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ACI-MD Analyse Globalisée des Images Radiologiques

Data composition patterns in service-based workflows

Johan Montagnat, I3S team, CNRS

Tristan Glatard, I3S team CNRS/INRIA Asclepios

Diane Lingrand, I3S team, CNRS

CNRS — I3S sophia antipolis — INRIA

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Introduction

- **Data parallel applications**
  - Many scientific applications
  - Well suited for exploiting distributed infrastructures
  - Workflow engines ease to transparently exploit parallelism
- **Data composition patterns in workflows**
  - Data-intensive workflows description
  - Expressiveness problem. Trade-off between:
    - Compactness / representation simplicity
    - Flexibility
- **Problem**
  - Define a clear semantics for data composition inside a workflow

Job submission vocabulary

- **Task-based approach** — **Global computing**
  - Each job submitted is a **task**
  - Requires a job description language
    - To define: I/O data, executable, command line...
  - Middlewares examples: GLOBUS, LCG2, gLite... batch computing
- **Service-based approach** — **Meta computing**
  - Each job is a **service**
  - Requires a standard invocation interface (Web Service, GridRPC)
    - Input/Ouput data are parameters for the service
    - The service is a 'black box' hidding the submission infrastructure
    - Very flexible
  - Example middlewares: DIET, Ninf, Netsolve...

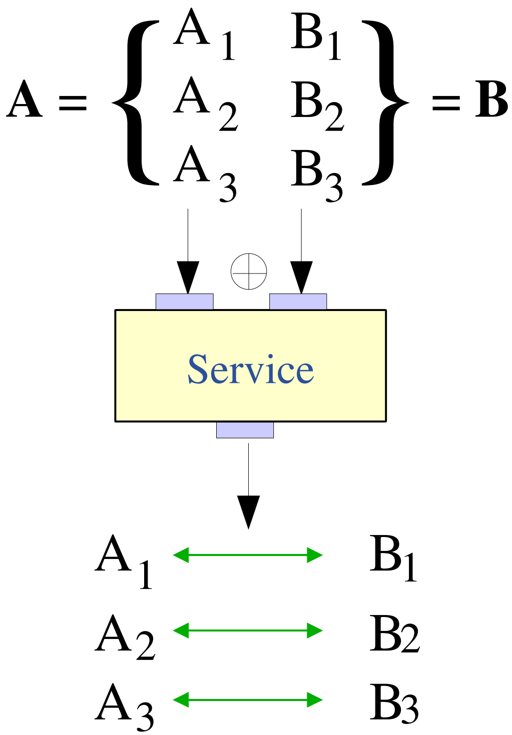
Workflow managers

- **Workflow description**
  - Business workflows (*e.g.* BPEL)
    - Control-centric
  - Scientific workflows (*e.g.* Scufl)
    - Data-centric
- **Workflow execution**
  - **Task-based** workflows (*e.g.* DAGMan) ← **CS friendly**
    - Explicit mention of data dependencies
    - Complex workflow, simple optimisation
  - **Service-based** workflows (*e.g.* Taverna, Triana, Kepler, MOTEUR)
    - Independent expression of processors and input data-sets
    - Simple workfkows, complex optimisation ← **user friendly**

Data composition strategies

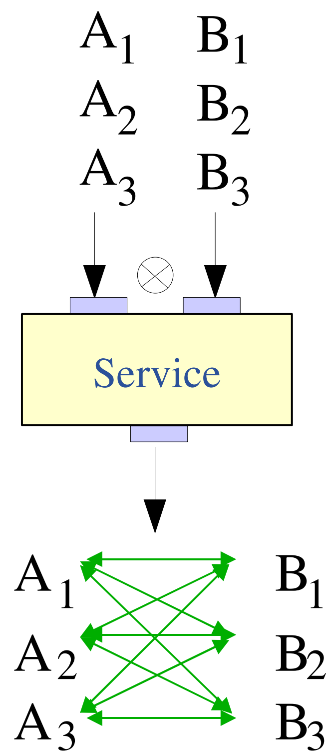
- **Data composition patterns : data intensive applications**

One-to-one



$$\mathbf{A} \oplus \mathbf{B} = \{A_1 \oplus B_1, A_2 \oplus B_2, \ldots\}$$

All-to-all

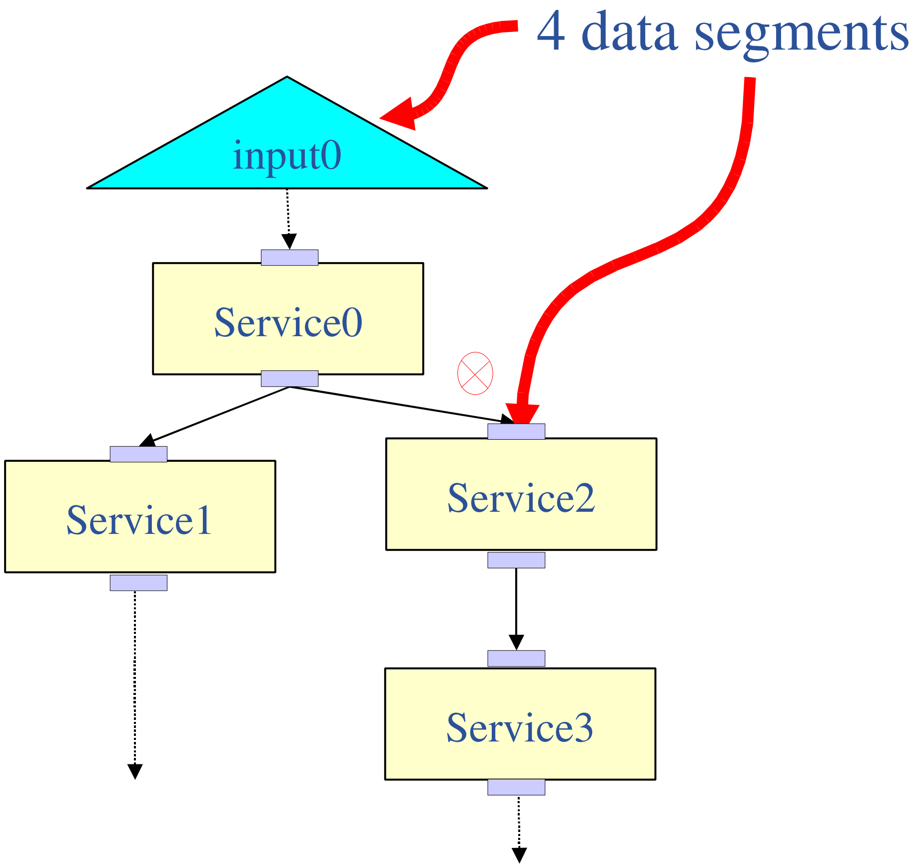


$$\mathbf{A} \otimes \mathbf{B} = \{A_1 \otimes B_1, A_1 \otimes B_2 \ldots A_1 \otimes B_m, A_2 \otimes B_1 \ldots A_2 \otimes B_m \ldots \ldots A_n \otimes B_1 \ldots A_n \otimes B_m\}$$

