# Knowledge Representation and Processing in Intelligent Software Measurement System (ISMS)

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## Abstract

*Intelligent Software Measurement System (ISMS) is an agent-based system that is able to automatically produce a software measurement implementation plan based on users' initial business or measurement goal(s). The ISMS is composed of a Personal Assistant agent (PA) as the client interface, and a cluster of Expert Assistant agents (EA). The PAs provide users with simple business goals template for selection, and then through communication with the EAs they proceed to the goal(s). A central component of EA is the Knowledge Base (KB). We present a step by step methodology for building the knowledge base for ISMS. Unlike conventional knowledge based systems, the knowledge base in ISMS is composed of a series of relational tables, weights and factual rules. Automated learning and update mechanisms are also provided for performance improvement.*

***Keywords:*** *Knowledge representation, Knowledge processing, goal-driven software measurement.*

## 1. INTRODUCTION

Software measurement, in order to be effective, must be [4] focused on specific goals; applied to all life-cycle products, processes and resources; and interpreted based on characterization and understanding of the organizational context, environment and goals [4].

The Goal-Question-Metric (GQM) was developed in response to the need for a goal-oriented approach that would support the software measurement. A GQM model starts with a measurement goal. The goal is refined into several questions, and then each question is refined again into metrics.

For measurement to be cost effective, it must be designed and targeted to support the Business Goals of the organization [1]. Goal-Driven software measurement, which is a 10 steps GQM-centric process, is able to help users find and define software measurement that directly supports the organization's business goals. These measurements are traceable back to the business goals, so that the data-collection activities are better focused on users' intended objectives.

The 10 steps of Goal-Driven process are organized into three sets of activity (Fig. 1.): identifying goals, defining indicators and data needed to produce them, and creating an action plan to guide the implementation [6]. The first set of activities translate business goals into quantifiable measurement goals. The second set of activities produce a measurement plan that is aligned with the organizations' business processes. Successful design and implementation of this plan depends on experience of the measurement team. Identifying relevant questions, grouping questions, refining subgoals, identifying entities and attributes, formalizing measurement goal, and defining quantifiable questions and related indicators [1] all require measurement team members' knowledge and experience.

The Intelligent Software Measurement System (ISMS) is developed following the Goal-Driven Software Measurement Process. In the ISMS project we automate the 10 steps of the process. The main development tasks of ISMS are eliciting the knowledge and experience from software measurement experts, representing it in a flexible yet well-structured way, and building a knowledge base infrastructure for the system. Using the knowledge infrastructure, ISMS provides users with a series of interactive screens and views which guide them through the Goal-Driven process.

This paper presents a methodology for building the knowledge base of ISMS, which helps users obtain measurement goals from business goals.

## 2. KNOWLEDGE REPRESENTATION

### 2.1 Domain analysis

In order to build a knowledge base for intelligent systems, firstly we must understand the domain well enough to confirm what entities and facts are necessary to be discussed and what material can be ignored [2]. In

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this case, within the domain of goal-driven software measurement, our main purpose is finding out measurement goals to support the corresponding business goal. We follow a five-step procedure for implementing this target.

