

Intuitionistic Fuzzy Extensions to the Information Technology Infrastructure Library Configuration Management Database

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1. Introduction

Information Technology Infrastructure Library (ITIL®) is the de facto standard in Service Management. ITIL is a process oriented; quality focused; public domain; best practices framework. It was developed in late 1980's as a guide to the UK government and since then, the framework is used worldwide. ITIL principles are the basis for BS15000 and the currently developed ISO 20000.

Configuration management is an integral part of all other ITIL processes. According to [1] configuration management aims to assist with managing the economic value of the IT services by maintaining a logical model of the IT infrastructure and IT services, and providing information about them to other business processes. Configuration Management implements this by identifying, monitoring, controlling and providing information about Configuration Items and their versions.

In the terminology of Configuration Management, IT components and the services provided with them are known as Configuration Items (CIs). Each IT component is considered a CI.

As shown in Fig1, CIs can include hardware, software, active and passive network components, servers, documentation, services and all other IT components.

The scope of Configuration Management can be extended to include Information Systems rather than only Information Technology and in this case IT users, IT staff and business units can be considered CIs as well.

All CIs are included in the Configuration Management Database (CMDB). The CMDB keeps track of all IT components and the relationships between them. In its most basic form, a CMDB could consist of paper forms or a set of spreadsheets.

The relationships between CIs are useful for diagnosing errors and predicting the availability of services. Many different logical and physical relationships can be recorded.

Physical relationships:

- Forms part of: this is the parent/child relationship of the CI, e.g. a floppy disk drive forms part of a PC, and a software module forms part of a program.
- Is connected to: e.g. a PC connected to a LAN segment.
- Is needed for: e.g. hardware needed to run an application.

Logical relationships:

- Is a copy of: copy of a standard model, baseline or program.
- Relates to: a procedure, manuals and documentation, a SLA, or customer area.
- Is used by: e.g. a CI needed for providing a service, or a software module which is called by a number of programs.

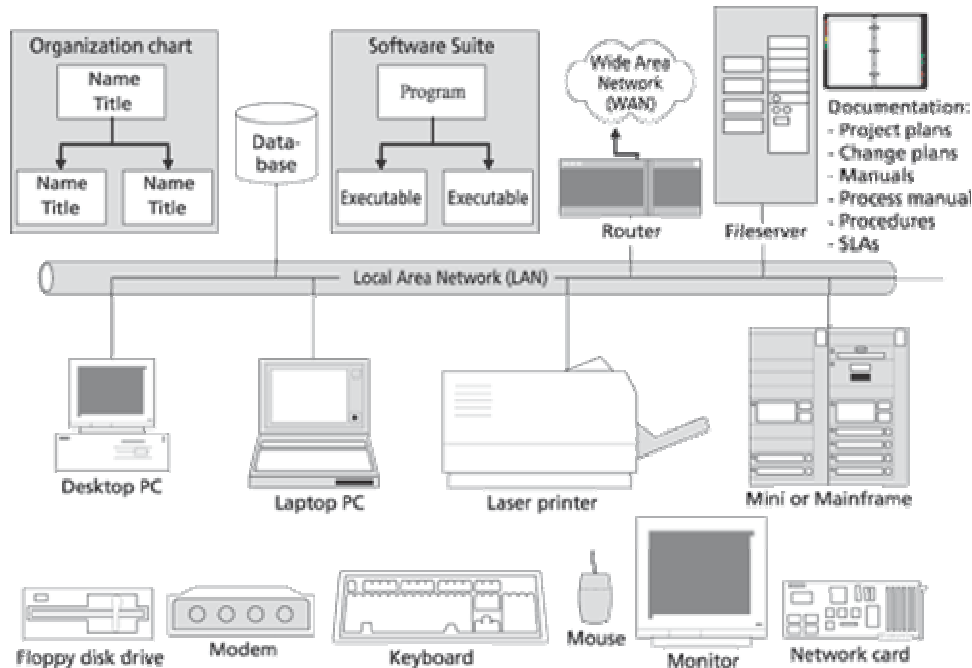


Fig. 1. Configuration Items

There can be many other types of relationships that help in different ITIL processes and activities. In this paper we focus on two of the most important ones: impact analysis and troubleshooting.

