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Transforming Object-Aware Processes into BPMN: Conceptual Design and Implementation

Abschlussarbeit an der Universität Ulm

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4 Transforming Object-Aware Processes into BPMN

In this chapter, a conceptual transformation model is proposed that fulfills the defined requirements for the transformation of object-aware processes into BPMN (cf. Chap. 3). First, an overview of the necessary transformations and mapping rules for the mentioned conception is given (cf. Sect. 4.1). Next, the concrete mapping (cf. Sect. 4.2) and another component of the conception - Robotic Process Automation (RPA) (cf. Sect. 4.3) - are explained in more detail. Finally, an algorithm for transforming object-aware processes into BPMN can be developed as a result (cf. Sect. 4.4).

4.1 Transformation Compendium

The transformation model is divided into three different types: Object, Permission, and Relation, with each type providing different functionalities to fulfill a different concern in the transformation model. In addition, an external component completes the latter.

Type 1 (Object Transformation)**.** *Informell sagen was passiert.*

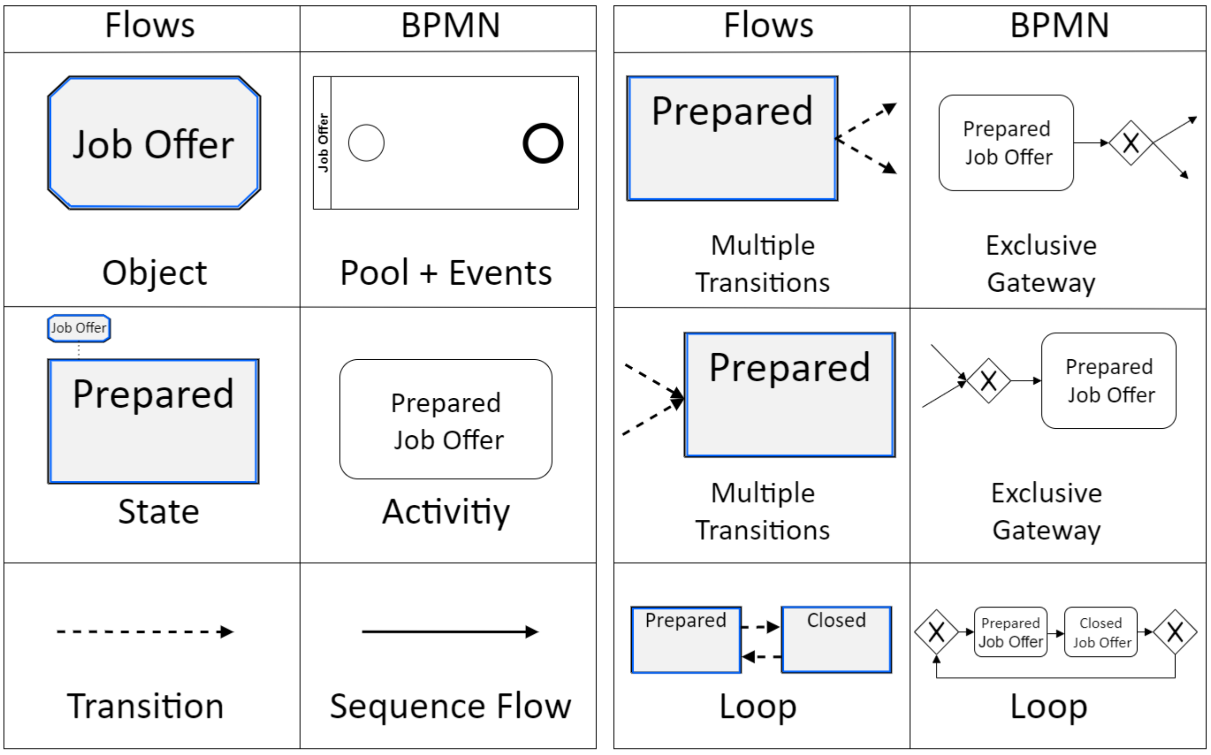

Abbildung 4.1: Initial example

Type 2 (Permission Integration)**.** *Informell sagen was passiert.*

Type 3 (Relation Integration)**.** *Informell sagen was passiert.*

4.2 Object Transformation

The object transformation deals with the task of transforming an object in terms of BPMN. For this purpose, the individual elements, i.e., states, steps, and transitions, that occur within the lifecycle of the object, are transformed individually. Furthermore, other BPMN-related elements are included in the object transformation, namely pools, events, gateways, and data objects.

Definition 1 (Object Transformation)**.** *Let* $\omega = (\mathrm{n}_\omega, \Phi, \Theta)$ *be an object. Then: function* $OTA : \Omega \to \Delta$ *generates a 5-tuple of BPMN process elements* $\delta = (E, A, T_\delta, K, N)$.

Informally stated, OTA receives an object as input, along with its name, lifecycle, and a set of attributes, and returns a 5-tuple of BPMN process elements corresponding to the object, i.e., a set of events, a set of activities, a set of transitions, a set of gateways, and a set of data objects. Algorithm 1 describes the generation of these components in pseudo code, partly using separate functions, where each function transforms a different component. Later in this section, these functions are explained in more detail.