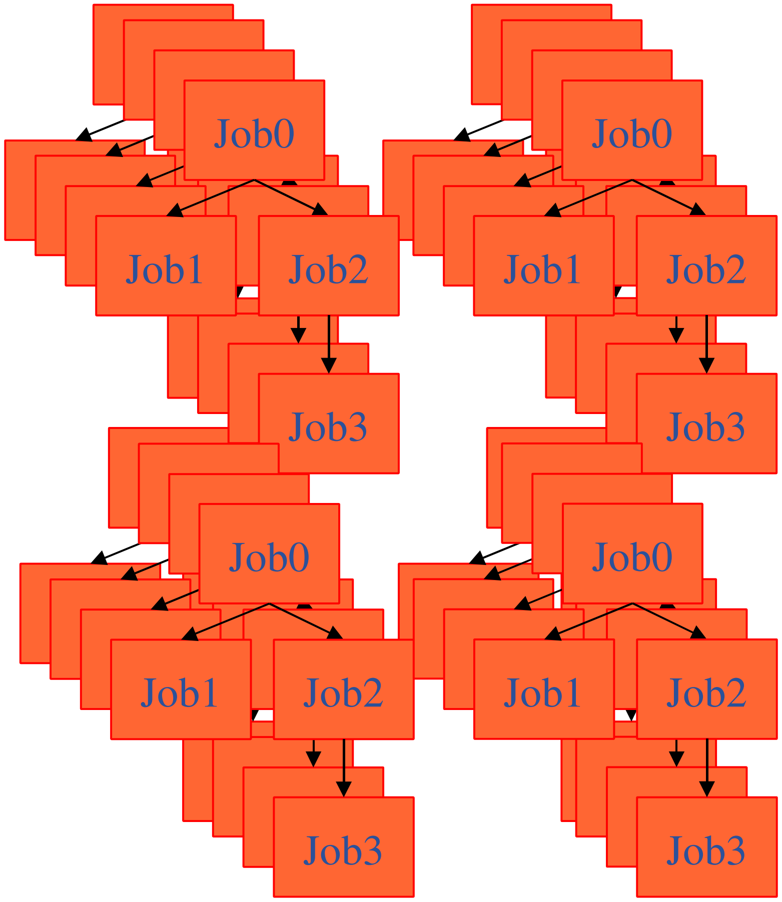
Combinatorial data composition

- **Service-based approach versus task-based approach**

Graph of services

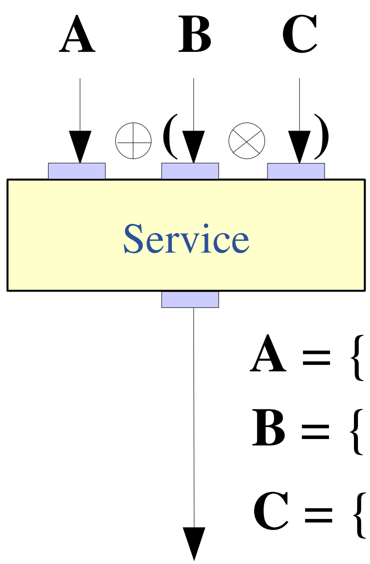


DAG of tasks



Ternary operator

- **Explicit priority (parenthesized expression)**

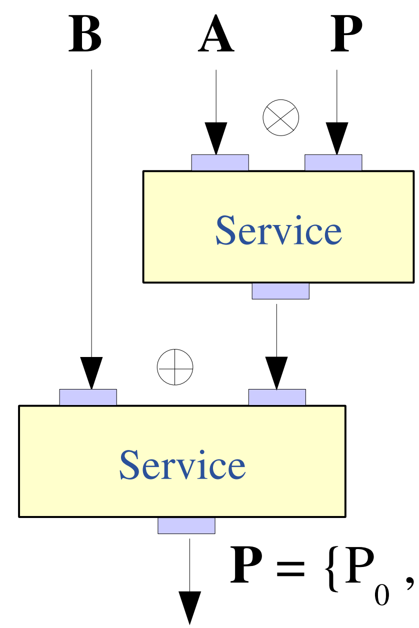


$\mathbf{A} = \{A_0, A_1\}$

$\mathbf{B} = \{B_0, B_1\}$

$\mathbf{C} = \{C_0, C_1, C_2\}$

$$\mathbf{A}\oplus(\mathbf{B}\otimes\mathbf{C}) = \left\{ \begin{array}{ll} A_0 \oplus (B_0 \otimes C_0), & A_1 \oplus (B_1 \otimes C_0), \\ A_0 \oplus (B_0 \otimes C_1), & A_1 \oplus (B_1 \otimes C_1), \\ A_0 \oplus (B_0 \otimes C_2), & A_1 \oplus (B_1 \otimes C_2) \end{array} \right\}$$



$\mathbf{P} = \{P_0, P_1, P_2\}$

$$\mathbf{B}\oplus(\mathbf{A}\otimes\mathbf{P}) = \left\{ \begin{array}{ll} B_0 \oplus (A_0 \otimes P_0), & B_1 \oplus (A_1 \otimes P_0), \\ B_0 \oplus (A_0 \otimes P_1), & B_1 \oplus (A_1 \otimes P_1), \\ B_0 \oplus (A_0 \otimes P_2), & B_1 \oplus (A_1 \otimes P_2) \end{array} \right\}$$

Data composition in different languages

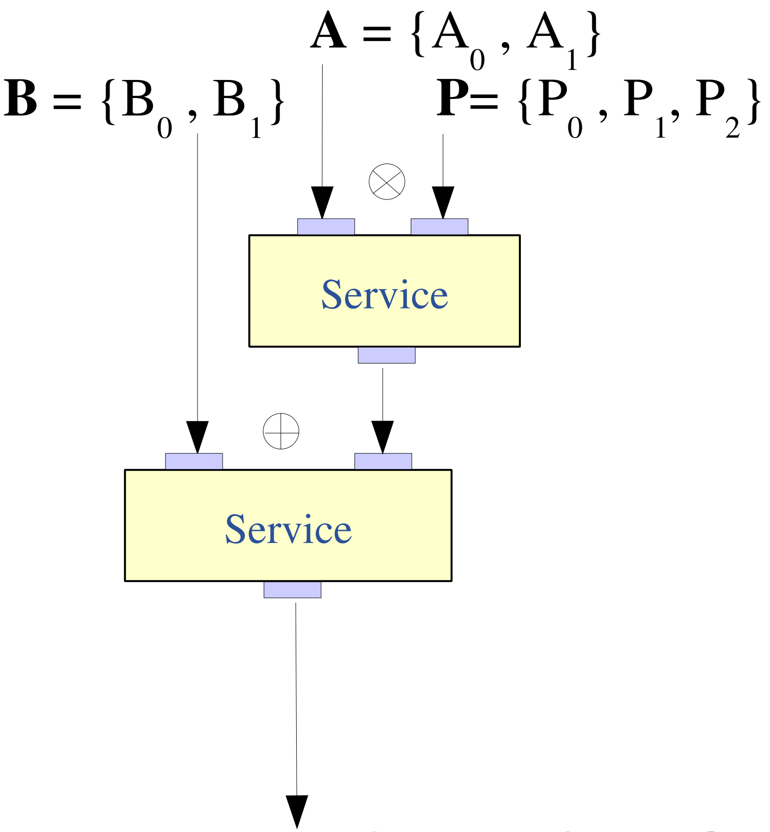
- **Taverna**
  - One-to-one (dot product) and all-to-all (cross product) operators included in Scufl
  - One-to-one composition results in processing the *min(#**A**, #**B**)* of compositions
  - Based on sequential order
- **Kepler**
  - One-to-one composition
  - Implemented a new actor for all-to-all semantics with the PN director (require work-arounds)
- **Triana**
  - One-to-one composition

MOTEUR workflow manager

- **Efficient workflow enactment**
  - Interfaced to a grid infrastructure (distributed computing)
  - Transparently exploits application (data+service+workflow) parallelism
  - Special emphasis on data-parallelism
- **Includes data composition patterns**
  - Use the Scufl description language
  - Implements the one-to-one composition semantics described in this paper
- **Where?**
  - http://www.i3s.unice.fr/~glatard
- **How?**
  - CeCILL (French-GPL) license

