Case Study

USAGE PROFILES FOR SYSTEM REQUIREMENTS

Understanding how the customer uses the system, and how its behavior deviates from the expected (and designed) behavior, is the main question that Philips MR wanted to answer by usage profiling. Philips MR is a division of Philips Healthcare that builds systems for magnetic resonance imaging (MRI). MRI is a non-invasive diagnostic imaging method.

MR systems (see Figure 1) are heavily parametrized. This means that scan parameters like position, orientation, etc. can have different values configured for different applications. Furthermore, new methods appear constantly and guidelines for the usage of the MRI with respect to a particular diagnostic are vague most of the time.

Therefore, usage profiling for an MR system starts with answering how one can define usage. To be able to define 'system usage' in a way that it can be understood by the application specialists, we needed to overcome two main challenges:

1. The low-level scan parameters had to be translated into meaningful activities.

2. The ability of process mining to look at sequences of these activities was crucial to analyze the usage profiles in the context of the medical guidelines.

Figure 1: Philips MRI Scanner

- **Process Mining application for medical device usage profiling**
- **Ability to look at sequence of scans proved crucial for the application specialists**
- **Key success factor was the abstraction of the event data**

Data Abstraction

The MR system records very detailed information about which functions are used on the device and when. From a process mining perspective, the case ID is the so-called exam ID corresponding to a patient examination. The timestamps that are needed for process mining are also there. However, for the activity name this event data is too detailed (and too technical) for the application specialists who need to interpret the usage of the system from a medical perspective.

To bridge this gap, we took a step back and looked at how an application specialist looks at the usage process. An MRI examination is defined by its purpose (the diagnostic part) and by the applied methods. Therefore, we chose to abstract the purpose in terms of the anatomic region (the body part) that needs to be imaged. In terms of the method, practitioners use a set of scans to produce multiple images that will later on provide evidence for/against a particular diagnosis. So, from the many recorded events we only needed the actual scans.

For the scan events there were also a lot of parameters recorded. For example, the orientation or the contrast of the image can be configured differently for two different scans. Each scan is in fact defined by these parameters from a medical perspective. Different parameter combinations can be stored and configured when the machine is set up (and later during the usage period) to be re-used for different applications.[1]

So, the usage of an MRI system is defined by the performed examinations. At the lowest level, the usage is thus represented by the parameters of a scan. However, when trying to use all parameters used for a scan to define a scan we realize that comparing two scans becomes a highly complex task for two reasons: 1) for a specific scan, in average, less than 10% of the parameters are used and, 2), the parameter types are highly heterogeneous: categorical, numerical and Boolean.

A solution to the above challenges was found by mapping the logged parameters to so-called “tags” defined by MRI literature and, at the same time, selecting a reduced number of tags to represent a scan. For the mapping and selection, we used input from medical guidelines and practitioners.

This approach made scan parameters easily understandable by practitioners and facilitated an exam analysis based on expected behaviour and medical guidelines.

From Scan Parameters to Profiles

Figure 2 shows the implemented workflow to define and analyze the usage profiles. First, we defined a mapping from the actual scan parameters to “tags”. We use domain-specific language (DSL) technology (represented by a combination of Xtext/Xtend) to allow Philips specialists to define the mapping. Once such a mapping is created, the framework automatically generates python code that tags the extracted data.

[1] Note that the set of parameters available for a scan depend on the characteristics of a particular system. Therefore, we decided to focus our investigation on a particular system release.

