DEFINITION OF BUSINESS PROCESS INTEGRATION OPERATORS FOR GENERALIZATION

Georg Grossmann, Yikai Ren, Michael Schrefl, Markus Stumptner
University of South Australia, Advanced Computing Research Centre
Mawson Lakes, SA 5095, Adelaide, Australia

Keywords: workflow, cross organisation workflow, business process integration.

Abstract: Integration of autonomous object-oriented systems requires the integration of both object structure and object behavior. However, research in this area has so far mainly addressed the integration of object structure. Based on our earlier work that identified behavior-based correspondences between business processes and defined a set of permissible integration operators to enable the construction of linked or integrated business processes. In this paper, we define the integration operators themselves in terms of a set of high level operation calls and demonstrate them on a car dealer and car insurance example. For modelling purposes we use a subset of UML activity diagrams.

1 INTRODUCTION

Integration is a key theme in current database and applied computing research in general. A special issue of the *Communications of the ACM* (CACM, 2002) and several articles in subsequent issues have dealt with integration topics. Integration of applications is a matter of significant concern at the level of level of classical database applications as well as web services or workflows.

1.1 Behavior-based integration

A key aspect of existing research on the integration of information systems is that it has concentrated almost exclusively on the structural aspects e.g.(Bukhres and Elmagarmid, 1996; Conrad, 1997; García-Solaco et al., 1995; Klas and Schrefl, 1995; Parent and Spaccapietra, 1998; Schmitt, 1998; Schrefl and Neuhold, 1988). Integration of object behavior has received some attention, but only at the level of single operations or “activities” at the conceptual level (Vermeer and Apers, 1997).

In (Stumptner et al., 2004), we described a generic approach and resulting architecture for the behavior oriented integration of business processes. It is based on a meta-class architecture that uses inheritance and instantiation relationships to describe high-level integration operators that can adapt and produce individualized integration plans (i.e., groups of operations) for the integration of processes from a particular domain.

In (Grossmann et al., 2004), we have described an integration process which consists of the identification of business process correspondences and associated integration operators. The correspondences are specified via relationships between equivalent and non equivalent business processes and their activities respectively. For each identified relationship we proposed proper integration options which build a new integrating model. This resulting integrated model is a generalization of the input models. Our approach resulted in the first coherent categorisation of integration options, building on a history of detailed examination of individual options using generalization (Preuner and Schrefl, 1998; Preuner et al., 2001; Frank and Eder, 1999). The key outcome of this work was the identification of permissible combinations of integration options (cf. Figure 1).

In this paper we build the capstone on the concept of behavior generalization-based integration, by explicitly describing the key integration steps that correspond to each specific integration situation.

In general the following steps will be performed (Grossmann et al., 2004):

[*]This research was partially supported by the Australian Research Council under Discovery Grant DP0210654. Authors are listed in alphabetical order.

Grossmann G., Ren Y., Schrefl M. and Stumptner M. (2005).
DEFINITION OF BUSINESS PROCESS INTEGRATION OPERATORS FOR GENERALIZATION.
In *Proceedings of the Seventh International Conference on Enterprise Information Systems*, pages 510-517
DOI: 10.5220/0002539305100517

- **Examination** of the relationships between real world objects and relationships between activities
- **Integration options** contain basic integration operators which can be applied to the processes involved. (The integration options are not uniquely determined by the relationships identified in the examination step.)
- **Integration choice** means the combination of the outcome of the examination and the integration options, resulting in integration choices which determine the outcome of the last step in the integration process, the model transformation. For each relationship we have suggested preferred and alternative integration options as shown in Figure 1.
- **Model transformation**: For each identified relationship the model is transformed by applying the proper (for the integration choice) integration operator.

The core notation chosen for our approach are UML 2.0 Activity Diagrams. To enable unambiguous tool implementation we have defined a subset of the full language with clear semantics (not discussed here for space reasons).

In the main sections of the paper we first briefly recapitulate the different activity correspondences, then build the infrastructure for the model transformation operators and then give the individual transformation operator definitions, with a larger example at the end.

1.2 Activity Correspondences

The discussion on correspondences between activities in business processes is based on a relationship between one activity in a process and one activity in another process (1:1). The relationship may be extended to a relationship between one activity and a group of connected activities (1:n). A "1:n" occurrence can involve the same relationships as a "1:1" occurrence. To simplify the cases of identified relationships, activities in the processes are composed or decomposed so that only "1:1" activity relationships are created.