Taverna semantic

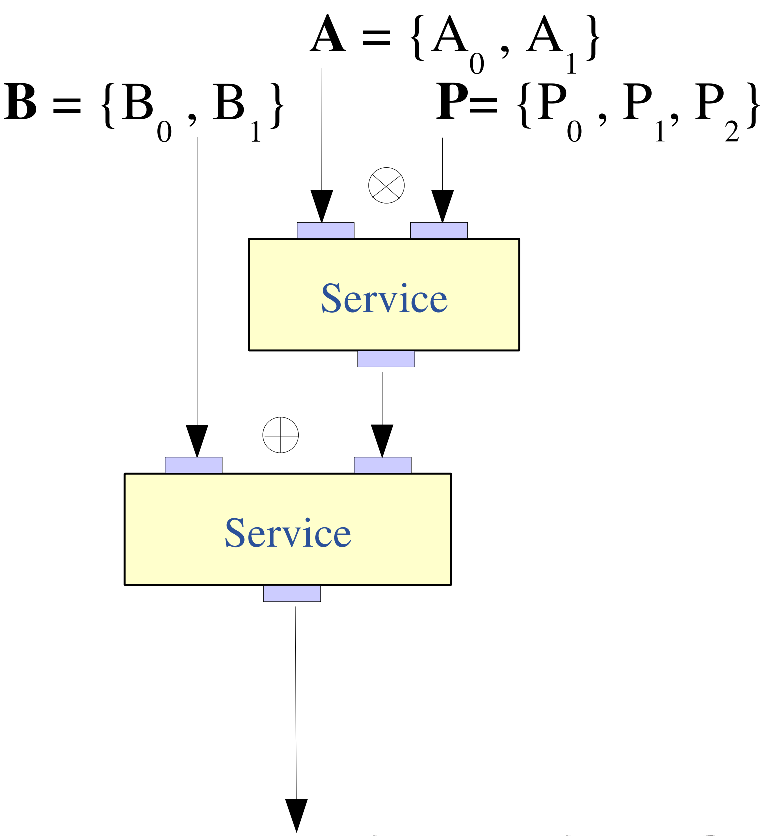
- **Sequential order semantic**

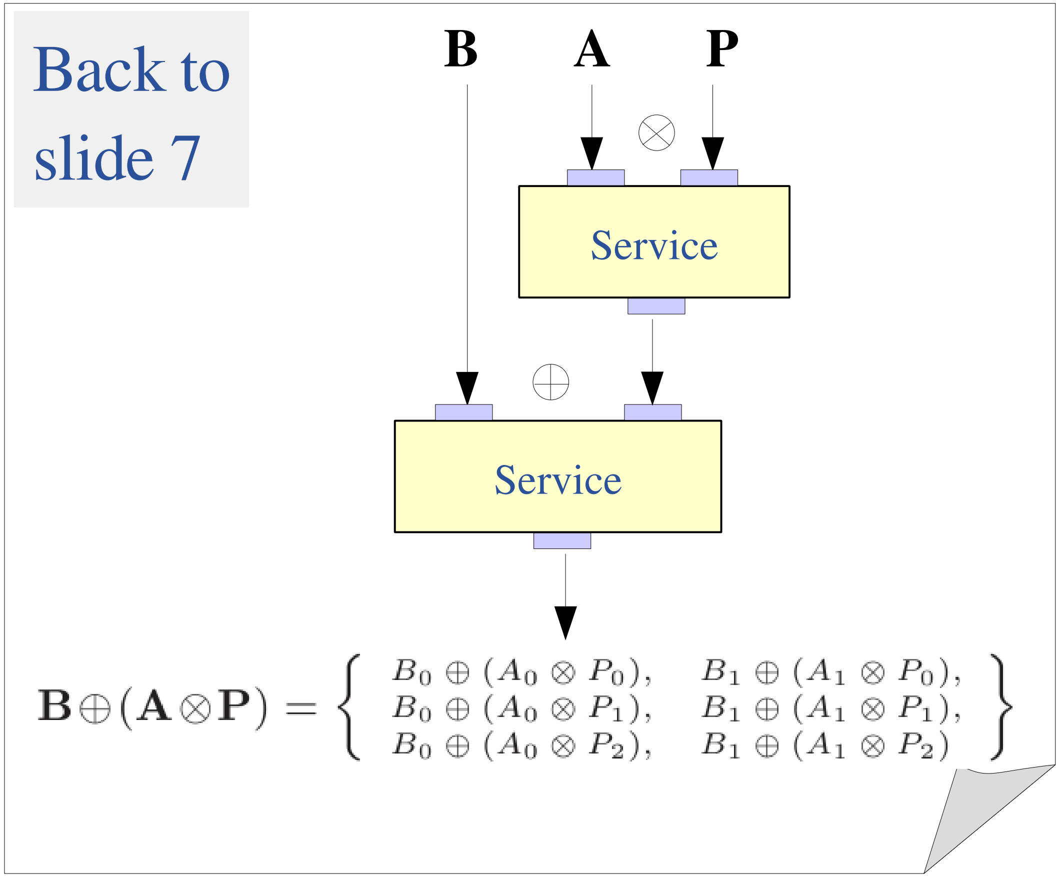


$$\mathbf{B} \oplus_{\text{Taverna}} (\mathbf{A} \otimes \mathbf{P}) = \{ \; B_0 \oplus (A_0 \otimes P_0), \quad B_1 \oplus (A_1 \otimes P_0) \; \}$$

Different semantics?

- **Sequential order semantic**





$$\mathbf{B} \oplus_{\text{Taverna}} (\mathbf{A} \otimes \mathbf{P}) = \{ \; B_0 \oplus (A_0 \otimes P_0), \quad B_1 \oplus (A_1 \otimes P_0) \; \}$$

One-to-one composition semantic?

- **One-to-one composition makes sense if data sets are correlated**

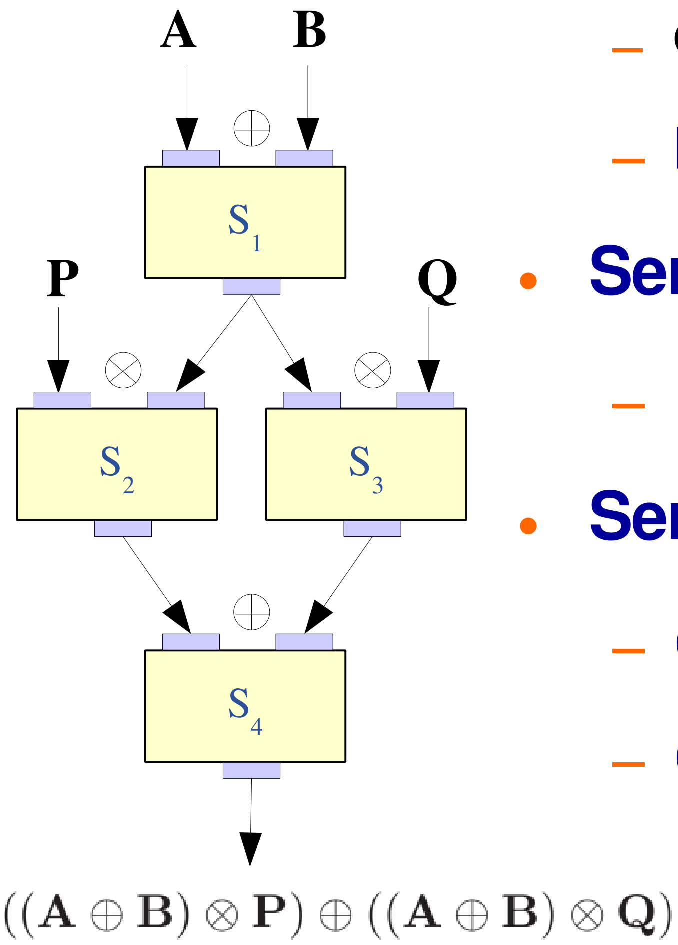
$$\mathbf{B} \oplus (\mathbf{A} \otimes \mathbf{P}) = \left\{ \begin{array}{ll} B_0 \oplus (A_0 \otimes P_0), & B_1 \oplus (A_1 \otimes P_0), \\ B_0 \oplus (A_0 \otimes P_1), & B_1 \oplus (A_1 \otimes P_1), \\ B_0 \oplus (A_0 \otimes P_2), & B_1 \oplus (A_1 \otimes P_2) \end{array} \right\}$$

if A and B are correlated (application dependent, user defined)

  - Sequential order may be relevant (but not reliable in case of a data- and service-parallel workflow enactor)
  - Our hypothesis: explicit description of correlated data sets, or sequential order (default behavior)

- **No unique answer: depends on application expressiveness needs**

Explicit correlation through groups



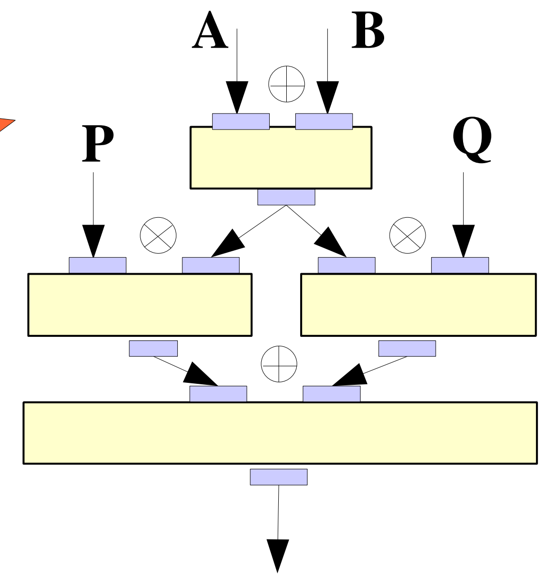
- **The user defines correlation groups:**
  - $\mathbf{G} = \{(A_0, B_0), (A_1, B_1), \ldots\}$
  - No relation between A_i and P_k
- **Service S_1:**
  - $\oplus$ composition: A_i and B_j combined iff i=j
- **Service S_4:**
  - $(A_i \oplus B_i) \otimes P_k$ and $(A_j \oplus B_j) \otimes Q_m$ combined iff i=j
  - $((A_i \oplus B_i) \otimes P_k) \oplus ((A_i \oplus B_i) \otimes Q_m)$ for all k and m

