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INTEGRATE INFORMATION CONSUMER NEED BASED ON INFORMATION AND ACCURACY MODELING WITH TIME CONSIDERATION

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Abstract - This paper presents a temporal information modeling and describes its use in the context of intelligent instruments. First, we propose an information modeling for the use of measurement information that takes into account the response time. This model offers the advantage of computing the uncertainty associated with the information. Information can be obtained from several sources. From the proposed model, the uncertainty associated with information comming from each source is computable at any time. We present a structure that makes it possible to use the knowledge of a consumer needs in order to obtain the best quality of required information.

Keywords: information and uncertainty modeling, time variation modeling, distributed intelligent instruments.

1. INTRODUCTION

Intelligent instruments, i.e. intelligent sensors and actuators, are now commonly used in industry and home automation [1][2]. Recent studies [3][4][5] discuss their design. In order to facilitate interoperable functionality manipulations, intelligent instrument modeling can be based on external representations. Staroswiecki *et al*. propose to model a sensor by a set of services [6]. The approach, discussed in [7] describes the model of existing instruments from the external point of view. In particular, the instrument external model can be used to build a global model for applications involving several instruments.

Information associated with the external point of view of intelligent instruments is often modeled by events. They are generally supposed to be immediately propagated onto the network. Currently, the delay of propagation of an event depends on:

- the type of network (TCP-IP protocol or fieldbus constraint with priority data level),
- the priority level especially when using a fieldbus,
- the traffic on the bus.

At the network supervisor level, a node can be considered as a service provider. A general approach consists in considering services independently of nodes. Then, the credibility of information transmitted over the intelligent instrument network, depends on the system response time and the instruments in use. Note that the execution time could be considered as being included in this system response time .

In addition, the configuration of a sensor can be such that it acquires and/or provides measurements using a fixed time period. Several consumers could require this measurement (i.e. all information about this measurement), but at different dates and occuringbetween two sensor acquisition dates.

These two aspects (response time delay and request for one measurement at different dates) show that using the measurement at any time is relevant in order to obtain the best quality of measurement information.

In this paper, we present a model to deal with functionalities expressed, at the application level, in terms of maximum accepted inaccuracies. Note that at the network level, information inaccuracies are due to network configuration. Therefore, it is difficult to integrate new needs for applications without questionning the configuration of the network. The proposed model, presented in section 2, takes time variation of data uncertainty and refreshment operation consequences into consideration.

The consumer of a measurement can have several strategies in the use of this piece of information. The criteria determining the quality of measurements could then be different from one strategy to another. Section 3 focuses on how a consumer, in an intelligent instrument network, could be asked and could obtain the best quality of measurement according to its strategy. We show that a consumer strategy can affect the information suppliers and how the proposed model facilitates this.

2. MEASUREMENT INFORMATION MODELING

2.1 Introduction

Introducing uncertainty at the application level leads to interesting problems in terms of decision. Let us illustrate one of them. At time t_d, a decision is required. At the application level, two possibilities are offered:

- the system may immediately take the available information from the network but with its uncertainty at that time (t_d),
- the system may decide to wait for the next refreshment operation, at time t_r, to have more accurate information. Note that, in the general case, information

will be available on the network after a delay that depends on computing time and bus traffic.

When the uncertainty is not taken into consideration, the first strategy is the usual one. But, if the uncertainty increases with time (due to the use of non-updated measurement), it may lead to a poor decision because of the information quality. The second strategy is more complex but constitutes an interesting alternative. It requires a model for representing information entities with their uncertainty and a model associated with the refreshment process. This problem is illustrated in Fig. 1 where uncertainty is represented by a confidence interval.

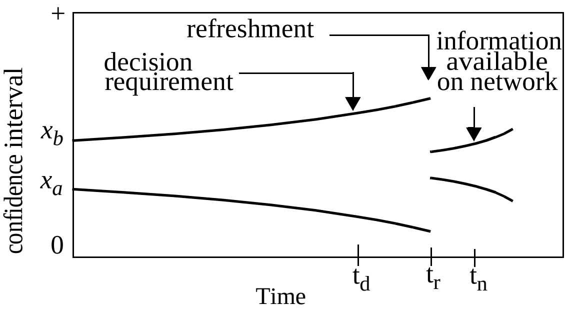

Fig. 1. Decision problem.

Another interesting feature, that comes from the explicit representation of uncertainty, is to define, at the application level, a threshold corresponding to the maximum acceptable uncertainty, as shown in Fig. 2. Note that, in the next figures, time is not represented on the horizontal axis but on the vertical axis.