Algorithm 1 Object Transformation Algorithm (OTA)

```
Require: $\omega = (\mathrm{n}_\omega, \Phi, \Theta)$
  $E, A, T_\delta, K, N \leftarrow \perp$
  $E.add(\epsilon_\delta^{start})$
  $E.add(\epsilon_\delta^{end})$
  $A \leftarrow AGA(\Sigma)$
  for all $\tau\ in\ \Theta.\mathrm{T}_\omega$ do
      $\tau_\delta \leftarrow FTTA(\tau_\omega)$
      $\mathrm{T}_\delta.add(\tau_\delta)$
  end for
  for all $\psi\ in\ \Theta.\Psi$ do
      $\tau_\delta \leftarrow BTTA(\psi)$
      $\mathrm{T}_\delta.add(\tau_\delta)$
  end for
  for all $\alpha\ in\ \mathrm{A}$ do
      $\tau_\delta \leftarrow ESFA(\alpha)$
      if $\tau_\delta \neq \perp$ then
          $\mathrm{T}_\delta.add(\tau_\delta)$
      end if
      $\mathrm{K} \leftarrow GGA(\mathrm{T}_\delta)$
      $\nu \leftarrow DGA(\alpha)$
      $\mathrm{N}.add(\nu)$
  end for
  $\delta \leftarrow (\mathrm{E}, \mathrm{A}, \mathrm{T}_\delta, \mathrm{K}, \mathrm{N}, \Xi)$
  $\rho \leftarrow (\mathrm{n}_\rho, \delta)$
  return $\rho$
```

However, some components are not handled by functions, but are predefined at the beginning of the transformation, for the reason, that these components belong to every BPMN process according to the predefined guidelines (cf. TBD). More specifically, at the beginning of the transformation a pool is defined, where the name of the pool corresponds to the name of the respective object. Within the pool, the remaining BPMN elements are defined. Furthermore, a start and end event within the pool are predefined, since every object has a start and end state. In the course of this section, the transformation is applied step by step onto the object *Job Offer* from Example 1 to illustrate the transformation. For the sake of simplicity, however, only the state-based view of *Job Offer* is considered. Fig. TBD shows the beginning of the transformation, i.e., with generated pool and events, onto the object *Job Offer*.

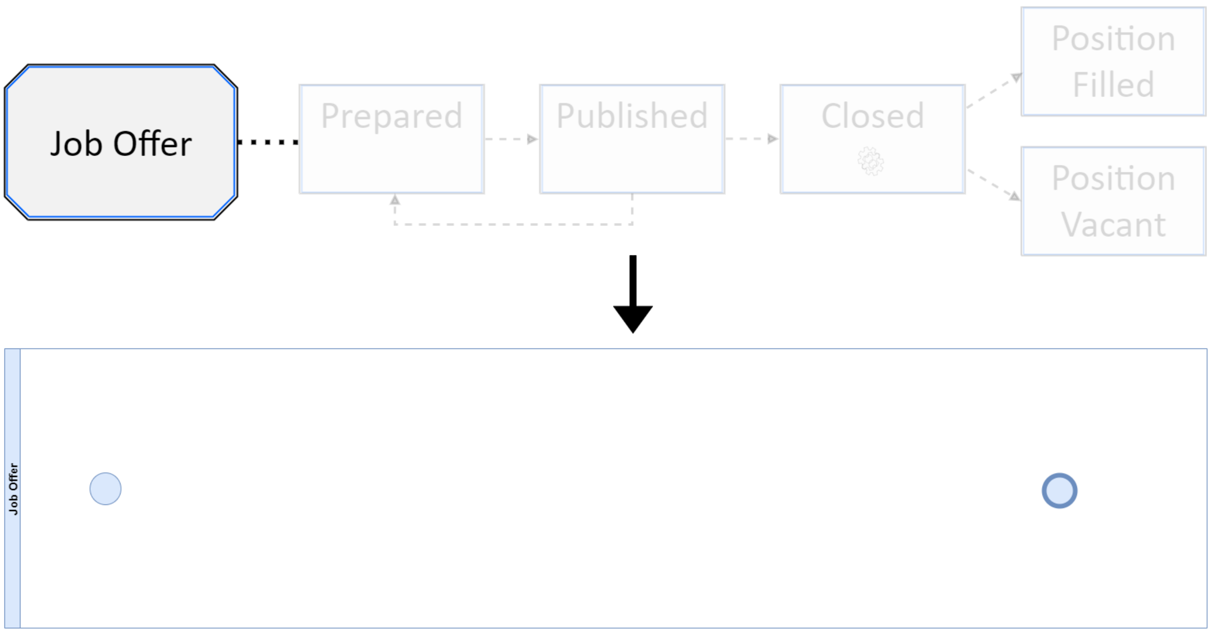

Abbildung 4.2: Initial example

4.2.1 Activity Generation

This transformation step deals with the transformation of states in terms of BPMN. In this context, trivially, each state σ is transformed into an activity α. However, depending on the steps that a state may have, certain cases must be distinguished that lead to one of three types of activities a state can be transformed into:

1. State contains more than one step. In this case, the state is transformed into a *sub-process*.
2. State contains exactly one step, and this step is a computational step. In this case, the state is transformed into a *service task*.
3. In any other case, the state is transformed into an activity without any kind of type, i.e., a *non-type activity*.