Algorithm

- Implement the semantics for any workflow graph

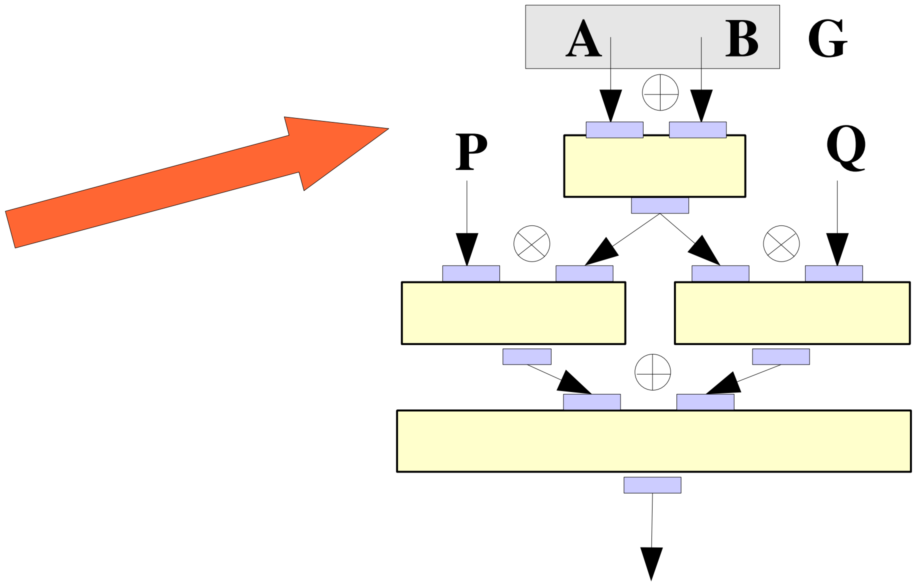
Algorithm

1. **Build the workflow directed graph**

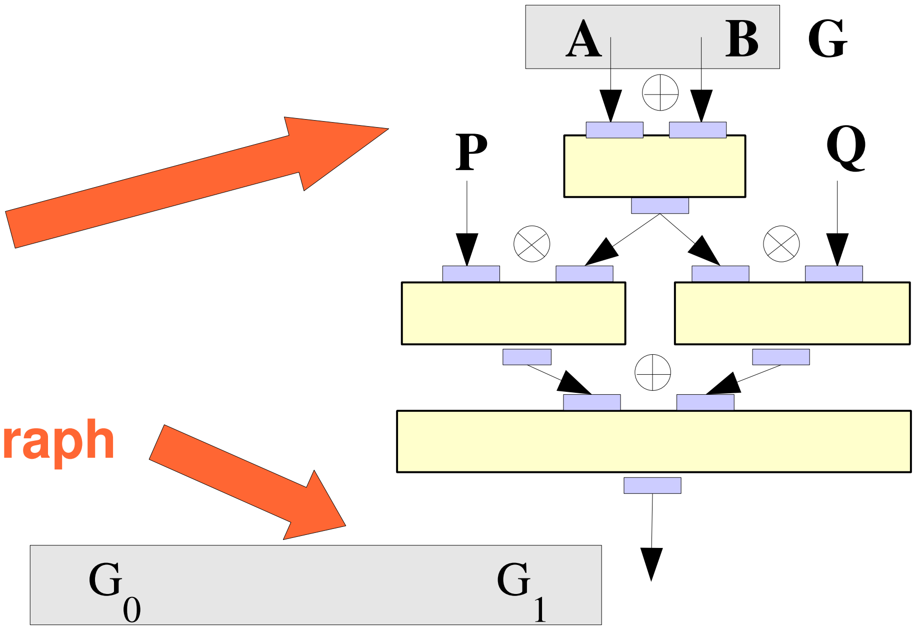


Algorithm

1. **Build the workflow directed graph**
2. **Add data groups to this graph**



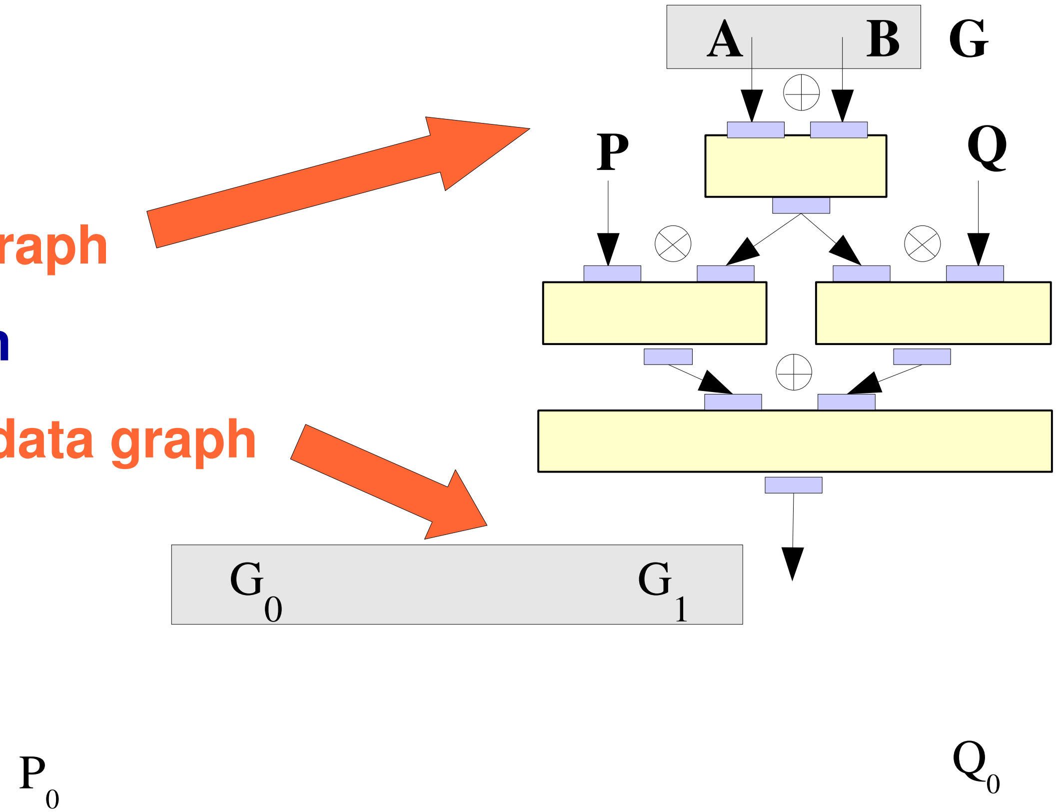
Algorithm



1. **Build the workflow directed graph**
2. **Add data groups to this graph**
3. **Initialize the directed acyclic data graph**
   1. Create root nodes from groups

Algorithm

1. **Build the workflow directed graph**
2. **Add data groups to this graph**
3. **Initialize the directed acyclic data graph**
   1. Create root nodes from groups
   2. Root nodes for orphan data