Identity-related activities (*ident_rel*): Identity relationship between two activities holds if the two activities model the same functionality. For example, 'select manufacturer' is an activity in both business processes car dealer and car insurance as shown in Figure 8. The identity relationship may be categorized into two types (extensional (e) and intensional (i) (Grossmann et al., 2004)):

- *Business processes in the same domain (ident_e_rel)*: In this case, the two processes may be derived from the same super-process and have many activities in common.
- *Business processes in the different domain (ident_i_rel)*: In this case, the two processes model different real world objects on the same schema.

Role-related activities (*role_rel*): The role relationship between two activities holds if the two activities model functionalities depending on special role of the processes, e.g., the activity 'specify salary' of a company employee and the activity 'specify salary' of an university employee. The business processes model the same object in different situations or context, e.g., the same person in the situation of a company employee and of an university employee.

History-related activities (*hist_rel*): Two activities are in a history relationship if they model the same functionality and the functionality depends on the points of time at which the processes model their instances, e.g., the activity 'submit CV' of two processes concerning an applicant and later as an employee. The business processes model the same person at different times.

Counterpart-related activities (*count_rel*): Two business process models can be counterpart-related if they model two different real world objects which are affected by some common activities but represent alternate situations in the real world, e.g., the booking system T for a train service and the booking system F for a flight service, both offer the service 'print schedule'. The activities may be counterpart-related if they model the same functionality but the functionality depends on the counterpart relationship of the processes.

Category-related activities (*cat_rel*): If two business processes share some common activities, e.g., one deals with house insurances and another with car insurances, then they are category-related. The corresponding activities of category-related objects model functionality which can be perceived to belong to a common category and are therefore category-related, e.g., the activity 'select value of the target object' of a house insurance and a car insurance. The difference between the category and the counterpart relationships is that the behavior of counterpart-related processes can be identical but not the behavior of category-related processes.

Distinct activities: Distinct activities are activities which are not comparable because there exists no equivalent activity in the other process. We say that an activity in a process is distinct if there exist no activity in the other process which is comparable to it at all points in time. Distinct activities are left unchanged by the integration process.

2 INTEGRATION OPERATORS AND THEIR USE

The integration of two business processes occurs in two steps: (1) identifying activity correspondences and (2) choosing an integration option for each relationship.

	sync	anyo	seq	sync_a	sync_r	stat_sel	user_sel	cond	dyn_b
ident_e_rel	P	P				P			
ident_i_rel									P
role_rel				P	A	P	P	P	
hist_rel			P						
count_rel				P	P		A		
cat_rel									P
cat_rel_s						P	P		

Figure 1: Integration choices for selected activity correspondences.

The choice of integration option is supported by the mapping of the correspondences to specific integration operators.

The identification of correspondences is the task of the designer of the integrated system; the set of correspondences identified is the specification for the integration process. We denote such a correspondence by relation(Act1,Act2), where relation is one of the activity correspondences from the previous section, and Act1 and Act2 are activities in two different business processes. For example,, e.g., ident_i_rel(A1,A2) states the existence of an identity relationship for business processes in different domains between the activities A1 and A2.

In this section we describe the identification of relationships, definition of integration operators, and mapping of semantic relationships to the integration options.

We next define the integration operators by describing each single step in form of base operations and auxiliary functions. Auxiliary functions return elements of a business process and can be seen as an information source, but have no side effects on the process model. Base operations are able to change the model and can appear several times in an integration operator.

For the definition we use the following notation: Variable N stands for nodes that can be activity (A) or control (C) nodes. F stands for fork nodes, J join nodes, M merge nodes, D decision nodes, and E edges.

2.1 Auxiliary functions

We define the following auxiliary functions used by the integration operators:

isControlNode(N) returns true if node N is a control node.

sourceEdge(A) returns the edge leading to activity A.

targetEdge(N) returns the edge outgoing from node N. N can be an activity, a join, or a merge node.

targetNode(E) returns the target node of edge E.

sourceNode(E) returns the source node of edge E.