Furthermore, in any case, the name of an activity n_α results from the name of the state, followed by the name of the object to which the state belongs, separated by a blank character. In the following, auxiliary functions are defined before finally an algorithm for the computation of the set of activies given an object is developed.

Definition 2 (Computational Step)**.** *Let* $\omega = (\mathrm{n}_\omega, \Phi, \Theta)$ *be an object and* $\gamma \in \Gamma$ *a step from the set of steps* Γ *from a state* $\sigma \in \Sigma$ *within the lifecycle* Θ *of* ω*. Then: function* $CS : \Gamma \to \mathbb{B}$ *determines whether the given step is a computational step.*

$$CS(\gamma) = \begin{cases} true, & \text{if } \gamma.\lambda \neq \bot. \\ false, & \text{otherwise.} \end{cases}$$

Definition 2.1 (Activity Type Generation). *Let $\omega = (\mathrm{n}_\omega, \Phi, \Theta)$ be an object and Γ the set of steps from a state $\sigma \in \Sigma$ within the lifecycle Θ of ω. Then: function*

$$\iota = ATG(\Gamma) = \begin{cases} suprocess, & \text{if } |\Gamma| > 1. \\ service\ task, & \text{if } (|\Gamma| = 1) \wedge\ (CS(\Gamma.\gamma) = true). \\ non - type, & \text{otherwise.} \end{cases}$$

determines the type ι of the activity α that is derived from the state σ.

Definition 2.2 (Subprocess Generation). *Let $\omega = (\mathrm{n}_\omega, \Phi, \Theta)$ be an object and $\sigma \in \Sigma$ with $|\sigma.\Gamma| > 1$ a state within the lifecycle Θ of ω. Then: $\iota = ATG(\sigma.\Gamma) = subprocess$. Further, then: function*

$$\delta_\alpha = SG(adHoc, \Gamma) = \begin{cases} (E, A, T_\delta, K, N) & \text{if } adHoc = false. \\ (E, A, T_\delta, K, N) & \text{otherwise.} \end{cases}$$

generates a 5-tuple δ_α containing the BPMN process elements within the subprocess α.

SG suggests that a subprocess can be specialized as ad hoc. In this case, for the generated 5-tuple δ_α, by default, it holds $E = T_\delta = K = \bot$, where only A and N need to be computed. Otherwise, every component needs to be computed. Fig. TBD illustrates both possibilities graphically for the object *Application* in one of its states, *Creation*.

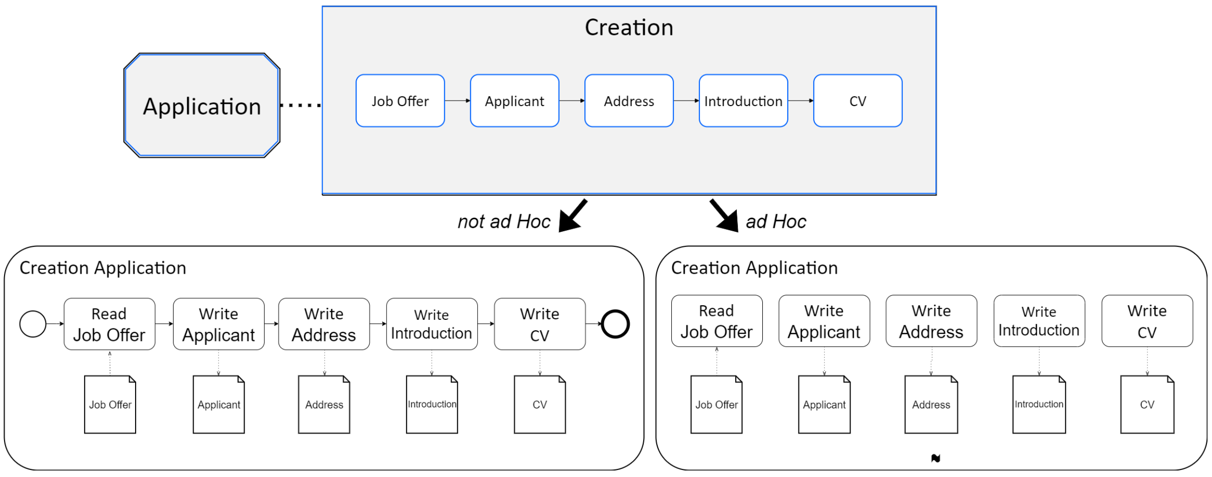

Abbildung 4.3: Initial example

In principle, a subprocess may contain every BPMN element that a BPMN process may.

Hence, the generation of the BPMN elements within a subprocess follows the same transformation model as described in this chapter, where every step can be transformed into an activity within the subprocess. However, there are differences in the naming of activities and the generation of data objects generated within a subprocess. First of all, depending on the data type of a step, the name of the generated activity from the step will either start with *Read* or *Write* followed by the attribute instance name of the respective step. The former case occurs, if the data type of the respective step is another related object. In such a case, the completion of the step implicitly demands, that another object instance is provided. Hence, the required data to complete the step has to be provided by the process itself and therefore can be read. Such generated activities further generate data objects, named after the respective attribute instance name, and have a reading association to the respective data object (e.g., *Read Job Offer*). On the contrary, the latter case occurs, if the data type of the respective step is not another related object (e.g., String, Boolean, Integer), hence, the completion of the step does not demand the provision of data from the process itself, but rather demands new data to be written externally from the process. Such generated activities further generate data objects, named after the respective attribute instance name, and, in turn, have a writing association to the respective data object (e.g., *Write Applicant*).