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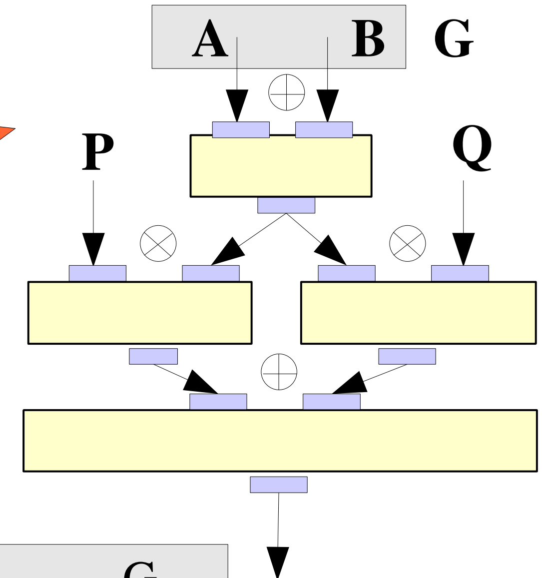
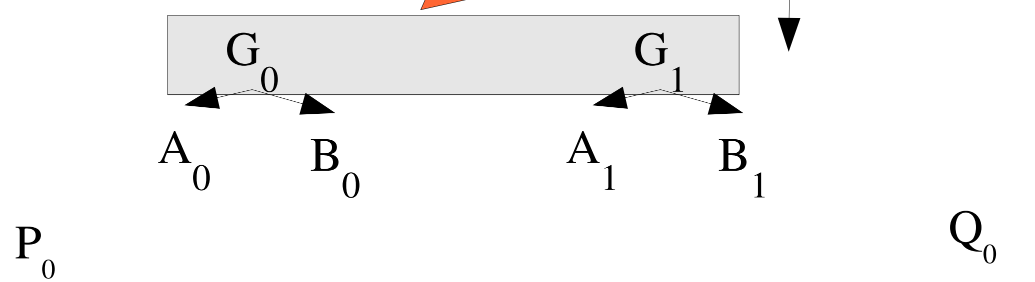
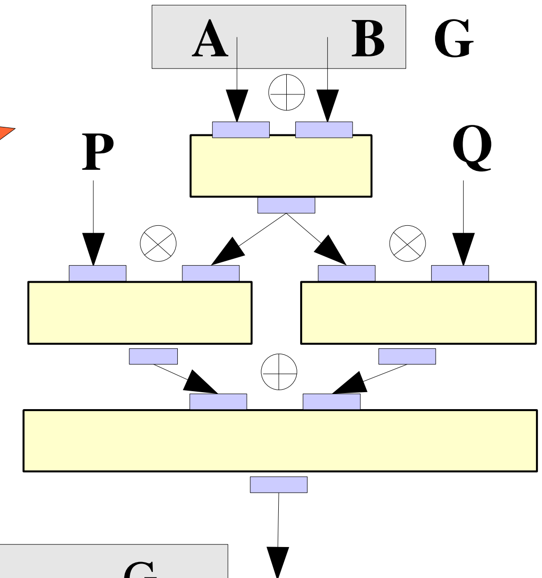
Algorithm

1. **Build the workflow directed graph**
2. **Add data groups to this graph**
3. **Initialize the directed acyclic data graph**
   1. Create root nodes from groups
   2. Root nodes for orphan data
4. **Start workflow execution**





Algorithm



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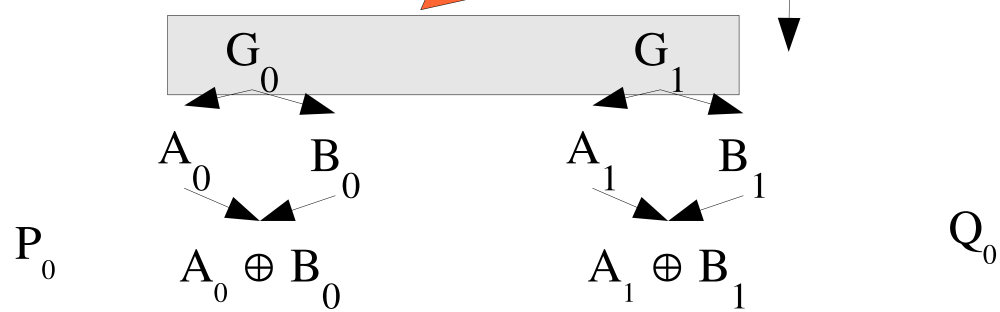
5. **At each service invokation**
    1. Update data graph



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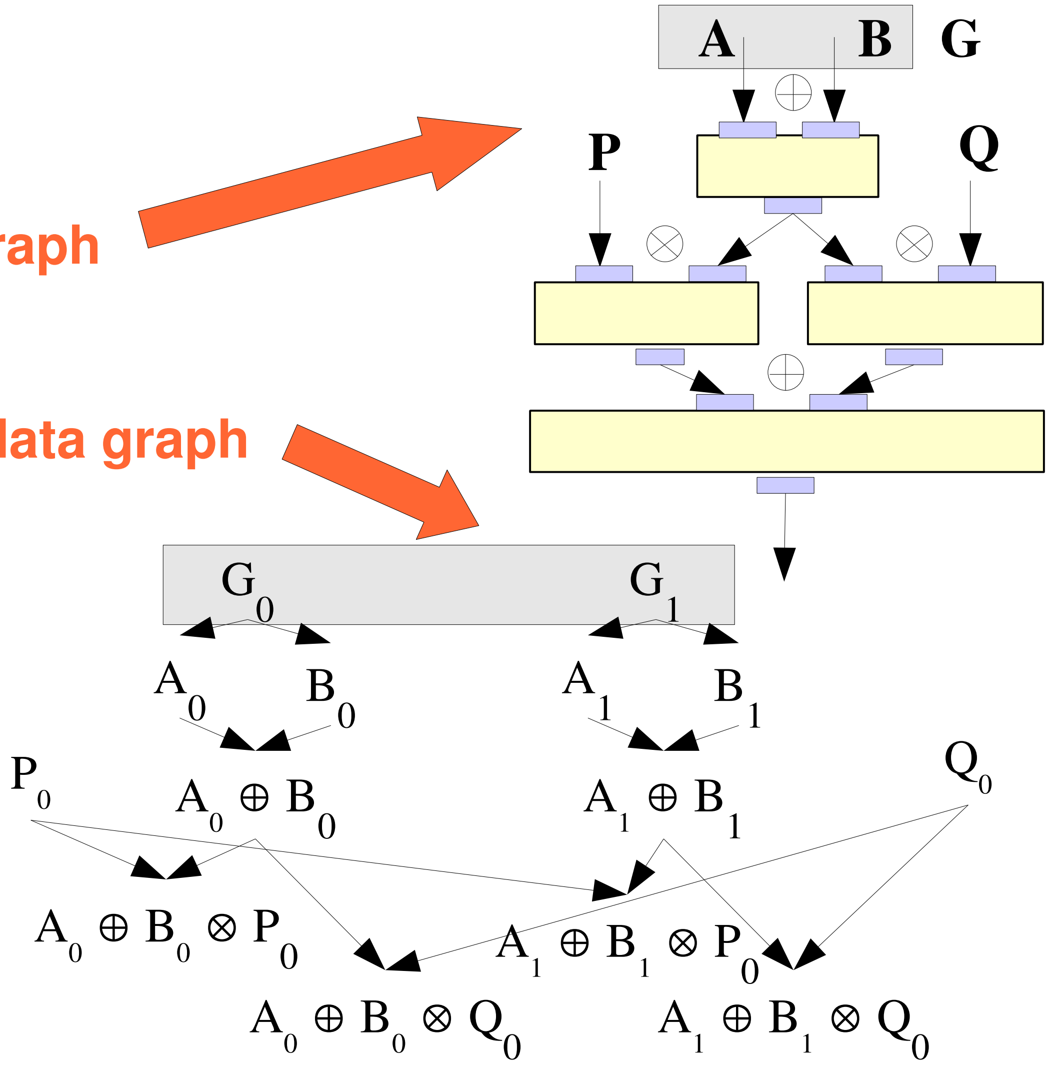
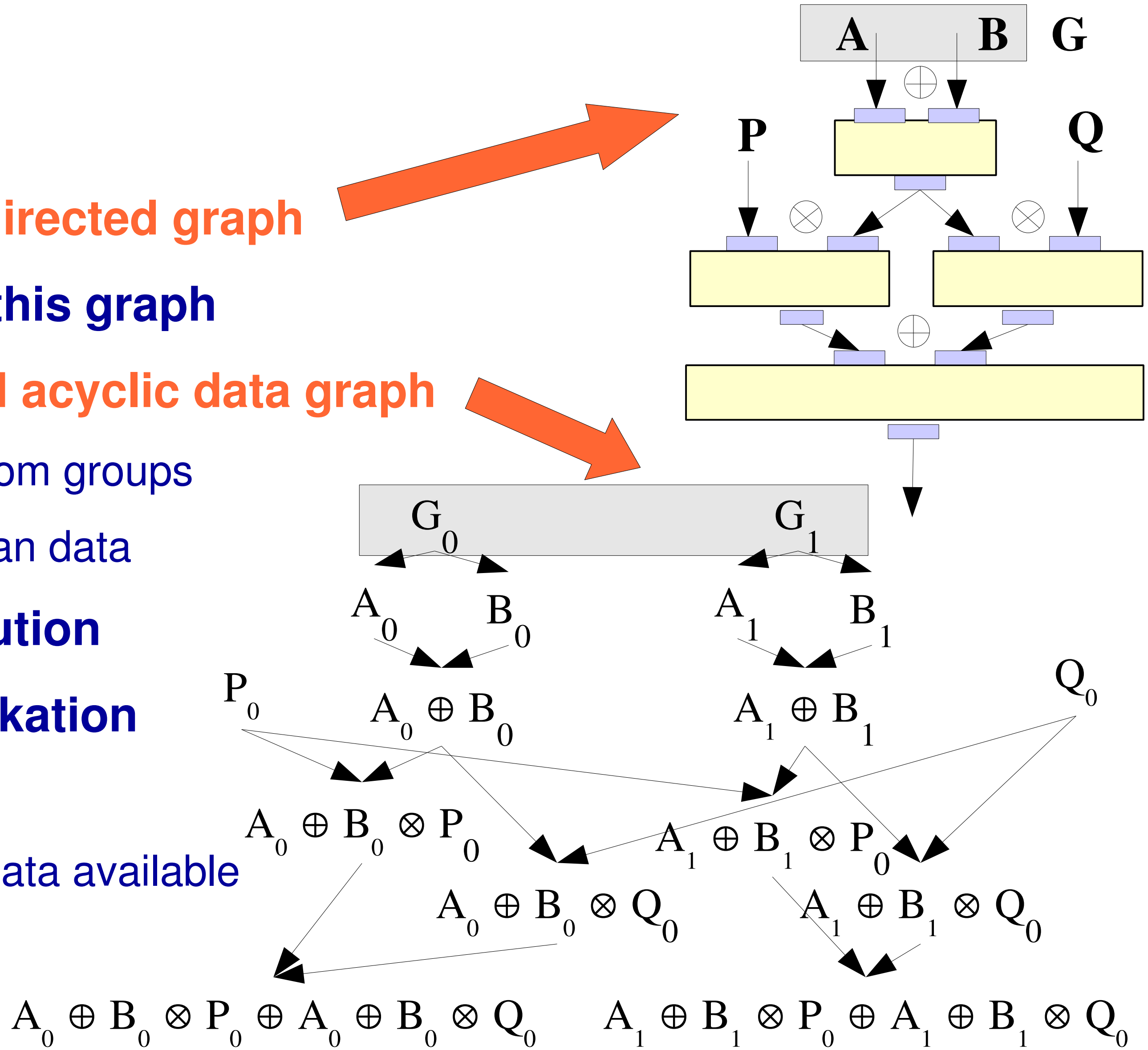


