9 Conclusion

In this book we have explored the conceptual and logical modeling of multilevel business processes. We have examined the automation of multilevel business processes and the use of the generated event log data for performance analysis. With respect to existing methodologies, the multilevel business artifact (MBA) allows for a better representation of dependencies between the various hierarchy levels within a company; the concretization mechanism provides flexibility while preserving the advantages of homogeneous models. The fundamentals of multilevel business process management being established, future work will further extend multilevel business process modeling techniques and investigate applications.

9.1 Summary

Companies perform value-creating activities at various hierarchy levels within an organization. These activities are interconnected and depend on each other, constituting a multilevel business process. At each hierarchy level, different data objects are involved in the multilevel business process. These data objects are hierarchically-organized, their order reflecting, to a certain extent, the organization hierarchy. The MBA modeling approach adopts a multilevel modeling technique in order to obtain an artifact-centric representation of multilevel business processes. This representation makes explicit, in the form of multilevel predicates, the synchronization dependencies between the activities at different levels within the hierarchy.

Rather than imposing a single fixed process, process models must account for the variability of real-world business problems. Each MBA represents the homogeneous schema of an entire hierarchy of business artifacts. Multilevel concretization allows for the introduction of heterogeneities in sub-hierarchies of business artifacts, which still comply with the homogeneous global schema. A concretizing MBA then constitutes a variant of an entire sub-hierarchy of business artifacts. The concretizing MBA also becomes the homogeneous model for this sub-hierarchy, which may again be concretized. At the same time, an MBA may associate different variants of life cycle models at different

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levels. By modeling meta-process activities in the life cycle models, the flexibility of the concretization mechanism may be deliberately restricted in order to enforce compliance with company-wide business policies.

A conceptual MBA model translates into an XML-based logical representation, using State Chart XML as the modeling language for the life cycle models at the different levels. The logical representation serves as the basis for the (semi-)automated execution of multilevel business processes, thereby producing event log data which enable performance analysis for multilevel business processes. Business analysts conduct slice and drill-down operations along a concretization hierarchy. Different sub-hierarchies may capture process performance data at a finer granularity.

9.2 Discussion

Multilevel modeling relaxes the restriction to two-level instantiation of traditional conceptual modeling, allowing for an arbitrary number of metalevels [59]. Adopting a *multilevel modeling* approach may prove beneficial in many practical, real-world situations. To multilevel business processes, the following patterns (see [59]) apply: (1) *type-object*, the dynamic introduction of types, (2) *dynamic features*, the dynamic introduction of features for a type, (3) *element classification*, application of specialization in the presence of the type-object pattern. More specifically, multilevel concretization, with its aggregation, instantiation, and specialization facets, embodies the type-object and element classification pattern. By explicitly representing meta-process activities in the life cycle model, MBAs realize the dynamic features pattern.

In general, an operational business process has a corresponding *management process* [42, p. 297 et seq.]. In analogy to the arbitrary number of metalevels in multilevel data modeling, multilevel business process modeling enables modeling of an arbitrary number of management levels. Each level of an MBA represents a management process for the lower levels. Furthermore, MBAs also represent the *process management processes* [42, p. 299 et seq.] for each level, meta-processes the output of which are again process models [101]. Each level of an MBA may represent, by modeling transitions with reflective methods as trigger, a meta-process for the lower levels.

With respect to the four-worlds framework for process engineering [101], we characterize multilevel business process management as follows. The *subject world* of multilevel business process management consists of business processes at various organizational levels within a company as well as the interactions between processes at different levels. Concerning the *usage world*, in the process model domain, MBAs represent the conceptual model of multilevel business process management. MBA-based business process models have a descriptive purpose in the sense that they aim for a better description of the interdependencies between organizational levels; they have a prescriptive purpose in the sense that they describe legal execution orders of the methods of data objects. The XML representation of MBAs serves as the logical format in the model enactment domain and as the fundamental for the business process management activities associated with the process performance domain. Concerning the *system world*, the MBA-based representation adopts a data- or artifact-centric view. The level of detail of the business process descriptions as well as the modeling language may vary. Concerning the *development world*, MBA-based modeling is a top-down, hetero-homogeneous approach for the representation of abstraction hierarchies of data objects as well as their life cycle models, allowing for the local introduction of heterogeneities in an otherwise homogeneous model.