Finally, Algorithm AGA describes the computation of the set of activities given an object in pseduo code based on Definition 2, 2.1 and 2.2.

Algorithm 2 Activity Generation Algorithm (AGA)

```
Require: $\omega$
  $A \leftarrow \perp$
  for $\sigma \in \omega.\Theta.\Sigma$ do
    $\mathrm{n}_\alpha \leftarrow \sigma.\mathrm{n}_\sigma + \omega.\mathrm{n}_\omega$
    $\iota \leftarrow ATG(\sigma)$
    if $\iota$ = subprocess then
      $SP \leftarrow SG(adHoc, \sigma.\Gamma)$
    else
      $SP \leftarrow \perp$
    end if
    $\alpha \leftarrow (\sigma, \mathrm{n}_\alpha, \iota, SP)$
    $A.add(\alpha)$
  end for
  return $A$
```

Fig. TBD graphically illustrates how this transformation step can be applied to further transform the object *Job Offer*. For the sake of simplicity, *Prepared Job Offer* is modeled as a collapsed subprocess, but can be modeled as an expanded subprocess according to Definition 2.2.

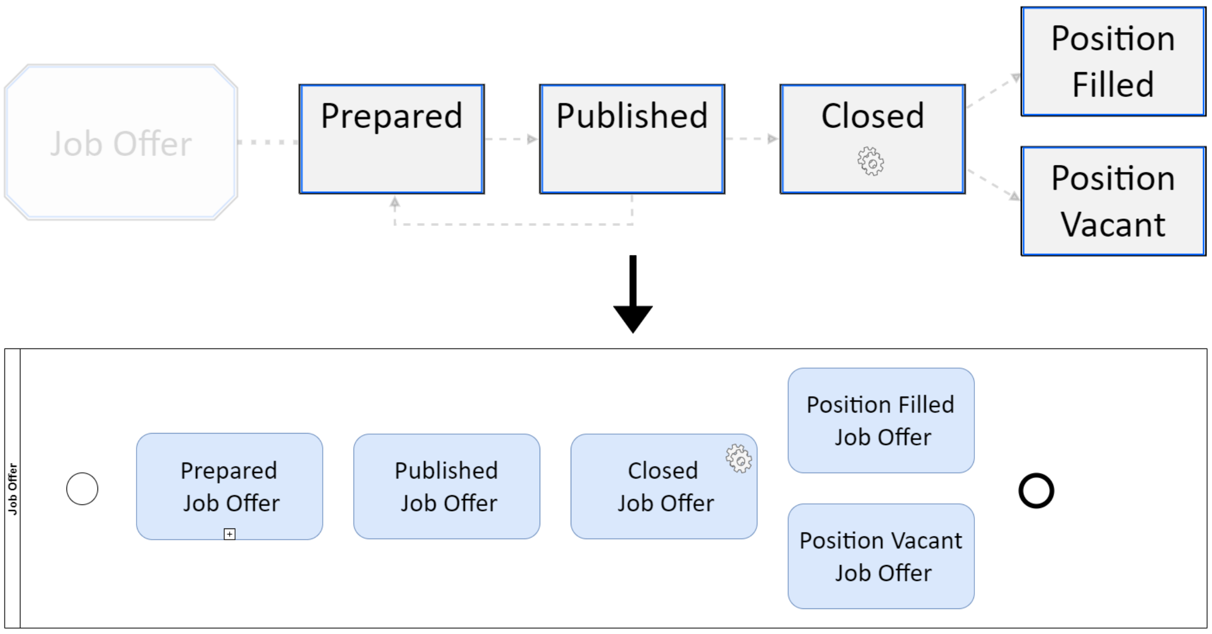

Abbildung 4.4: AGA example

4.2.2 Transition Generation

This transformation step deals with the transformation of transitions from an object in terms of BPMN. In BPMN, transitions between elements can be regulated by sequence flows. Therefore, in this section, an algorithm transforming an object transition into a sequence flow is provided. Two types of object transitions are possible - forwards and backwards transitions. In the former, a transition is made between two steps from one or more states of an object (e.g., *Prepared Job Offer* to *Published Job Offer*), while in the latter, a transition is made between two states of an object (e.g., *Published Job Offer* to *Prepared Job Offer*). In contrast, more than two types of transitions are possible in BPMN, for example, between two activities, between an activity and an event, or between an activity and a gateway. Consequently, generating sequence flows is not as trivial as generating activities. The latter holds especially true for the transformation of forwards transitions. Backwards transitions, however, can be easily transformed by establishing a sequence flow between the two respective activities that were generated from their respective states with $\mathrm{Algorithm2}$ (cf. Sect. 4.2.1) beforehand. On the contrary, since forwards transitions establish transitions between two steps from one or more objects, two different cases must be distinguished in order to transform them properly:

1. Transitions between two steps belonging to the same state. This case implies that the respective state is a subprocess (cf. Sect. 4.2.1 Definition 2.1). Hence, the transformed transition, i.e., the sequence flow, belongs to the respective subprocess of the activity, rather than the BPMN process of the current object itself. Consequently,

the transformation of such a transition is regulated during the transformation of the respective subprocess.