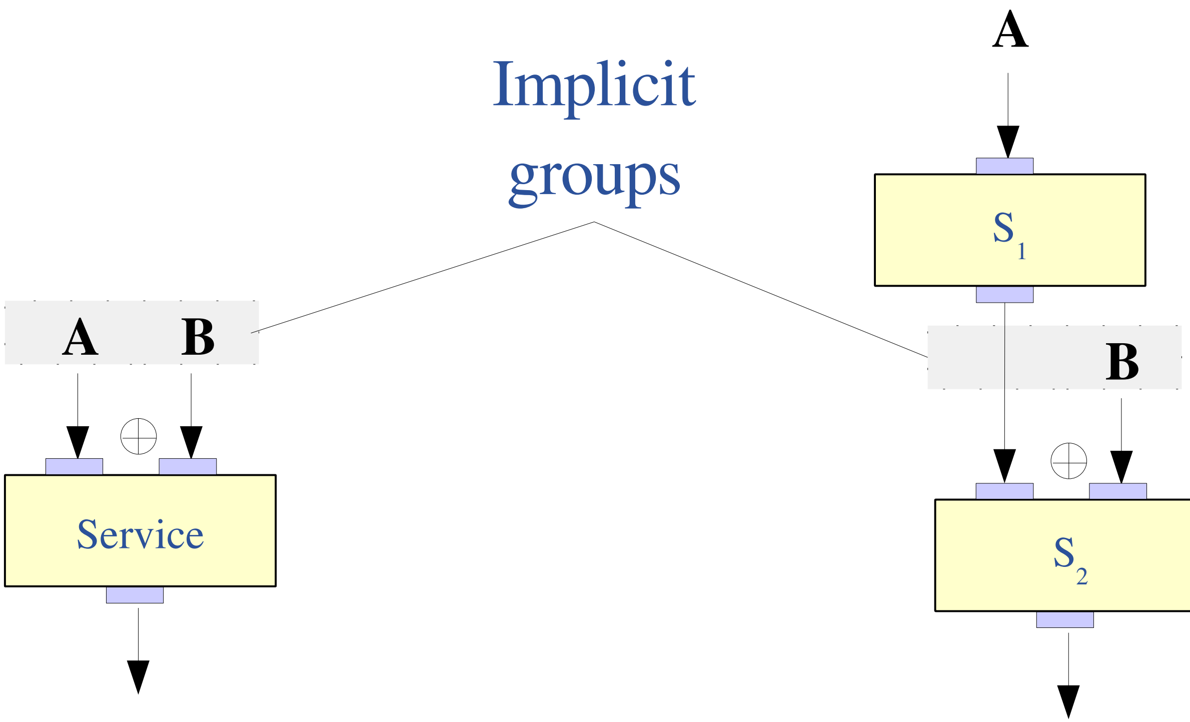
Algorithm

1. **Build the workflow directed graph**
2. **Add data groups to this graph**
3. **Initialize the directed acyclic data graph**
   1. Create root nodes from groups
   2. Root nodes for orphan data
4. **Start workflow execution**
5. **At each service invokation**
   1. Update data graph
   2. Loop until no more data available



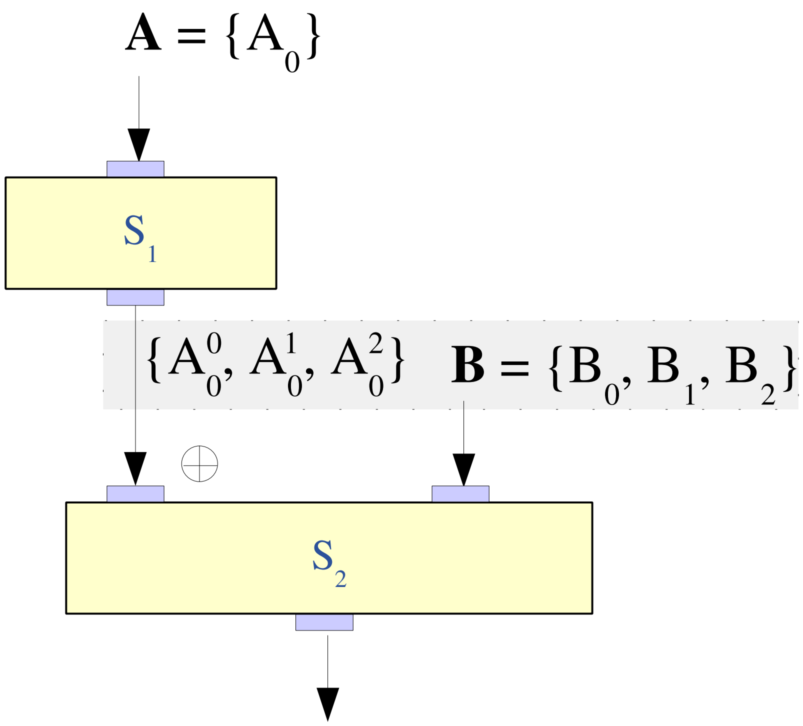
Implicit groups

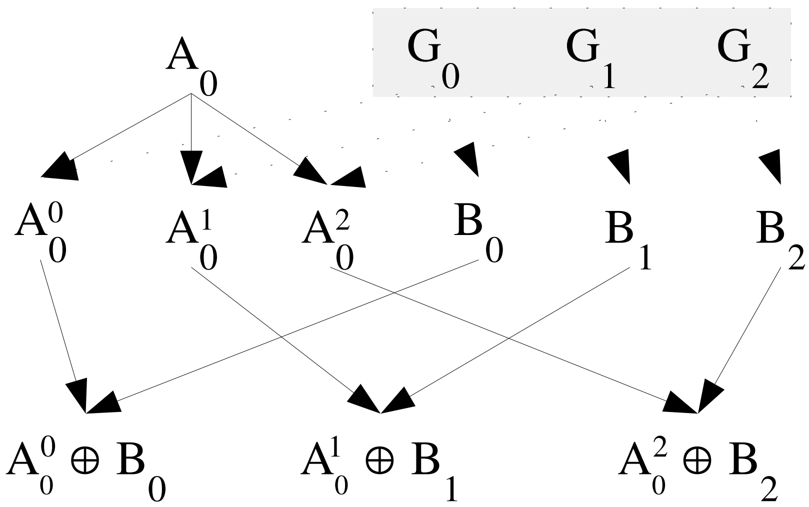
- **Implicit grouping of orphan input data sets composed by a one-to-one operator**