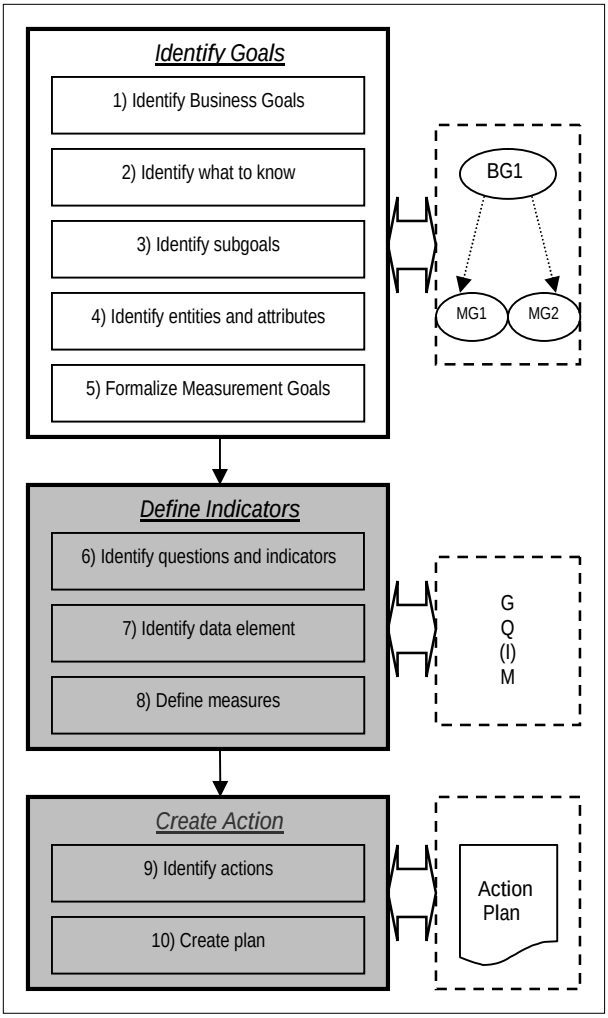


**Fig. 1. Goal-Driven software measurement process.**

With the business goal identified, the second step is identifying the necessary information that related to the activities in order to achieve the business goal. This is done by asking entity-questions. After that, based on the pre-defined grouping keywords, above questions are grouped under several categories, which are manageable subgoals. The next step is to use the prioritized subgoals and entity-questions to refine entities and attributes. Finally, by collecting this information with purpose, perspective and environment elements, we can formulize measurement goals to support our original business goal.

By the analysis of the process, all the elements needed to achieve the goal can be identified. For this, the initial input is business goal, and the terminal output is measurement goals. Besides the input and output, there are a set of objectives related to every step. Each objective is described by one or more dimensions shown in Table 1.

**Table 1. Objectives and dimensions**

| | Objectives | Dimensions |
|---|---|---|
| 1 | Business goal | - Business goal |
| 2 | Entity-Question list | - Entity-Questions |
| 3 | Subgoal | - Grouping keywords<br>- Subgoals |
| 4 | Entity/Attribute | - Entities<br>- Attributes |
| 5 | Complete measurement goal | - Purpose<br>- Perspective<br>- Environment |

## 2.2 Organizing knowledge

We have broken the domain into five smaller clusters of knowledge.

- **Business goal:** The target of an organization, that the organization is able to reach [1].
- **Entity-Question list:** A list includes important process entities and a set of questions related to entities for supporting the business goal [1].
- **Subgoal:** The manageable convergent category title, by which entity-questions can be grouped and then the issue they address can be identified. The grouping keywords are the index of grouping procedure.
- **Entity/Attribute:** The entities that are implicit in the questions and the pertinent attributes related to objectives. The pairs of entity and attributes are potential objects of measurement.
- **Measurement goal:** A five dimensions goal based on the general corporate objectives, which includes object of interest (entity), quality focus (attribute), purpose, perspective, and environment description [3].

## 2.3 Refining relationship

We used the reverse engineering technique to translate business goal into the five tuples of the measurement goal from the original business goal. Formal measurement goals come from integration of entities, attributes and other information. The necessary entity-attribute pairs are identified from entity-questions, and these questions have been grouped under some prioritized and elected subgoals. The goal of setting entity-question list is to find associated entities in order to support business goals.

In the five dimensions of a measurement goal, the purpose, perspective, and environment context are easily figured out by user. The remaining two, entity and attribute, both are included in entity-question list. Hence, these activities form a "question-centric" process. Therefore, it is important to define a well entity-question template including entity and attribute information.

On the other hand, the above process is a pipeline, whose workflow consists of a single swim lane [5]. Therefore, we need to build templates for each step to describe the content and relationship between it and its adjacent steps.

**2.3.1 Business goal template.** For business goal, according to its depth and granularity, it can be defined at any level. But in practice, it is usually set intuitively and with a particular business target in mind. We have set 3 categories of high level business goals: enhancement of a positive target, reduction of a negative target, and achievement of official standard.

**2.3.2 Entity-question list template.** With the identified business goal, we enumerate entity-questions to obtain the quantitative information to achieve the goal. Before the questions can be set up, we should define the perspective and then, we list all entities addressed in four categories: inputs and resources, products and by-products, internal artifacts, and activities and flow paths [1]. All the questions are asked for the better understanding of an attribute that is related to the entity included in the questions.

**2.3.3 Subgoal template.** That grouping questions based on entities, and translating them into manageable subgoals is a convergent process. We define a set of grouping keywords and the corresponding subgoals to organize the questions.

**2.3.4 Entity-attribute template.** The elements of entity and attribute are derived from entity-questions. Therefore, the entity-attribute pairs are related to questions, subgoals, and grouping keywords. All the above tuples are included in this template.

**2.3.5 Measurement goal template.** We organize the five dimensions and represent a measurement goal as the following template: Analyze the *ENTIEY* with respect to the *ATTRIBUTE* from the *PERSPECTIVE* for the *PURPOSE* in the *ENVIRONMENT*. [4]

## 2.4 Setting relational tables

For describing all elements and the relation among them in the five steps, we assume there is a mental big map. In this map, we would see that an identified business goal is supported by a set of questions, which include perspectives, entities, attributes, and grouping keywords. Indexed by grouping keywords, these questions are cataloged into some subgoals. With the prioritized and selected questions, three dimensions of measurement goals can be abstracted, and then with the purpose and environment information, formal measurement goals are derived. In the ISMS project, all the knowledge and relations from business goal to measurement goals are represented and implemented by these tables.