2. Transitions between two steps that belong to different states. In this case, a sequence flow is drawn between the activities generated from the respective states to which the respective steps belong.

Note that sequence flows between the events and activities of the process are still needed to prevent a deadlock in the process. To this end, this transformation step further iterates through each generated sequence flow so far and determines which activitiy occurs neither as source nor as target of a sequence flow. In the former, sequence flows between the respective activities and the end event of the process are generated, whereas in the latter sequence flows from the start event of the process to the respective activities are generated.

Definition 3 (Sequence Flow Generation)**.** *Let* $\omega = (\mathrm{n}_\omega, \Phi, \Theta)$ *be an object. Further, let* T_ω *be the set of forwards transitions and* Ψ *be the set of backwards transitions within the lifecycle* Θ *of* ω*. Last, let* υ *be a BPMN element that is able to have at least one incoming or outgoing sequence flow, i.e., an activity, an event or a gateway). Then:*

Definition 3.1 (Forwards Transitions Transformation). *Function* $FTTA : \mathrm{T}_\omega \to \mathrm{T}_\delta$ *generates a sequence flow* $\tau_\delta = (\upsilon_{source}, \upsilon_{target})$ *given a forwards transition* $\tau_\omega = (\gamma_{source}, \gamma_{target})$.

Definition 3.2 (Backwards Transitions Transformation). *Function* $BTTA : \Psi \to \mathrm{T}_\delta$ *generates a sequence flow* $\tau_\delta = (\upsilon_{source}, \upsilon_{target})$ *given a backwards transition* $\psi = (\sigma_{source}, \sigma_{target})$.

Definition 3.3 (Event Sequence Flows). *Function* $ESFA : \mathrm{A} \to \mathrm{T}_\delta$ *complements* T_δ *by the missing sequence flows between the events and activities. Given an activity* α*, ESF determines whether a sequence flow between* α *and an start event* ϵ_δ^{start} *or an end event* ϵ_δ^{end} *shall be generated.*

Fig. TBD graphically illustrates the application of this transformation step onto the object *Job Offer*.

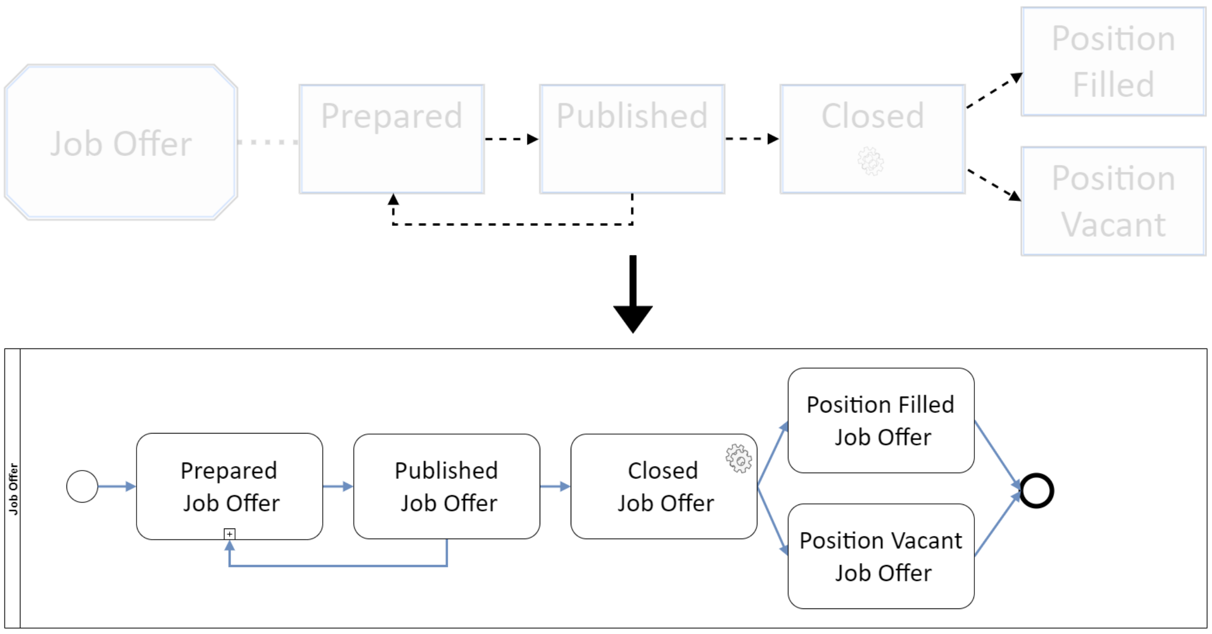

Abbildung 4.5: TGA example

4.2.3 Gateway Generation

At this point in the transformation, activities may have more than one incoming or outgoing sequence flow. In the case of the object transformation, such cases may occur due to backwards transitions or the existence of predicate step instances. In the former, such case can be modeled in BPMN via a loop, whereas in the latter case, exclusive gateways are used to show that the process flow depends on different conditions. In any case, both cases demand exclusive gateways in the BPMN process in order to not contradict with the guidelines for BPMN process modeling (cf. TBD). This transformation step is concerned with regulating both cases in the context of the object transformation:

A. Loop

The transformation of a backwards transition in context of the sequence flow generation (cf. Sect. 4.2.2) results into a cycle within the BPMN process or, in other words, the BPMN process has a loop. Fig. TBD illustrates how to handle such case in terms of BPMN onto the object *Job Offer*.