2.2 Base Operations

In the following we list the base operations used for the definition of the higher level integration operators:

addJoin(E1,E2,N) adds a new join node J to the model such that preexisting edges E1 and E2 now lead to J, and an edge (J,N) is added. The function returns J.

addFork(N,E1,E2) adds a new fork node F and an edge (N,F) to the model. The two preexisting edges E1 and E2 are changed to have F as their source node. F is returned.

addMerge(E1,E2,N) adds a new merge node M to the model. The preexisting edges E1 and E2 are changed have M as target node. An edge (M,N) is added. The function returns M.

addDecision(N,E1,E2) adds a new decision node D to the model and returns it. From N leads an edge to D. E1 and E2 are leaving D. D is returned.

addActivity(S) adds a new activity node A with the description S to the model and returns A.

addMergeDecision(E1,E2,E3,E4) adds a new merge-decision node MD to the model and returns it. The two incoming edges are E1 and E2, and the two outgoing are E3 and E4.

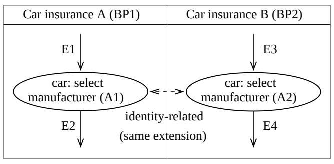
addActivity(S) adds a new activity node A with the description S to the model and returns A.

addEdge(N1, N2, [G]) adds an edge E to the model directing from node N1 to node N2 with the optional guard condition G. It returns E. Precondition: If N2 is an activity, there must not be an edge pointing at N2. If N1 is an activity, there must not be an edge going out of N1. If N1 is a decision node, G must be set.

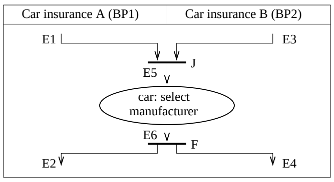
changeSource(E, N) sets N as the source node of edge E. Returns E. The pre- and postconditions associated with the edge E associated with the edge E must not be violated, and must not refer to the former source node.

changeTarget(E, N) changes the target-node of edge E to N. Returns E. The pre- and postconditions associated with the edge E must not be violated and must not refer to the former target node.

removeNode(N) removes the node N if it is not connected to any edge.



(a) Example of identity-related activities.



(b) Example of applying *sync*.

Figure 2: Example of using *sync*.

removeEdge(E) removes the edge E if it does not contain a guard condition.

addGuardCondition(E, G1) adds a guard condition G1 to edge E. If E already contains condition G0, then the new condition will be "G0 AND G1". Returns E.

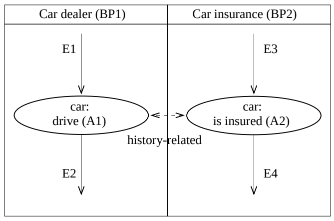
2.3 Model transformation

We now define the different high level transformation operators. They take two activities that are part of a diagram and transform the local neighbourhood of the diagram to provide consistent integrated behavior. The context of the transformation is determined by the permissible choices in Figure 1 - the listed preferred (P) and alternative (A) options will produce meaningful outcomes when the corresponding operators are applied.

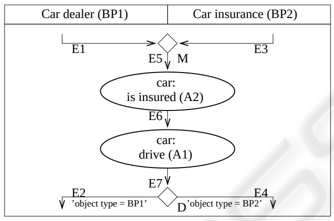
1. *sync*: The aim here is to provide synchronous execution for the identity-related activities A1 and A2 shown in Figure 2(a). The operator generates the integrated model shown in Figure 2(b). The following commands synchronize the flows of both models leading into one of the two input activities, removes the other activity, and add two outgoing flows leading to the former destination of the input activities:

sync(A1, A2)
```
begin
addJoinNode(sourceEdge(A1),
            sourceEdge(A2),A1);          /* J */
addForkNode(A1, targetEdge(A1),
            targetEdge(A2));             /* F */
removeNode(A2);
end
```

2. *anyo*: Another preferred integration option for *ident_e* relationships is *anyo* (any order). In that case the user can choose between seq(A1, A2) or seq(A2, A1) (see below).
3. *seq*: Figure 3(a) shows the history-related activities A1 and A2. The integration option for this relationship is *seq* (sequential execution) which produces the output shown in Figure 3(b). In this case the activities are set in a sequence according to the time of their execution.



(a) Example of history-related activities.



(b) Application of *seq*.