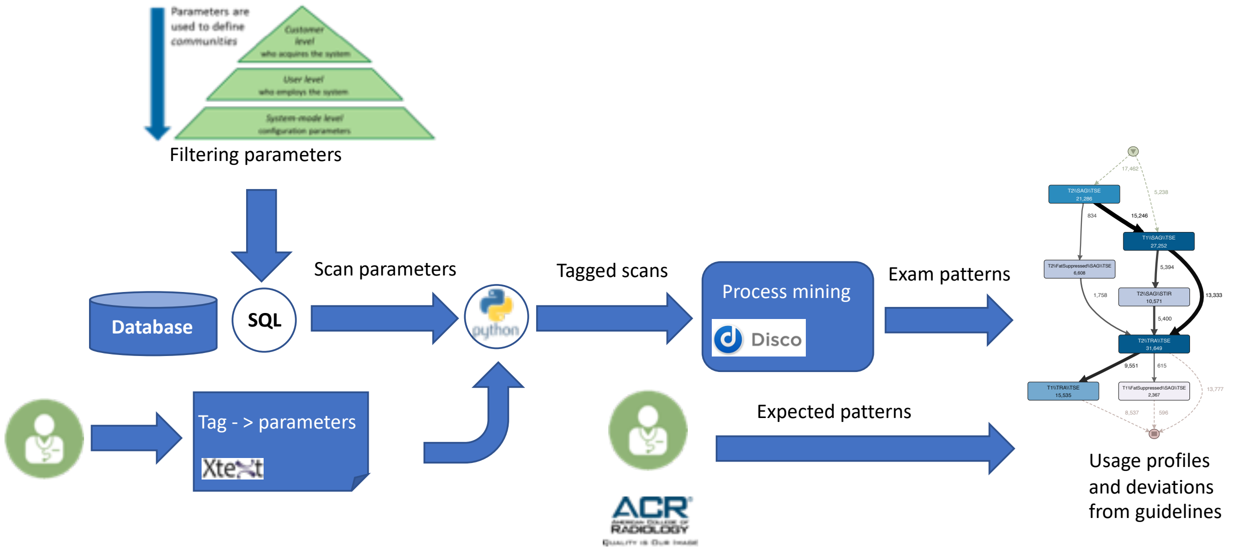

Figure 2: Processing workflow for creating usage profiles

This processed data could now be analyzed with process mining techniques, because the activities were on the right level that MRI specialists could understand.

The big benefit of process mining is that to understand the usage profile of an MRI application you actually need to look at the sequence of scans (not just an individual scan). There could be same type of scan used in the context of a knee MRI as well as for a spine MRI, but the sequence will be different. So, to judge the usage profile one needs to look at the sequences of scans and this is what process mining now allows the application specialists to do.

Figure 3 shows a process map that was created based on the tagged data. Each activity is defined by a combination of tags[2]. The top-most activity node consists of the tags “T2”, “SAG”, and “TSE”, which each refer to parameter configuration in the scan. If the parameter configuration is different than the tag will be different. For example, “T1” and “T2” are two different tags referring to different configurations of the same parameter in the scan.

Once the usage profile is obtained, a practitioner can compare the workflow with known medical guidelines (such as the ones provided by American College of Radiology – ACR).

Figure 4 shows an excerpt of the medical guideline for the MRI of an adult spine. This is the medical guideline that belongs to the usage profile shown in Figure 3. For example, the “T1” and “T2” in the medical guideline refer to the the same tag that has been matched from the event data in the discovered process map.

Note that the thickness of the edges in the process map in Figure 3 is correlated to the number of direct relations between the scans. The thicker the edge, the more frequently the relation is observed in the data.

[2] To combine multiple columns into the activity name, these columns are all configured as ‘Activity' during the import.