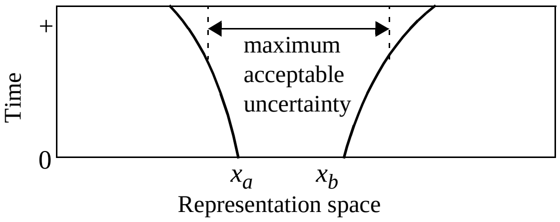

Fig. 2. Using an uncertainty threshold.

This kind of consideration makes it possible to design intelligent instrument networking by including losses of variable accuracy. Thus, the acceptable uncertainty on the application level is distinguished from the uncertainties due to the technical choices. These can be propagated to the decision-making unit that can react by being aware of, i) uncertainties of entrance information and, ii) the desired acceptable uncertainty resulting from the application level.

2.2 *Representing uncertainty*

The original role of instruments or nodes in an intelligent instrument network consists in linking a physical state with an information entity [8]. The nature of this information entity depends on the chosen modeling. In a simple model, the information entity is a numerical value x on a representation space X as shown in Fig. 3. This figure shows the possibility distribution of the information entity. The degree of possibility for a value indicates the possibility that this value can represent the physical state.

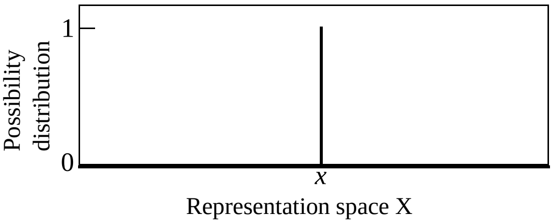

Fig. 3. Information entity as single value.

Uncertainty can be added on measurement by means of a confidence interval as shown in Fig. 4. It is then represented by a couple (x_a, x_b).

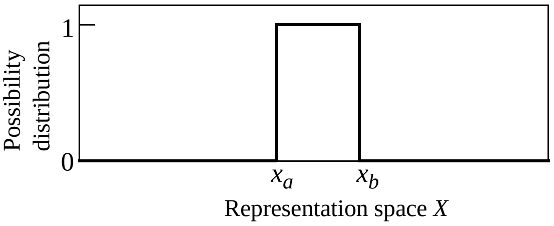

Fig. 4. Information entity as a confidence interval.

This modeling can be extended to a more complete one based on the possibility theory. Studies on use of the possibility theory for measurement and data fusion consist in retaining the model representation that is the most representative of experimentation results and which can be easily manipulated to facilitate mathematical operations and propagations from information. Modeling uncertainty information using possibility distribution is discussed in [9]. In this paper, the uncertainty is assumed to be simply represented by a confidence interval.

2.3 *Time variation consideration*

The simplest model is obtained by considering that time does not influence information entities, as represented in Fig. 5, that is information entities are static.

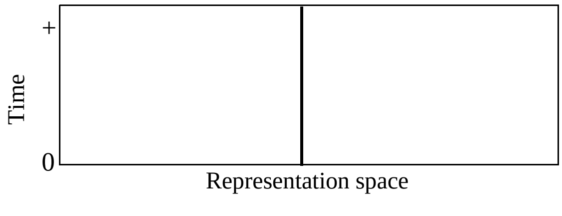

Fig. 5. Static information entity.

An information entity can also be considered as constant in time during a known period t_p and unknown after this period. This model, shown in Fig. 6

and based on information entity lifetime, is implemented into fieldbus like WorldFIP.

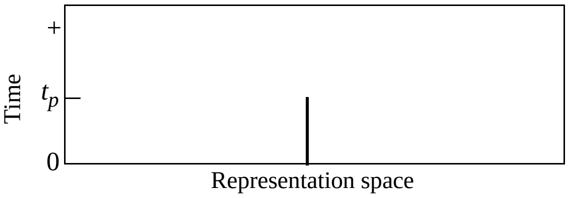

Fig. 6. Limited lifetime information entity.

The time variation of information entities, i.e. of dynamic information entities, can also be taken into account as shown in Fig. 7.

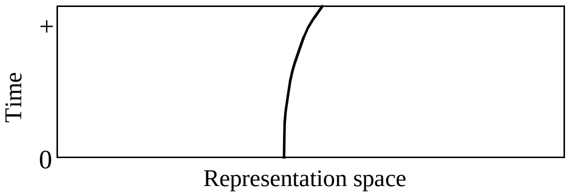

Fig. 7. Dynamic model of an information entity.