Data fragments

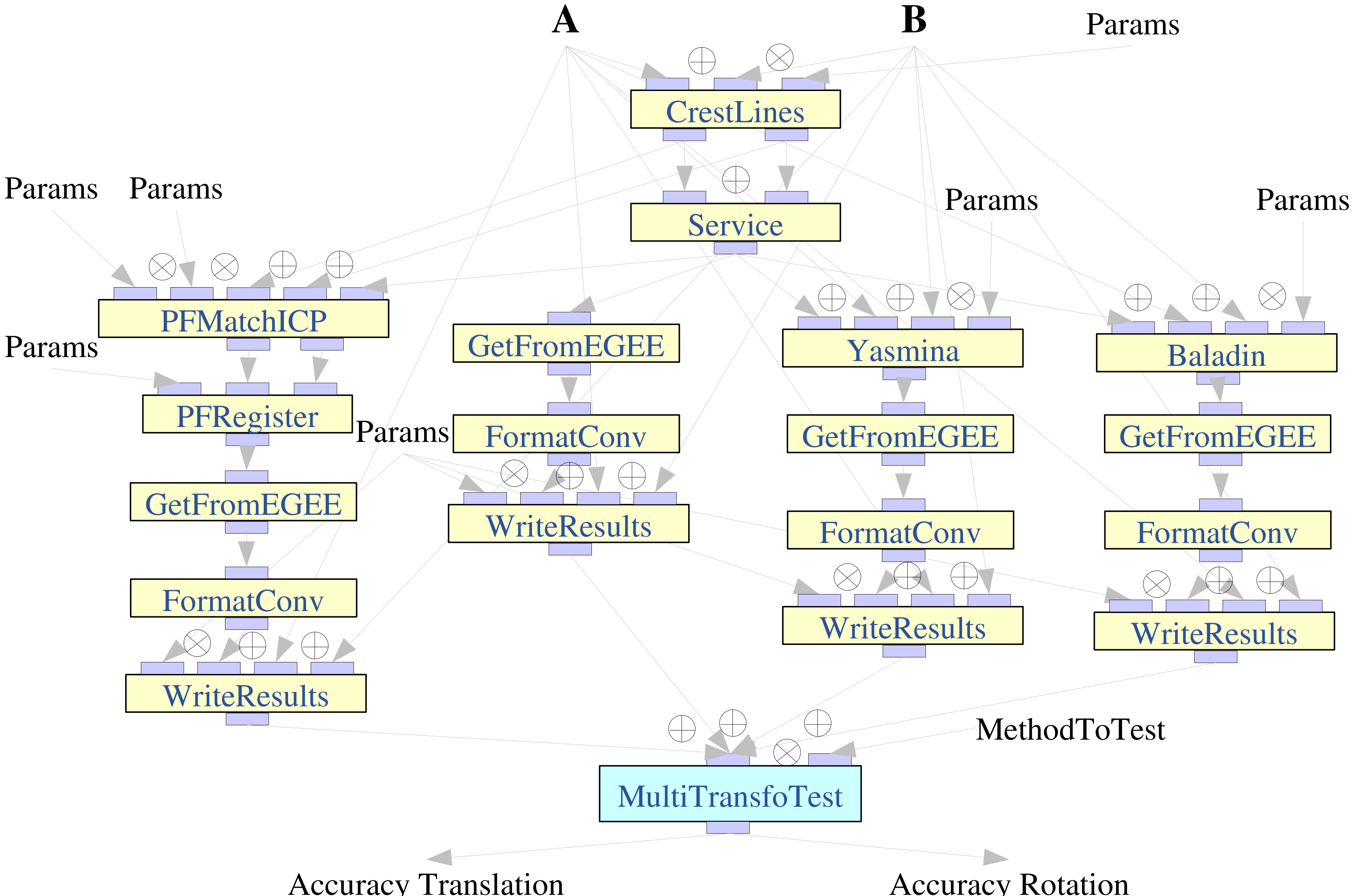
- **A service may produce more (or less) data than it consumes**





- **But this breaks the data parallelism assumption!**

Bronze Standard application example



Conclusions

- **Service-based workflow enactors**
  - User friendly approach
  - Well suited for scientific, data-intensive applications
- **Data composition patterns**
  - Very compact framework
  - Powerful expressiveness
  - Non-trivial operators semantics
- **Perspectives**
  - Data parallelism with data fragments
  - More composition patterns (all-to-all-but-one...)
  - Different semantics for one-to-one composition (one-to-one-inclusive, one-to-one-strict...)

References

- **MOTEUR code and tutorial**
  - http://www.i3s.unice.fr/~glatard
- **Publications**
  - Overview: Tristan Glatard et al, I3S tech report #06-07, HPDC'06 http://www.i3s.unice.fr/%7Emh/RR/2006/RR-06.07-T.GLATARD.pdf
  - Overview, performances: Tristan Glatard et al. HPDC'06 poster http://www.i3s.unice.fr/~johan/publis/HPDC06.pdf
  - Software architecture: Tristan Glatard et al. GELA'06 (HPDC) http://www.i3s.unice.fr/~johan/publis/GELA06.pdf
  - Performances: Tristan Glatard et al. EXPGRID'06 (HPDC) http://www.i3s.unice.fr/~johan/publis/EXPGRID06.pdf
  - Medical imaging: Tristan Glatard et al. HealthGrid'06 http://www.i3s.unice.fr/~johan/publis/HealthGrid06b.pdf

Shortcomings of the task-based approach

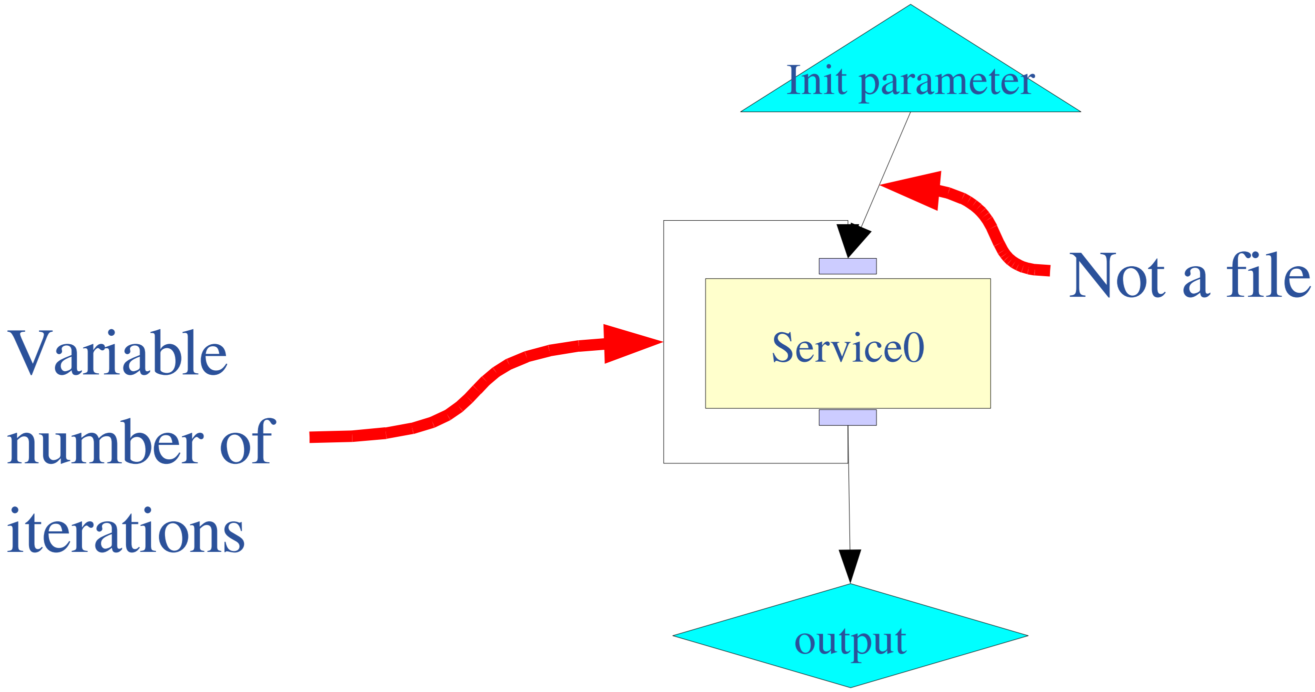
- **The task-based approach mixes processing description and target data:**
  - Static description of tasks
  - Usually single execution per Job Description File
    - *Why are multiple-data jobs submitter so rare?*
  - Tedious invocation process: first write a Job Description File

