Customer Input Ports
- c.f_offer.cost
- c.f_offer.schedule
- c.h_offer.cost
- c.f_offer.hotel
- c.f_offer.dist_map
- c.booked.cost
- c.booked.info

Customer Output Ports
- c.request.date
- c.request.loc

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The VTA Case Study

- C.request.date
- C.request.loc
- H.offer.cost
- F.offer.cost
- F.offer.schedule
- H.offer.info
- F.booked.info
- M.info.map
- F.request.date
- F.request.loc
- H.request.loc
- C.h_offer.cost
- C.booked.cost
- C.f_offer.cost
- H.request.date
- H.offer.date
- C.f_offer.schedule
- M.request.from_loc
- M.request.to_loc
- C.h_offer.hotel
- C.booked.info
- C.h_offer.dist_map
- C.h_offer.dist_map
The VTA Case Study

C.request.date -> F.request.date

C.request.loc -> F.request.loc -> H.request.loc

H.offer.cost

F.offer.cost

F.offer.schedule

F.booked.info

M.request.from_loc

M.request.to_loc

M.info.map

C.booked.cost

C.h_offer.cost

H.offer.info

C.f_offer.cost

C.f_offer.schedule

C.booked.info

C.h_offer.hotel

C.h_offer.dist_map
The VTA Case Study

C.request.date → ! → F.request.date
C.request.loc → L → H.request.loc
H.offer.cost → C.h_offer.cost
F.offer.cost → C.booked.cost → C.f_offer.cost
F.offer.schedule
H.offer.info
F.booked.info
M.info.map

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A Data Flow Modeling Language for WS Composition
The VTA Case Study

C.request.date → ! → F.request.date

C.request.loc → F.request.loc

H.offer.cost → C.h_offer.cost

F.offer.cost → C.booked.cost

F.offer.schedule → C.f_offer.schedule

M.request.from_loc → M.request.to_loc

H.offer.info → C.h_offer.hotel

F.booked.info → C.booked.info

M.info.map → C.h_offer.dist_map
The VTA Case Study

C.request.date → ! → F.request.date
C.request.loc → ! → F.request.loc → H.request.loc
H.offer.cost → ! → C.h_offer.cost
F.offer.cost → ! → prep_cost → C.booked.cost
F.offer.schedule → ! → get_date → H.request.date
F.booked.info → ! → C.f_offer.schedule
M.request.from_loc → get_airport → M.request.to_loc
H.offer.info → ! → M.request.from_loc
F.booked.info → ! → prep_info → C.booked.info
M.info.map → ! → prep_info

Prep_cost
Get_date
Get_airport
Get_loc
Prep_info
C.h_offer.dist_map
Future Works

- extend the composition framework to support the specification of data flow requirements in the composition goal
- develop a tool supporting the specification of data flow requirements
- extend the modeling language to support the specification of control flow requirements and complex termination conditions