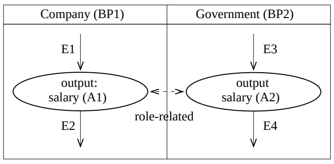
Figure 3: Example of using *seq*.

seq(A2, A1)
```
begin
addMerge(sourceEdge(A1),
         sourceEdge(A2), A2);            /* M */
addEdge(A2, A1);                         /* E6 */
addDecision(A1, targetEdge(A1),
            targetEdge(A2));             /* D */
end
```

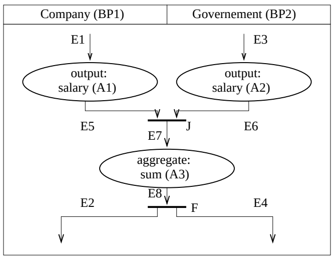
4. *sync_a*: The example of role-related activities is shown in Figure 4(a). One preferred integration option is *sync_a* (synchronous execution and aggregate results). The result is modeled in Figure 4(b). The following command block synchronizes the flows leaving the two input activities A1 and A2. A new activity is added to the model which consists of an aggregation function, e.g., building the sum of the results of A1 and A2 in a new object.

sync_a (A1, A2)
```
begin
addActivity('aggregate: sum');           /* A3 */
addJoin(addEdge(A1,A3),
        addEdge(A2,A3), A3);             /* J */
addFork(A3, targetEdge(A1),
        targetEdge(A2));                 /* F */
end
```

5. *sync_r*: In the example shown in Figure 5(a) the activities A1 and A2 are counterpart-related, with *sync_r* (synchronous execution and relating results) being preferred. See Figure 5(b). The function sync_r() synchronizes the flows leaving the input activities A1 and A2 and insert a new activity after the synchronization which relates the results of



(a) Example of role-related activities.



(b) Application of *sync_a*.

Figure 4: Example of using *sync_a*.

A1 and A2, e.g., select the minimum. The difference to sync_a is that one of the objects is selected and the other one will be dismissed.

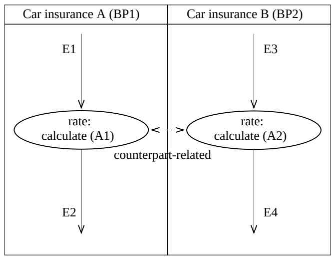
```
sync_r (A1, A2)
  begin
  addActivity('relate: select minimum');        /* A3 */
  addJoin(addEdge(A1,A3),
          addEdge(A2,A3),A3);                   /* J */
  addDecision(A3,targetEdge(A1),
              targetEdge(A2));                  /* D */
  addGuardCondition(E2, 'object type = BP1');
  addGuardCondition(E4, 'object type = BP2');
  end
```

6. *stat_s*: The activities A1 and A2 are category-related and represent the first activities in the business process. The user chooses one preferred object type before the integration process, e.g., a static sequence stat_s(A1, A2) or stat_s(A2, A1). In the example below the activity A1 is preferred:

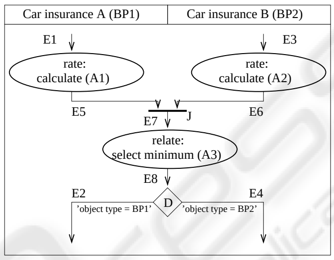
```
stat_s(A1, A2)
  begin
  addMerge(sourceEdge(A1),
    sourceEdge(A2),A1);                         /* M */
  addDecision(A1,targetEdge(A1),
    targetEdge(A2));                            /* D */
  removeNode(A2);
  end
```

7. *user_s*: The activities in Figure 4(a) are role-related. Another preferred integration is *user_s* (runtime selection based on user input) which produces the output shown in Figure 7. The following commands add an activity which handles user input and leads to a decision node which directs to the user chosen activity.

```
user_s (A1, A2)
  begin
  addActivity('ask user: which role?');         /* A3 */
  addMerge(sourceEdge(A1),
```



(a) Example of counterpart-related activities.



(b) Example of applied *sync_r*.

Figure 5: Example of using *sync_r*.

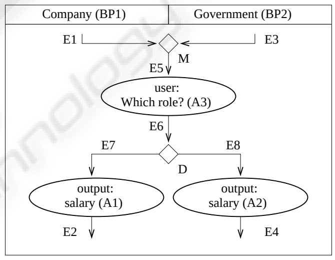
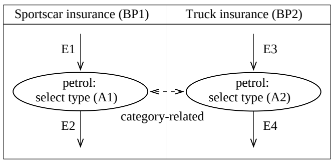


Figure 6: Example of using *user_s*.