We introduce a new type of relationship between the CIs that describes the impact that one CI has on another. The meaning of the relationship is “In case of CI₁ failure what is the probability of CI₂ failure?”. Considering this, we will introduce the notion of partial impact between components, expressed by means of intuitionistic fuzzy values carrying probabilistic information.

This new type of relationship should be stored in the CMDB and that is why we propose a new Intuitionistic Fuzzy CMDB (IFCMDB) model. It extends the usual CMDB model by adding intuitionistic fuzzy relationships between the CIs. This model allows us to approach impact analysis and troubleshooting in a different way.

The theory of intuitionistic fuzzy sets (IFS) is proposed by K. Atanassov in [3] as an extension of the classical fuzzy sets theory. Each element of an intuitionistic fuzzy set has degrees of membership (μ) and non-membership (ν), which don't sum up to 1 thus leaving a degree of indefiniteness ($\pi = 1 - \mu - \nu$). A classical fuzzy set is a particular case of an IFS, where $\pi = 0$.

$$\begin{aligned} 0 &\leq \mu \leq 1; \\ 0 &\leq \nu \leq 1; \\ 0 &\leq \mu + \nu \leq 1. \end{aligned}$$

Let a and b be intuitionistic fuzzy logical statements with estimations respectively $\langle \mu_a, \nu_a \rangle$ and $\langle \mu_b, \nu_b \rangle$, where μ_a is the degree of truth and ν_a is the degree of falsity of statement a . The logical operations conjunction (&), disjunction (\vee) and negation (\neg) are defined in two variants (classical and probabilistic) as follows:

<i>Operation</i>	<i>classical</i>	<i>probabilistic</i>
$a \ \& \ b$	$\langle \min(\mu_a, \mu_b), \max(\nu_a, \nu_b) \rangle$	$\langle \mu_a \cdot \mu_b, \nu_a + \nu_b - \nu_a \cdot \nu_b \rangle$
$a \ \vee \ b$	$\langle \max(\mu_a, \mu_b), \min(\nu_a, \nu_b) \rangle$	$\langle \mu_a + \mu_b - \mu_a \cdot \mu_b, \nu_a \cdot \nu_b \rangle$
$\neg a$	$\langle \nu_a, \mu_a \rangle$	

2. The Intuitionistic Fuzzy Configuration Management Database Model

The information in an IFCMDB is organized in the form of an intuitionistic fuzzy oriented graph, where vertexes correspond to configuration items (components of the service infrastructure), while the presence of an intuitionistic fuzzy arc expresses the impact between two components along with its degree of certainty.

2.1. Definition of IFCMDB

$$IFCMDB = (C, D),$$

where C is a set of configuration items (components) and D is the intuitionistic fuzzy set of relationships between components:

$$D = \{ \langle a, b, \mu_D(a, b), \nu_D(a, b) \rangle / a \in C, b \in C \},$$

where the functions $\mu_D: C \times C \rightarrow [0, 1]$ and $\nu_D: C \times C \rightarrow [0, 1]$ define the probabilistic degrees of truth and falsity of the existence of a dependency between the components a and b .

2.2. Direct Impact

The IFCMDB graph represents the direct impact relations (dependencies) between components as arcs. For the example on *Fig.2* if component a crashes and we define the direct impact of item a to item b as intuitionistic fuzzy probability that component b is still usable.

Determining the intuitionistic fuzzy probabilistic direct impact between CIs is out of the scope of this paper. It can be determined using statistical information, expert knowledge or some other means.

We assume that direct impact relationships between CIs are predefined.