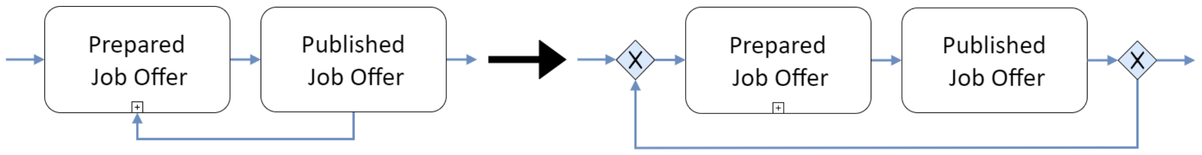

Abbildung 4.6: Initial example

B. Conditions

When transforming a step

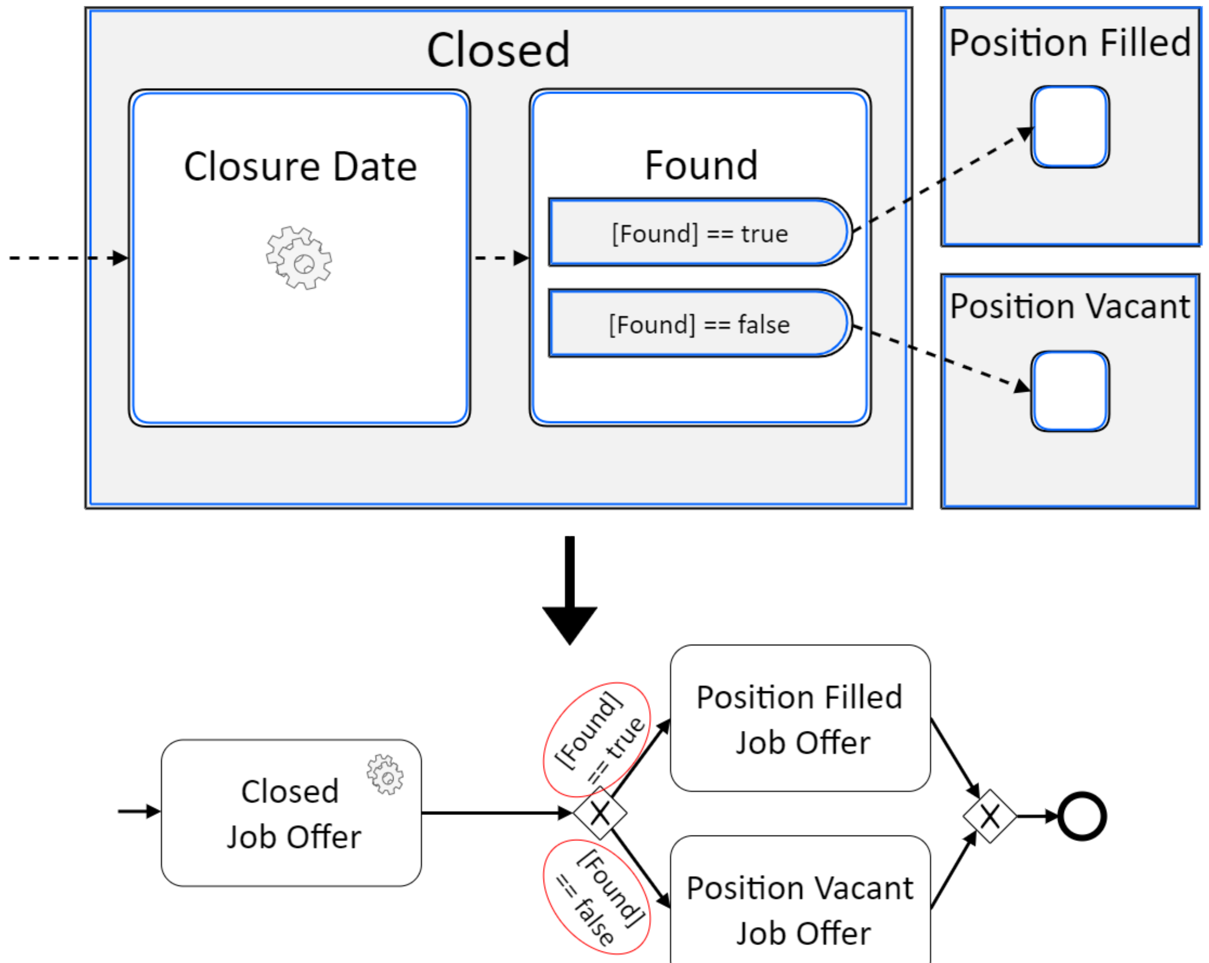

Abbildung 4.7: Initial example

Furthermore, the sequence flows of the process must be updated so that the respective BPMN element no longer has multiple incoming or outgoing sequence flows, while preserving the logic of the process.