In practice, a multitude of use cases for business process management exist. The multilevel approach to business process modeling covers the following use cases (see [2] for use cases): (1) *design model*, the MBA serves as the conceptual representation, (2) *refine and enact model*, an XML representation of MBAs allows for multilevel business process automation, (3) *select model from collection*, concretization hierarchies organize business process models, (4) *design configurable model*, an MBA may associate several business process model variants with each level, (5) *log event data and analyze performance using event data*, the (semi-)automated MBA-based execution of business processes produces event data which can be used for analysis.

The PHILharmonicFlows framework [57, 56] provides an integrated perspective on data and business process. Object-relational data models represent the data. From the relationships between data objects in the data model derives a classification of data objects into *data levels* which are similar to the levels of abstraction in the MBA approach. The coordination concepts of process context and aggregation [56, p. 245] correspond to the use of multilevel predicates over states of ancestors and descendants in pre-conditions of the transitions of an MBA's life cycle models. The MBA approach, in addition, provides a mechanism and guidelines for handling heterogeneities in the hierarchical organization of data objects as well as in data and life cycle models. For specific partitions of data objects, the level hierarchy may comprise additional levels with specialized data and life cycle models. As opposed to data levels in PHILharmonicFlows, which are determined by relationships between data objects, level hierarchies of MBAs result from an explicit top-down definition of levels.

The map-driven approach towards business process modeling is goal-oriented, a map consisting of intentions and sections [103]. An intention specifies what is to be achieved by performing the process, a section models the application of a strategy to a particular situation in order to achieve an intention. The map approach relies on stepwise refinement for the modeling of business processes [83]: Another map may refine an individual section of a map. In a spiral, maps are recursively refined. A map of the current situation and a map of the desired situation serve as the basis for the identification of sections that need refinement. Each of these sections is then refined by a map which serves as the input for a new spiral iteration. In the course of such an iteration, individual sections of the map are further refined. In connection with the MBA-based modeling approach, the map approach may assist with the definition of the life cycle models of the individual levels of an MBA, recursively refining the various states of a level. In this sense, the map approach is orthogonal to the MBA-based approach. On the other hand, the MBA-based modeling approach allows for an incremental specification of business process models. The MBA-based approach, however, places focus on the preservation of heterogeneities in well-defined partitions of the data while, at the same time, describing the common elements of all data objects.

9.3 Future Work

In many cases, a company will already have some sort of representation of their business processes. Therefore, *multilevel business process discovery* techniques will obtain multilevel business process models from existing process descriptions. The thus obtained multilevel business process models constitute views over existing models. The advantage of these views is twofold. First, they provide an explicit representation of synchronization dependencies between life cycle models at different levels of abstraction. Second, the hetero-homogeneous nature of the obtained data models may present advantages for performance analysis.

A process cube organizes event log data in a multidimensional space, allowing for slice, roll-up, and drill-down operations on the business process models obtained through process mining [4]. Process cubes present similarities to previous work [113] on ontology-valued measures in OLAP cubes, which organizes business models in the cells of an OLAP cube, thereby allowing for the combination of knowledge from different contexts. Future work will introduce the notion of *hetero-homogeneous process cube*, building on existing work about hetero-homogeneous OLAP cubes [80].

Game development and graphics programming are other potential application areas for the MBA-based modeling approach. More specifically, the representation of action state machines [35, p. 621 et seq.] may benefit from the use of MBAs and hetero-homogeneous models. Action state machines abstract from low-level programming of animations, for example, of bodies and body parts, and allow for a more model-driven approach towards graphics programming. As many complex animated objects are composed of multiple individual components with different kinds of movement which interact with each other, the representation of such objects using multilevel models seems only logical. The hetero-homogeneous nature of MBAs may increase flexibility and code reusability in graphics programming.

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