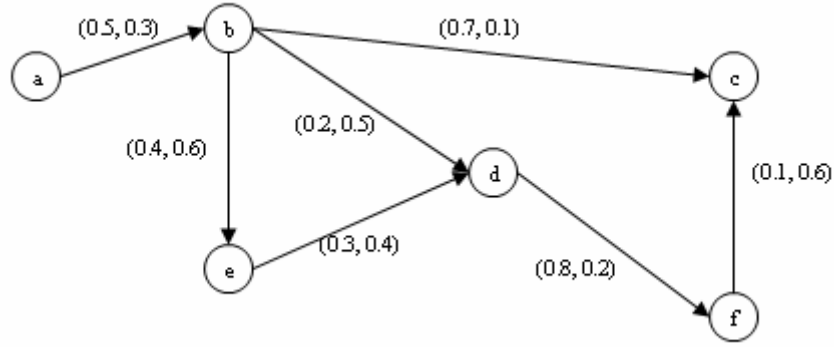


Fig.2. Example of IFCMDB graph

2.3. Indirect Impact

Indirect impact is calculated instead of entered/maintained by the operator. The indirect impact between CIs has to be calculated considering the probabilities for direct impact. For the example on Fig.2 if component *a* crashes and we need to know the probability that component *c* is still usable or not, we have to calculate the impact of *a* to *c*. We will propose a method for calculating indirect impact, using the intuitionistic fuzzy logical operations *conjunction* and *disjunction*:

Let $ddep(x, y)$ denotes the direct impact (dependency) of component *y* from component *x*:

$$V(ddep(x, y)) = \begin{cases} \langle \mu_D(x, y), \nu_D(x, y) \rangle, & \text{if } \langle x, y \rangle \in D \\ \langle 0, 1 \rangle, & \text{if } \langle x, y \rangle \notin D \end{cases}$$

Let $idep(x, y)$ denotes the indirect impact of component *y* from component *x*:

$$V(idep(x, y)) = \begin{cases} \bigvee_{(i,y) \in D} idep(x, i) \& ddep(i, y), & \text{if } x \neq y \\ \langle 1, 0 \rangle, & \text{if } x = y \end{cases}$$

2.4. Optimistic or pessimistic impact analysis

Different types of impact analysis involve the usage of classical or probabilistic variants of the logical operations *conjunction* and *disjunction* in calculation of indirect impacts. Depending on which combination of operations will be used, the indirect impacts may be greater or smaller. Three basic types of impact analysis are introduced: worst case (pessimistic), best case (optimistic) and moderate impact analyses.

2.4.1. Semantics of dependencies and relationships between components

The intuitionistic fuzzy dependencies between components may have different kinds of semantics depending on the type of information they represent.

- A probabilistic dependency between b and d means “the probability that d is out of order in case b is out of order”;
- An ordinary fuzzy dependency between b and d means that “if b is out of order, then d is partially out of order”.

The relationships between components may also have different kinds of semantics for components, which depend on multiple other components. In our example, the two incoming arcs for node d may mean different things:

- “ d depends on the proper working of both b and e ”.
- “ d is properly working if either b or e is properly working”. This case is not yet investigated, anyway an operation different from *disjunction* must be used for the calculation of indirect impact for components with multiple incoming arcs.

2.4.2. Worst case impact analysis

The worst case impact analysis involves the usage of classical conjunction and probabilistic disjunction in calculation of indirect impacts. Thus a greater value for the degree of truth of indirect impacts is achieved:

$$V(p \& q) = \langle \min(\mu(p), \mu(q)), \max(v(p), v(q)) \rangle$$

$$V(a \vee b) = \langle \mu(a) + \mu(b) - \mu(a) \cdot \mu(b), v(a) \cdot v(b) \rangle$$

where V is the evaluating function of an intuitionistic fuzzy statement.