According to the pipeline style of goal-driven process, we can break the mental big map into some small tables. After the templates for the five steps are defined, we enumerate all meta-elements following the templates, and identify both input and output for each step. Further, we set some relational tables (Table 2. to Table 5.) to associate the isolated information between the adjacent steps to each other.

**Table 2. Business goal-question table**

| Business Goal | Questions | | |
|---|---|---|---|
| Reduce cost | Q1. How many people are necessary? | ... | Qn. … … …. |

**Table 3. Question – keyword - P/E/A table**

| Question | Grouping Keyword | Perspective | Entity | Attribute |
|---|---|---|---|---|
| How many people are necessary? | People | Project manager | People | Number |

**Table 4. Question - keyword - subgoal table**

| Question | Grouping Keyword | Subgoal |
|---|---|---|
| How many people are necessary? | People | Improve human resource management. |

**Table 5. Measurement goal table**

| Environment | Purpose | Perspective | Entity | Attribute |
|---|---|---|---|---|
| ... | Predict | Project manager | People | Number |

# 3. KNOWLEDGE PROCESSING

## 3.1 Goal question relationships

So far we have reverse engineered the process and extracted the knowledge and the possible solution for specific problems. Now it is necessary to apply the

knowledge in a forward engineering way to help user with a business goal. The entity question table set will help us with this. Table 6. is a portion of entity-question weights form, which is a 3-D relational table. This table reflects the tightness degree of the relationship between the entity-questions and a specific business goal from different perspectives. In this table, all questions are given weights, whose scale is from 0 to 4; the larger the number means the tighter the relation. By the weight, the relation between questions and business goals is described and stored. For an identified business goal, with predefined criteria, a subset of related questions can be selected from the complete entity-question list.

## 3.2 System learning and updating

The Users of ISMS use the GQM analysis to receive a measurement plan from goals they entered into the system. They will receive feedback for each step of the GQM method. Particularly, there is also the option of skipping GQM steps if the result has been previously used. ISMS can record all the original business goals, and the information asked by system, also the solutions would be stored. Further, if the input information were repeated in any project, system would provide the final solution automatically based on the knowledge that system learned from previous projects. In this case, the human-machine communication in some GQM steps can be skipped.

In addition to general users' functionality, the expert users will be able to add, modify, and delete their own entries in their own changeable knowledge base. After reviewing and verifying by the administrator of ISMS, the knowledge will be combined with system knowledge base for update.

## 4. CONCLUSIONS

The main purpose of ISMS is to automate the GQM process by building an intelligent system that accepts a business goal as its input and produces a measurement plan as its output. This paper introduced a method to build knowledge base for this system. By analyzing the software measurement domain, defining vocabulary and refining relationship we could reverse engineer the GQM process. In this system, the knowledge about goal-driven process is represented by relational tables. We processed the knowledge using weight tables and combinational methods. This is relatively different from and more flexible than the conventional rule-based expert systems because the system self-learning and updating functionality of the knowledge base is implemented and the consultation functionality by combining knowledge from multiple experts is included in the ISMS system.

**Table 6. Entity-question weights**

| Business Goal: Enhance product quality | Perspectives | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | User | Customer | Manager | Developer | Organization | Tester | Maintainer | Quality Manager |
| Questions | | | | | | | | |
| Is personal turnover hampering our goal? | 0 | 0 | 4 | 4 | 4 | 4 | 4 | 4 |
| How many people are necessary? | 0 | 0 | 4 | 4 | 4 | 3 | 3 | 3 |
| Are the people over-worked? | 0 | 0 | 4 | 2 | 4 | 2 | 2 | 4 |
| How is productive of the people currently? | 0 | 0 | 4 | 2 | 4 | 2 | 2 | 4 |
| In what area do the people need improve? | 0 | 0 | 4 | 2 | 4 | 2 | 2 | 4 |
| How is efficiency of the people currently? | 0 | 0 | 4 | 2 | 3 | 2 | 2 | 4 |
| Are the people motivated? | 0 | 0 | 4 | 2 | 3 | 2 | 2 | 4 |
| How is experience of the people currently? | 0 | 0 | 4 | 2 | 3 | 2 | 2 | 4 |
| How much the people are paid? | 0 | 0 | 4 | 2 | 4 | 2 | 2 | 3 |
| How is performance of the people currently? | 0 | 0 | 4 | 2 | 3 | 2 | 2 | 4 |

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