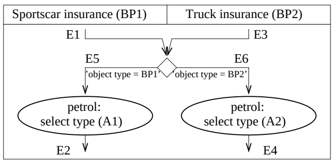
```
        sourceEdge(A2),A3);                     /* M */
  addDecision(A3,addEdge(A3,A1),
              addEdge(A3,A2));                  /* D */
  addGuardCondition(E5, 'object type = BP1');
  addGuardCondition(E6, 'object type = BP2');
  end
```

8. *dyn_b*: The *dyn_b* option is used for category-related activities as shown in Figure 7(a). The output of the integration operator *dyn_b* (dynamic binding, i.e., automatic runtime choice based on object type) is modeled in Figure 7(b).

```
dyn_b(A1, A2)
  begin
  addEdge(sourceNode(sourceEdge(A1)),
          A1);                                  /* E5 */
  addGuardCondition(E5, 'object type = BP1');
  addEdge(sourceNode(sourceEdge(A2)),
          A2);                                  /* E6 */
  addGuardCondition(E6, 'object type = BP2');
  addMergeDecision(sourceEdge(A1),
                   sourceEdge(A2),
                   E5,E6);                      /* MD */
  end
```



(a) Example of category-related activities.



(b) Application of *dyn_b*.

Figure 7: Example of using *dyn_b*.

2.4 Mapping of integration options

The most important eligible combinations between the high level operators and the activity correspondences are shown in Figure 1. For space reasons, only a subset of the relationships in (Grossmann et al., 2004) is given, and we do not address all operator subcategories. Note that the choice of operator is normally not unique, as we do not artificially overconstrain the considerable variability of the integration task. However, there is significant guidance as to which combinations are appropriate. The mapping is defined before the integration process by the execution of the function addPreferredIO() and addAlternativeIO() , e.g., executing addPreferredIO(ident_e_rel,sync) and addPreferredIO(ident_e_rel,anyo) according to Figure 1.

2.5 Integration choices

The second step of the integration process is the user choice of integration options for each identified relationship which is mapped to more than one option. The choices are submitted in the form chooseIO(RelShipID,IntOpt) where RelShipID is the chosen relation and and IntOpt is the desired integration option. After the user has assigned one integration option to each relationship, the integration can be executed.

3 A LARGER EXAMPLE

We demonstrate our integration approach on two business processes involving a car dealer and a car insurance. The two businesses are in different domains, one is in the insurances business domain and the other one is in the car trading domain. Both businesses deal with the same real world object "car". The integrated model allows customers to buy a car and a proper car insurance at the same time. The two models of the car dealer and the car insurance are shown in Figure 8 as business processes D and A. The integrated model brings the following advantages to the car dealer and customer:

- The car dealer can offer an additional service to his customers.
- The customer does not need to go to the effort of contacting an insurance company.
- The information about the car only needs to be provided once.

As explained in Section 1.2, we identify business process correspondences first which has already happened in Figure 8. The relationships are represented by dashed arrows which are labeled with the name of the specific relationship. In the example we have identified the following relationships:

- R1 = ident_e(D1,A2): The submitted details about the car are in both cases identical and so need not to be provided twice.
- R2 = ident_e(D3,A7): Although both activities belong to two different offers, they are transmitted in identical fashion. Both offers are sent together to the customer in the integrated model.
- R3 = ident_e(D4,A8): The two offers become one and so will be negotiated together.
- R4 = count(D5,A9): The offers between the customer, the car dealer and the insurance company are saved and administrated separately in each company but combined later for the customer.