Definition 4 (Gateway Generation)**.** *Let* $\delta = (\mathrm{E}, \mathrm{A}, \mathrm{T}_\delta, \mathrm{K}, \mathrm{N}, \Xi)$ *be a 6-tuple of BPMN process elements derived from an object* ω = $(\mathrm{n}_\omega, \Phi, \Theta)$*. Further, let* T_δ *be the set of transitions of* δ*. Then: function GGA receives* T_δ *as input to generate exclusive gateways* κ *and return them collected in* K*, i.e., GGA provides* δ *with the set of exclusive gateways* K*. As a side effect, GGA also updates* T_δ *to include or remove the sequence flows related to the exclusive gateways.*

Fig. TBD illustrates the result of this transformation step onto the current process of the object *Job Offer*, i.e., the generation of exclusive gateways where needed and updated transitions.

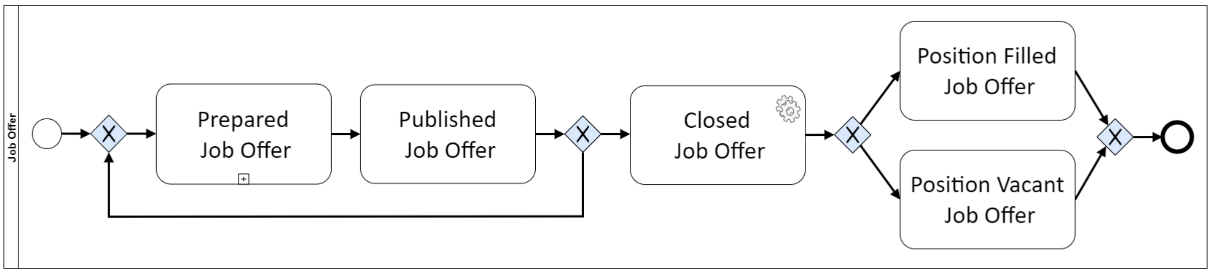

Abbildung 4.8: GGA example

4.2.4 Data Object Generation

Owing to the fact that the execution of the lifecycle process of an object is data-driven, it seems reasonable to consider this integration of data into the BPMN process. In BPMN, data objects can be used for this purpose. This transformation generates a data object for each activity in a process, where each such generated data object shall show, in which state the respective object of the process is in, after the activity in the process has been executed. For this purpose, each such generated data object is labeled with the name of the respective object followed by the name of the state at that point of process execution, with the state enclosed in square brackets. Last, for each such generated data object, it is specified which activities write the data object, i.e., change the state of the object with its execution, and read the data object, i.e., require a certain state of an object or the previous execution of an activity for its execution. However, in this step of the transformation, data objects are only written, while reading data objects is dealt with in a later part of the whole transformation model.

Definition 5 (Data Object Generation)**.** *Let* $\delta = (\mathrm{E}, \mathrm{A}, \mathrm{T}_{\delta}, \mathrm{K}, \mathrm{N}, \Xi)$ *be a 6-tuple of BPMN process elements derived from an object* ω *=* $(\mathrm{n}_{\omega}, \Phi, \Theta)$*. Further, let* $\alpha \in \mathrm{A}$ *be an activity in the process. Then: function* $DGA : \mathrm{A} \rightarrow \mathrm{N}$ *generates a data object* $\nu = (\mathrm{n}_{\nu}, \alpha_{\nu}, \mathrm{P}_{write}, \mathrm{P}_{read})$ *for the respective activity* α*.*

