3.3 Relating Data & Time

Aspects regarding time dependency of data have been extensively examined in the field of temporal databases. Here, we adapt the notions and definitions developed in that area (see Steiner, 1998; Liu and Özsu, 2009). According to them, any dataset is related to two temporal domains:

- internal time $\mathfrak{T}_i$ and
- external time $\mathfrak{T}_e$.

Internal time is considered to be the temporal dimension inherent in the data model. Internal time describes when the information contained in the data is valid. Conversely, *external time* is considered to be extrinsic to the data model. The external time is necessary to describe how a dataset evolves in (external) time. Depending on the number of time primitives in internal and external time, time-related datasets can be classified as shown in Figure 3.30.

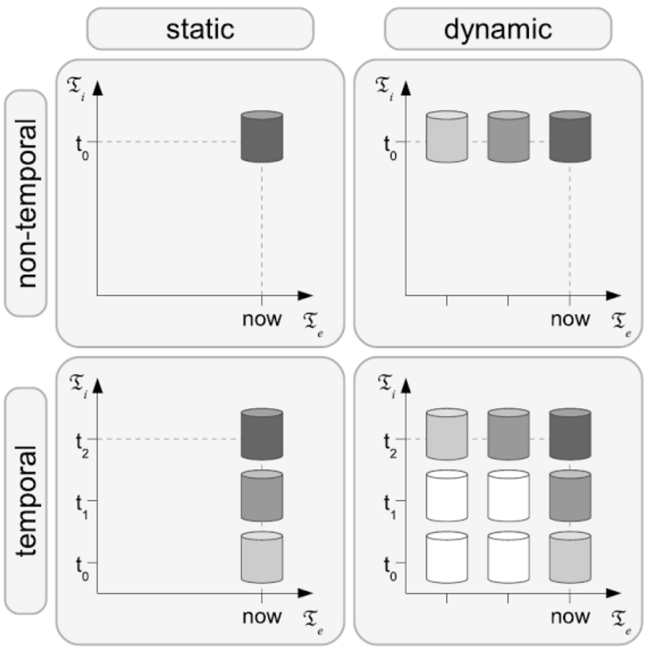

Fig. 3.30 Temporal characteristics of time related data. A dataset is related to the two temporal domains internal time $\mathfrak{T}_i$ and external time $\mathfrak{T}_e$. *Source: Adapted from Steiner (1998).*

Static non-temporal data If both internal and external time are each comprised of only one temporal element, the data are completely independent of time. A fact sheet containing data about the products offered by a company is an example of static non-temporal data. This kind of data is not addressed in this book.

Static temporal data If the internal time contains more than one time primitive, while the external time contains only one, then the data can be considered dependent on time. Since the values stored in the data depend on the internal time, static temporal data can be understood as an historical view of how the real world or some model looked at the various elements of internal time. Common time-series are a prominent example of static temporal data. Most of today's visualization approaches that explicitly consider time as a special data dimension address static temporal data, for instance the TimeSearcher (see Hochheiser and Shneiderman, 2004 and ↪ p. 188).

Dynamic non-temporal data If the internal time contains only one, but the external time is composed of multiple time primitives, then the data depend on the external time. To put it simply, the data change over time, i.e., they are dynamic. Dynamic data that change at high rate are often referred to as *streaming data*. Since the internal time is not considered, only the current state of the data is preserved; an historical view is not maintained. There are fewer visualization techniques available that explicitly focus on dynamic non-temporal data. These techniques are mostly applied in monitoring scenarios, for instance to visualize process data (see Matković et al., 2002 and ↪ p. 222). However, since internal time and external time can usually be mapped from one to the other, some of the known visualization techniques for static temporal data can be applied for dynamic non-temporal data as well.

Dynamic temporal data If both internal and external time are comprised of multiple time primitives, then the data are considered to be bi-temporally dependent. In other words, the data contain variables depending on (internal) time, and the actual state of the data changes over (external) time. Usually, in this case, internal and external time are strongly coupled and can be mapped from one to the other. Examples of such data could be health data or climate data that contain measures depending on time (e.g., daily number of cases of influenza or daily average temperature), and that are updated every 24 hours with new data records of the passed day. An explicit distinction between internal and external time is usually not made by current visualization approaches, because considering both temporal dimensions for visualization is challenging. Therefore, dynamic temporal data are beyond the scope of this book.

3.4 Summary

In this chapter, we structured and specified the characteristics of time and time-oriented data. We approached this from three perspectives: First, we characterized time and time models by discussing the related design aspects and abstractions. Second, we presented relevant data aspects and third, we analyzed different types of time-orientation. Figure 3.31 summarizes these perspectives and their corresponding aspects.

The first perspective mainly addresses time and the complexity of modeling time. Therefore, we needed to clarify the concepts of scale, scope, arrangement, and viewpoints in order to specify the design space, and to define granularity and calendars, time primitives, as well as temporal relations and determinacy of temporal elements in order to specify the abstractions.

The second perspective focuses on relevant aspects of the data variables using the understanding of time models explained above. This resulted in the definitions of