Now, the previous model can be increased to deal with the uncertainty associated with information entities. The uncertainty can be time dependent. The time variation model of the uncertainty is assumed to be known. In the following representations, we will suppose that uncertainty increases with time.

Fig. 8 shows the time evolution of a static information entity that is precisely known at time $t = 0$. As time increases, the uncertainty associated with the entity also increases.

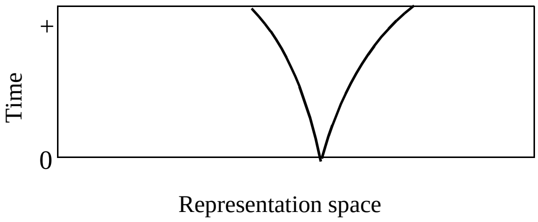

Fig. 8. Precise static information entity with an interval-based uncertainty.

Fig. 9 and Fig. 10 represent respectively static and dynamic information entities that are defined by an interval at $t = 0$ as described in Fig. 4.

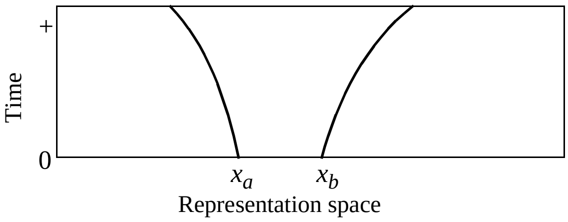

Fig. 9. Static information entity with interval based uncertainty.

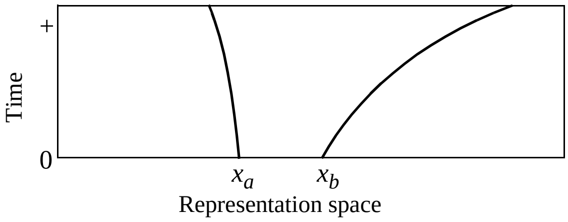

Fig. 10. Dynamic information entity with interval based uncertainty.

2.4 Refreshment model

2.4.1 Refreshment operation

Another extension of this approach consists in taking into consideration the refreshment time period or an assumed date of refreshment. The refreshment process will update the information entity with the measurement value which will be acquired at the refreshment date.

The refreshment principle is illustrated in Fig. 11 in the case of a static information entity. The information entity differs from an idealistic information entity that is permanently updated.

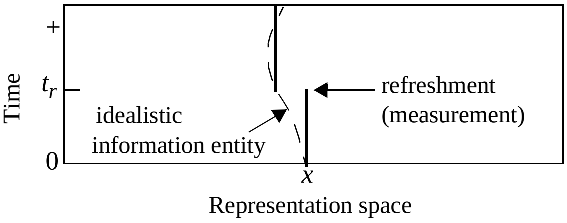

Fig. 11. Static information entity during refreshment.

In order to take into account the reliability of the representation (i.e. measurement), a lifetime may be used. In that case, if the information entity lifetime is smaller than the refreshment period, then the model given in Fig. 6 can be used which leads to the behavior represented in Fig. 12.

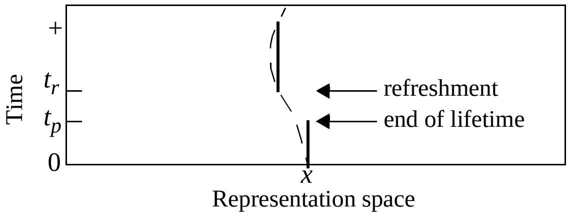

Fig. 12. Information entity with lifetime

A better solution, if available, consists in using a dynamic model that is periodically refreshed as shown in Fig. 13.

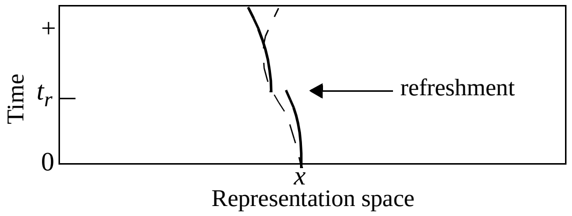

Fig. 13. Dynamic modeling with refreshment operation

This refreshment principle can also be applied when coping with uncertainties. The refreshment process will re-evaluate the uncertainty based model from the measurement acquired at the refreshment time as shown in Fig. 13 and Fig. 14.