2.4.3. Best case impact analysis

The best case impact analysis involves the usage of probabilistic conjunction and classical disjunction in calculation of indirect impacts. Thus a smaller value for the degree of truth of indirect impacts is achieved:

$$V(p \& q) = \langle \mu(p) \cdot \mu(q), v(p) + v(q) - v(p) \cdot v(q) \rangle$$

$$V(a \vee b) = \langle \max(\mu(a), \mu(b)), \min(v(a), v(b)) \rangle$$

where V is the evaluating function of an intuitionistic fuzzy statement.

2.4.4. Moderate impact analysis

The moderate impact analysis involves the usage of either probabilistic or classical logical operations in calculation of indirect impacts.

- Probabilistic operations are more applicable for IFCMDBs with probabilistic kind of component dependencies:

$$V(p \& q) = \langle \mu(p) \cdot \mu(q), v(p) + v(q) - v(p) \cdot v(q) \rangle$$

$$V(a \vee b) = \langle \mu(a) + \mu(b) - \mu(a) \cdot \mu(b), v(a) \cdot v(b) \rangle$$

- Classical intuitionistic fuzzy operations are more applicable for IFCMDBs with ordinary fuzzy kind of component dependencies:

$$V(p \& q) = \langle \min(\mu(p), \mu(q)), \max(v(p), v(q)) \rangle$$

$$V(a \vee b) = \langle \max(\mu(a), \mu(b)), \min(v(a), v(b)) \rangle$$

2.5. Example for impact analysis

For the example on *Fig. 2*, if *a* crashes and we need to determine the probabilities for any of the other components to be out of order, we have to calculate the indirect impact of other components from *a* using the probabilistic moderate impact analysis:

$$V(\text{idep}(a,b)) = V(\text{idep}(a,a) \& \text{ddep}(a,b)) = \langle 0.5, 0.3 \rangle$$

$$V(\text{idep}(a,e)) = V(\text{idep}(a,b) \& \text{ddep}(b,e)) = \langle 0.2, 0.72 \rangle$$

$$V(\text{idep}(a,d)) = V(\text{idep}(a,b) \& \text{ddep}(b,d) \vee \text{idep}(a,e) \& \text{ddep}(e,d)) = \langle 0.154, 0.5408 \rangle$$

$$V(\text{idep}(a,f)) = V(\text{idep}(a,d) \& \text{ddep}(d,f)) = \langle 0.1232, 0.63264 \rangle$$

$$V(\text{idep}(a,c)) = V(\text{idep}(a,b) \& \text{ddep}(b,c) \vee \text{idep}(a,f) \& \text{ddep}(f,c)) = \langle 0.358008, 0.31563072 \rangle$$

3. Conclusion

Implementing an IFCMDB helps ITIL based Service Management produce better Impact analysis. This area of techniques answer the question: “If/when a CI fails what is the impact on the other CIs”.

Depending on the coverage of the Configuration Management process the CIs can be hardware or software components, services exposed to the users/customers and even the business units of the company.

Several ITIL processes can use IFCMDB and the methods proposed. IT Service Continuity and Availability Management when performing risk analysis and component failure impact analysis. Change management needs to perform impact assessment in order to approve or reject a change.

IFCMDB – based methods have two basic advantages compared to other impact analysis methods used in ITIL (e.g. Component Failure Impact Analysis):

1. The IF component gives a model that is closer to reality
2. The Configuration Manager needs to define only “direct impact” relations and all the “indirect impact” relations are calculated.

These advantages significantly reduce the effort needed to perform impact analysis and produce results that are closer to reality.

4. Further work

IFCMDB can be used to perform better fault cause analysis. This area of techniques answer the question:

“If/when a CI fails what is the root cause for that failure?”

In this case the IFCMDB will be used in the should be made available to the entire Service Support group so that Incidents and Problems can be resolved more easily by understanding the possible cause of the failing component.

As a subject to further work we will investigate IFCMDBs with mixed kinds of dependencies between components. Thus we will be able to perform impact analyses on systems with redundant components (e.g. hard disks in RAID arrays).

REFERENCES

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- [3] Atanassov K. *Intuitionistic Fuzzy Sets*, Springer-Verlag, Heidelberg, 1999.