In a next step the proper integration options are chosen and then applied. According to the Figure 1 we take the preferred integration operators and apply them on the activities which hold a relationship. For the four relationships we choose the following options:

1. chooseIO(R1, sync)
2. chooseIO(R2, sync)
3. chooseIO(R3, sync)
4. chooseIO(R4, sync_a)

The result of the execution sequence is shown in Figure 9. The integrated model that is produced by the execution of the integration operators is not satisfactory because the model is not deadlock free. We identify two different deadlocks: (1) The business process waits for an incoming instance at a join node which can not arrive, e.g., after sending the offers to the customer, the insurance offer is accepted but not the car offer, (2) the business process is terminated although an instance is still running, e.g., the negotiation about the car offer is successful but the insurance is not. The problems can be solved by removing redundant control nodes from the model. In Figure 9 we identify two pairs of redundant decision nodes, (1) D1 and D2, (2) D3 and D4. In each of these two cases, both decision nodes refer to the same real world situation and

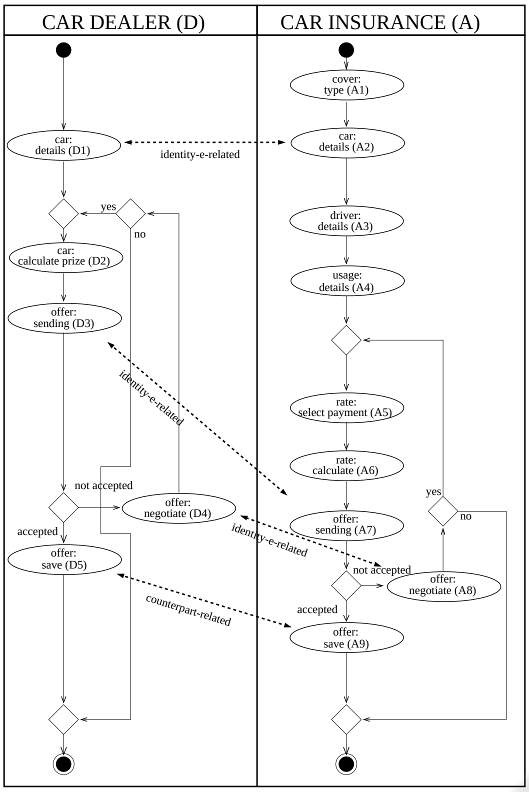


Figure 8: Car dealer and car insurance example.

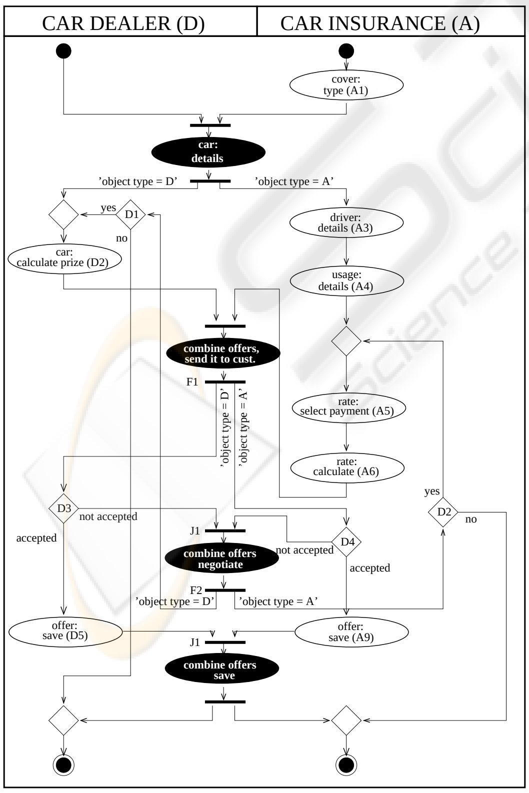


Figure 9: Integrated model of car dealer and car insurance.

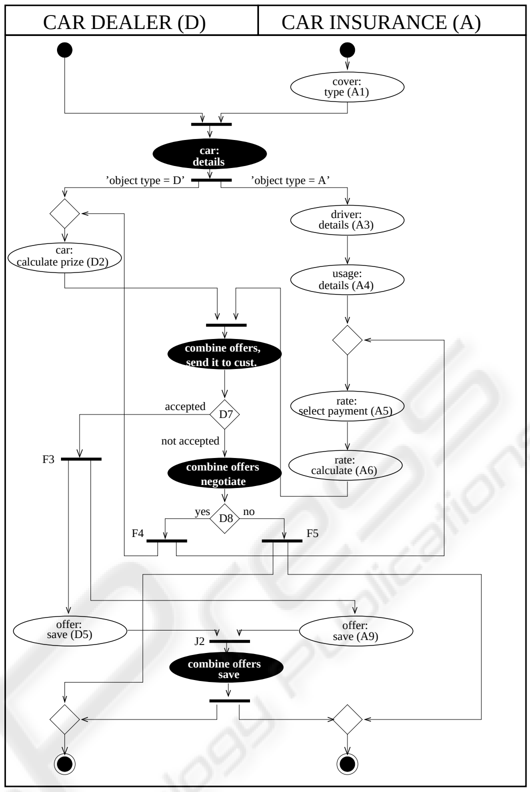


Figure 10: Integrated model after restructuring.

so can be merged.