- **Every piece of data is a file**
  - Specifying input parameters (int, string, ...) to a job is not possible

- **But legacy code execution is straight-forward**
  - Just write the command line

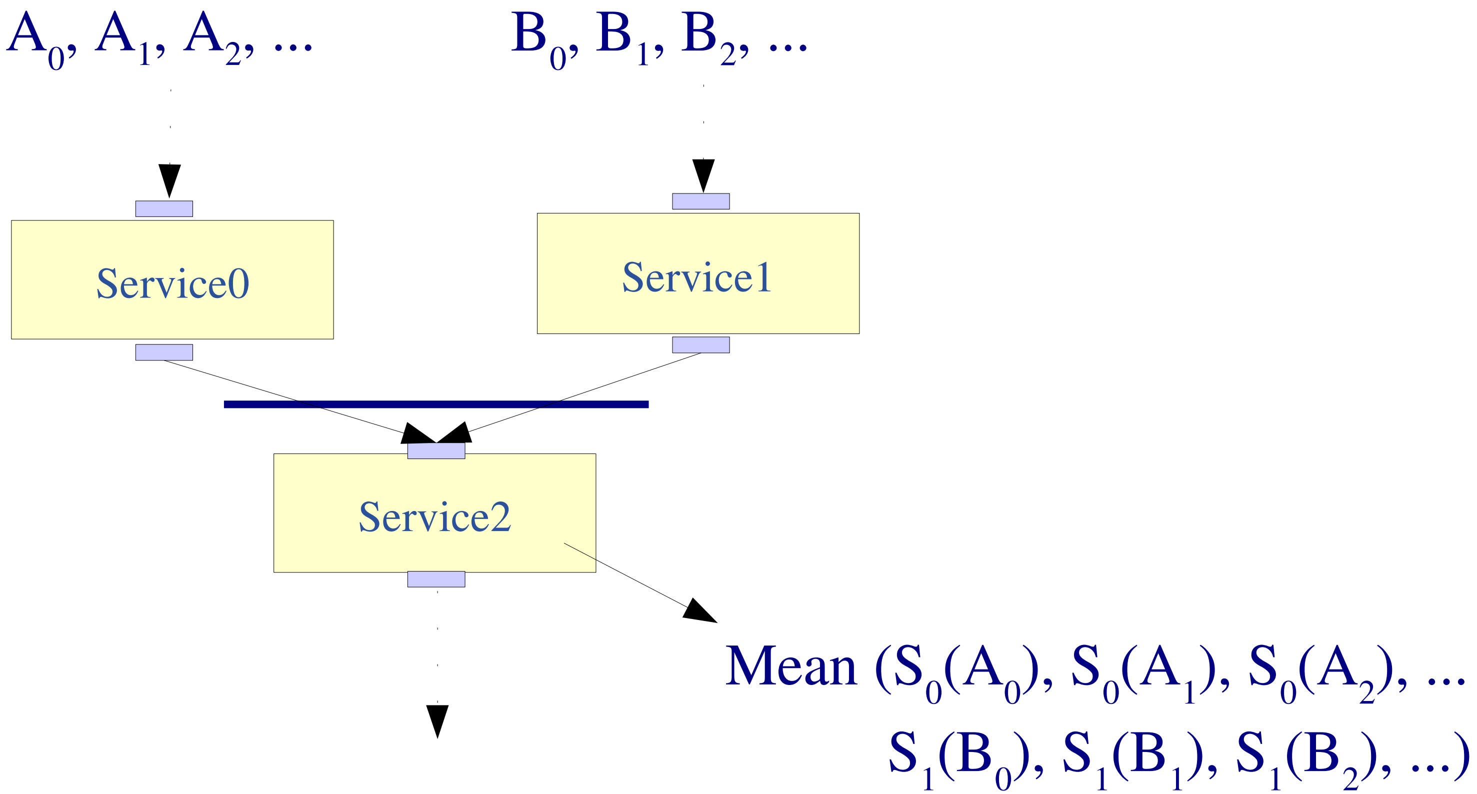
Loops (not a DAG)

- **Only acyclic graphs are possible in the task-based approach**
- **Description is static**
- **Example: optimization loop could not be described**



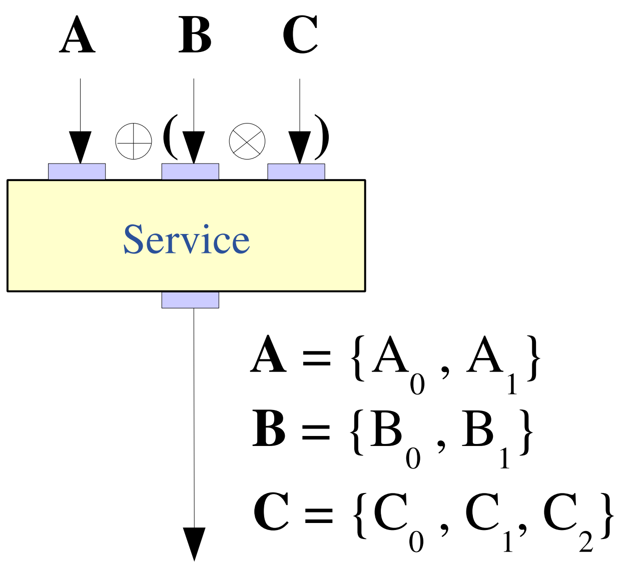
Synchronization barrier

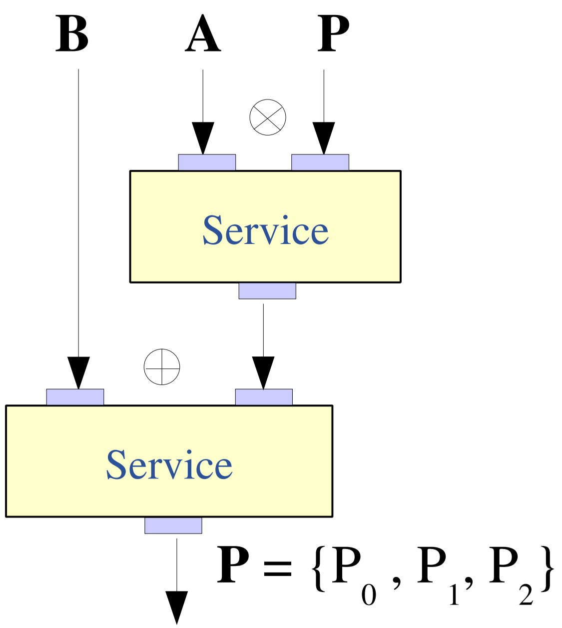
- **Data synchronization are difficult to describe**
  - Example: computing an average input



Taverna semantic

- **Sequential order semantic**





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$$(\mathbf{A} \oplus_{\text{Taverna}} \mathbf{B}) \otimes \mathbf{C} = \left\{ \begin{array}{l} \forall i, (A_0 \oplus B_0) \otimes C_i, \\ \forall i, (A_1 \oplus B_1) \otimes C_i \end{array} \right\}$$

$$\mathbf{B} \oplus_{\text{Taverna}} (\mathbf{A} \otimes \mathbf{P}) = \{ \ B_0 \oplus (A_0 \otimes P_0), \quad B_1 \oplus (A_1 \otimes P_0) \ \}$$