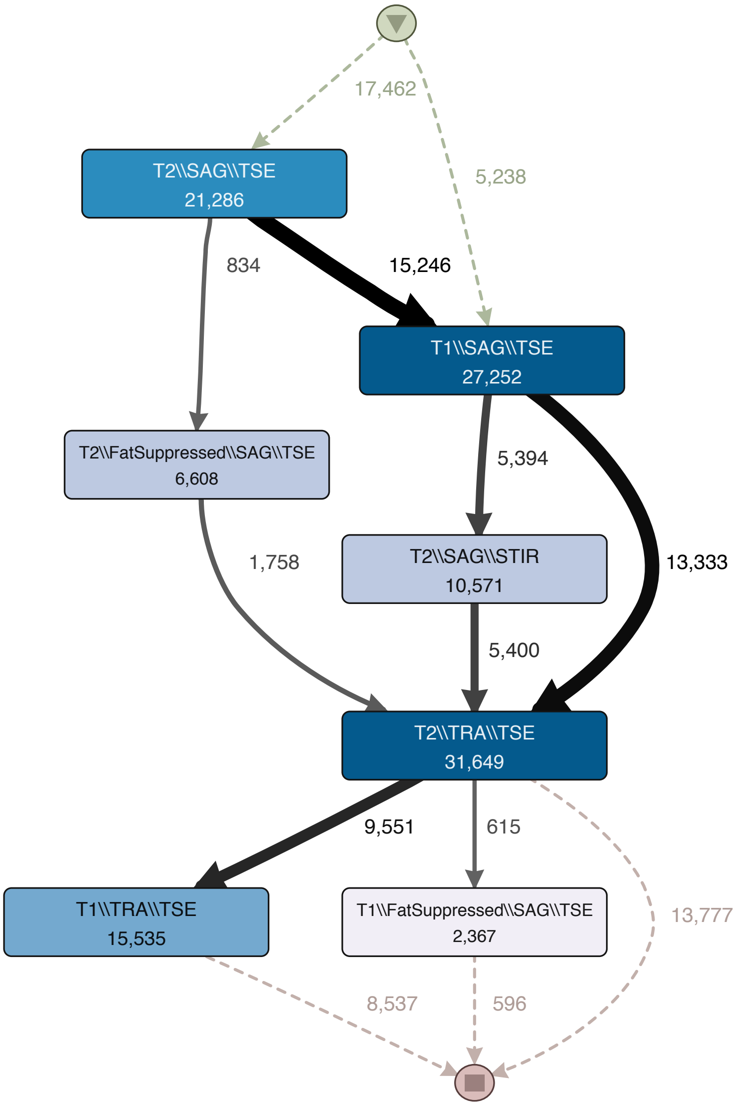

Figure 3: Usage profile created through process mining software Disco

It is easy to observe that most typical workflow is the one indicated in the guidelines: T1 Sagittal => T2 Sagittal => T2 Transversal (or Axial). However, a number of deviations are observed. These deviations are currently investigated by practitioners to understand whether there are special workflows employed by certain practitioners or there are anomalies due to system/user error.

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Minimum recommended pulse sequences for evaluating the spine for pain, radiculopathy, or suspected stenosis may include:

a. Cervical/thoracic spine
   -Sagittal T1-weighted
   -Sagittal T2-weighted or T2*-weighted
   -Axial T2-weighted or T2*-weighted
b. Lumbar spine
   -Sagittal T1-weighted
   -Sagittal T2-weighted or T2*-weighted
   -Axial T1-weighted and/or T2-weighted

In postoperative cases for differentiating scar from disk, postcontrast sagittal and axial T1-weighted series with or without fat suppression are useful. When evaluating spinal bone marrow for tumor, sagittal T1-weighted sequences, as well as short TI inversion recovery (STIR) sequences, fat-suppressed T2-weighted fast-spin-echo sequences, or other fat suppressed acquisitions are recommended. In addition, a contrast-enhanced or a fat suppressed contrast enhanced study can evaluate extraosseous extension of a neoplastic process. When evaluating soft tissues after trauma or surgery, STIR or other T2-weighted fat-suppressed fast-spin-echo sequences are recommended.

Figure 4: Excerpt from “ACR-ASNR-SCBT-MR practice parameter for the performance of magnetic resonance imaging (MRI) of the adult spine” (https://www.acr.org/-/media/ACR/Files/Practice-Parameters/MR-Adult-Spine.pdf)