In Figure 10 the nodes D3 and D4 were merged to D7, and D1 and D2 were merged to D8. A side effect of this merging is the need to commute the forks past the merged decision nodes, i.e., forks F1 and F2 are replaced by F3, F4, and F5.

An algorithm for automatic detection of deadlocks is described in (van der Aalst, 1998) where this problem is defined as soundness property. Our example does not include any constructs which are not able to be modeled in Petri nets and so the algorithm can be applied on our example as well. The final deadlock free model is shown in Figure 10.

4 CONCLUSION

In this paper we have defined a set of high level integration operators for business process descriptions based on UML 2.0 activity diagrams. The operator definitions are based on semantic categorisation of the correspondences between the processes to be integrated that was described in (Grossmann et al., 2004). These correspondences constrain the set of appropriate integration operator choices and provide clear guidelines for the integration task while retaining the flexibility to choose between different options. The operators are effective to use due to their simplicity, and provide a unique toolbox for behavior-based integration.

REFERENCES

Bukhres, O. A. and Elmagarmid, A. (1996). *Object-Oriented Multidatabase Systems: A Solution for Advanced Applications*. Prentice Hall.

CACM (2002). Special Issue on Enterprise Application Integration. *Communications of the ACM*, 45(10).

Conrad, S. (1997). *Föderierte Datenbanksysteme. Konzepte der Datenintegration*. Springer Verlag.

Frank, H. and Eder, J. (1999). Towards an Automatic Integration of Statecharts. In *Proc. 18th Int. Conf. on Conceptual Modeling (ER'99)*, LNCS 1728, pages 430–444, Paris. Springer-Verlag.

García-Solaco, M., Saltor, F., and Castellanos, M. (1995). A structure based schema integration methodology. In *Proceedings IEEE ICDE*, pages 505–512, Taipeh.

Grossmann, G., Schrefl, M., and Stumptner, M. (2004). Classification of business process correspondences and associated integration operators. In *Proc. Int'l Workshop on Conceptual Modeling Approaches for e-Business (eCOMO)*, LNCS 3289, pages 653–666.

Klas, W. and Schrefl, M. (1995). *Metaclasses and their Applications: Data Model Tailoring and Database Integration*. LNCS 943. Springer-Verlag, Berlin, Heidelberg.

Parent, C. and Spaccapietra, S. (1998). Issues and approaches of database integration. *Communications of the ACM*, 41(5es):166–178.

Preuner, G., Conrad, S., and Schrefl, M. (2001). View Integration of Behavior in Object-Oriented Databases. *Data and Knowledge Engineering*, 36(2):153–183.

Preuner, G. and Schrefl, M. (1998). Observation Consistent Integration of Business Processes. In *Proceedings of the Australasian Database Conference (ADC)*, Australian Computer Science Communications, Vol. 20, No. 2, pages 201–212.

Schmitt, I. (1998). *Schema Integration for the Design of Federated Databases*. Dissertationen zu Datenbanken und Informationssystemen, Vol. 43. infix-Verlag, Sankt Augustin.

Schrefl, M. and Neuhold, E. J. (1988). Object class definition by generalization using upward inheritance. In *Proceedings of the International IEEE Conference on Data Engineering*, pages 4–13. IEEE Computer Society Press.

Stumptner, M., Schrefl, M., and Grossmann, G. (2004). On the road to behavior-based integration. In *Proceedings 1st Asia-Pacific Conference on Conceptual Modelling*, pages 15–22.

van der Aalst, W. (1998). The Application of Petri Nets to Workflow Management. *The Journal of Circuits, Systems and Computers*, 8(1):21–66.

Vermeer, M. W. W. and Apers, P. M. G. (1997). Behaviour specification in database interoperation. In *Conference on Advanced Information Systems Engineering*, pages 61–74.