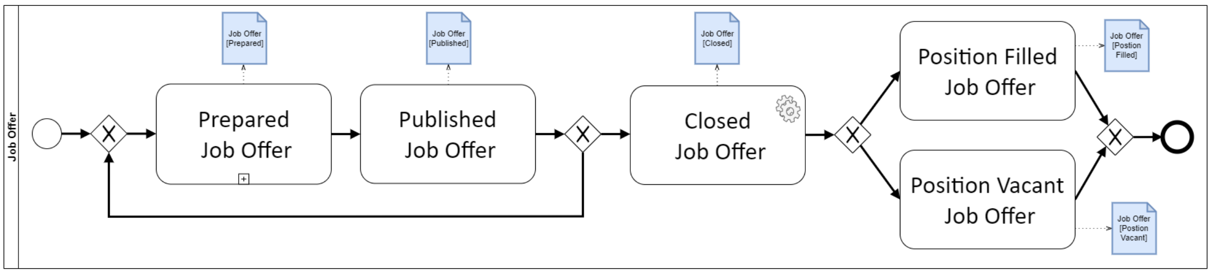

Abbildung 4.9: DOG example

4.2.5 Complementary Transformations

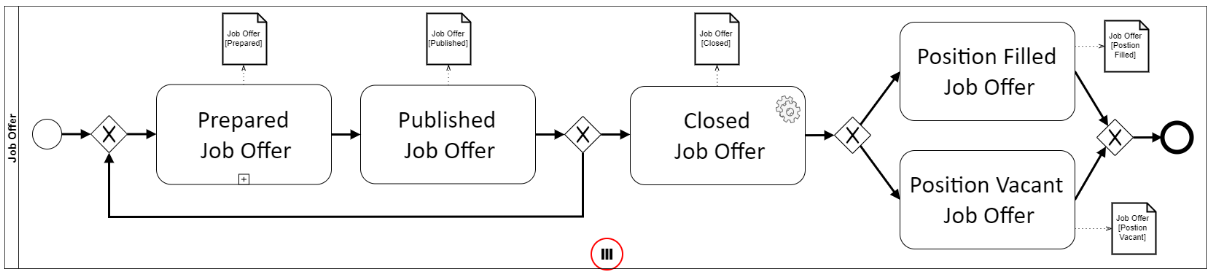

Abbildung 4.10: Initial example

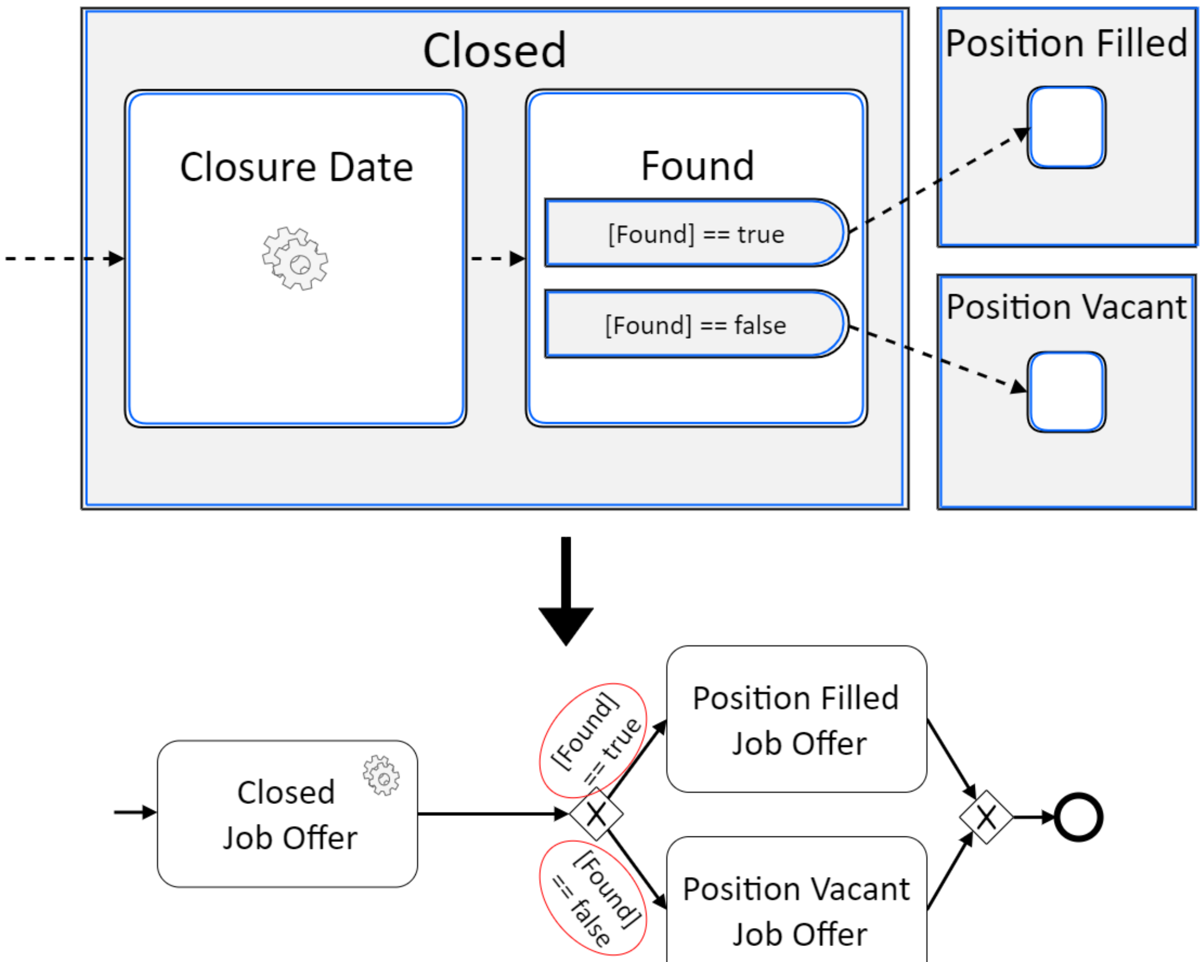

Abbildung 4.11: Initial example

4.3 Permission Integration

4.4 Relation Integration

4.5 Robotic Process Automation

4.6 Transformation Algorithm

Algorithm 3 Step One (S1)

```
Require: $\Omega$
  $\mathrm{P} \leftarrow \perp$
  for $\omega \in \Omega$ do
      $\rho \leftarrow (\omega, \mathrm{n}_\omega, \perp)$
      $\mathrm{P}.add(\rho)$
  end for
  for $\rho \in \mathrm{P}$ do
      $\rho.\delta \leftarrow OTA(\rho.\omega)$
  end for
  return $\mathrm{P}$
```

5 Implementation

- Explain Algorithm in words and provide Pseudocode

6 Evaluation

6.1 Functional Requirements

6.2 Non-Functional Requirements

6.3 Limitations

7 Related Work

8 Conclusion

8.1 Contribution

8.2 Outlook

A Attachments

In diesem Anhang sind einige wichtige Quelltexte aufgeführt.

```
public class Hello {
    public static void main(String[] args) {
        System.out.println("Hello World");
    }
}
```

Literatur

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Erklärung

Ich erkläre, dass ich die Arbeit selbständig verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel verwendet habe.

Ulm, den ....

Marko Pejic