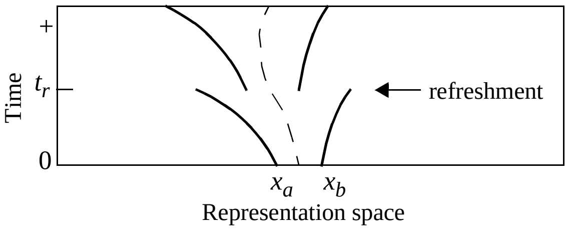

Fig. 14. Refreshment process with a dynamic model including interval based uncertainty.

2.4.2 *Refreshment modeling*

An interesting concept is to consider that refreshment dates cannot be precisely known. For example, this may occur in case of periodical refreshment due to network traffic. Therefore, instead of modeling the refreshment by a single event, a time confidence interval is introduced.

As shown in Fig. 15, there is now a family of possible trajectories for the information entity depending on when the refreshment effectively occurs in the time window.

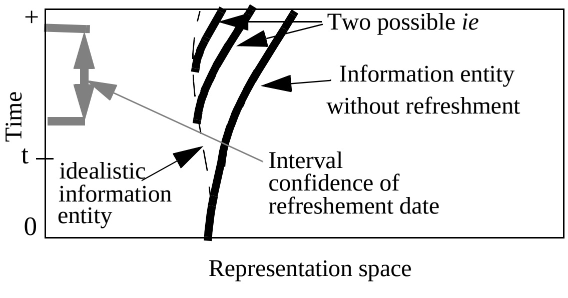

Fig. 15. Illustration of refreshment modeling based on a time confidence interval.

Dealing with time confidence interval generates a more complex decision problem. Fig. 16 illustrates this complexity with the problem that was presented in Fig. 1. The decision to be taken at time t_d consists in picking up the available information or waiting for updated information knowing that the refreshment will occur in the time interval $[t_{r\,min}, t_{r\,max}]$.

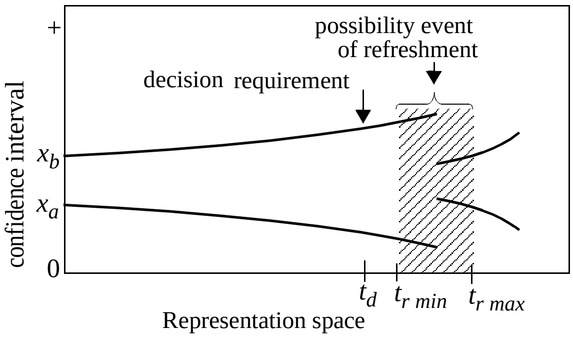

Fig. 16. Decision problem with time confidence interval.

2.5 *Final model*

The previous concepts can be used to define a general information entity model:

An information entity *ie* is a confidence interval defined on the representation space. This interval is time dependent. At each time of refreshment t_i, the information entity ie_{ti} is issued from a measurement. Between two times of refreshment, the information entity is predicted with a function *p*.

$$ie(t) = ie(t_i, \Delta t) = p(t_i, \Delta t) \qquad (1)$$

where t_i is the last time of refreshment.
At any time and at any place, an information entity *ie* is represented by:

$$<ie_{ti}, p\,, r, t_i> \qquad (2)$$

where *r* is the confidence interval for the next time of refreshment t_{i+1}. The instantaneous information entity can then be computed.

This model can now be implemented to make possible the sending of the required measurement information over the network. When received by a node, the uncertainty of a measurement can be computed at any time. To do so, each node is assumed to have a synchronized clock.

Section 3 describes the consumer strategy based on this information model.

3. CONSUMER STRATEGY AND ITS IMPACT ON THE PRODUCTION OF REQUIRED INFORMATION

3.1 *Introduction*

The possible strategies of a consumer can be translated in terms of confidence interval and response time.

For example, the strategy of a consumer can be to get the information as soon as possible, even if the confidence interval is large. Another strategy can be to obtain information with a smaller measurement uncertainty, even if the consumer has to wait for it.

An upper bound of uncertainty required by a consumer influences the choice of the sensors. The sensor is usually chosen to provide a measurement within the desired uncertainty upper bound. The desired confidence interval can become smaller than the confidence interval given by the sensor. In this case, it is nevertheless possible to provide the measurement while adhering to this uncertainty constraint using specific methods. For example, when using CCD sensors, it is possible to use sub-pixel techniques and/or accumulation procedures to increase the accuracy. Indeed, the accumulation process applied on CCD-sensor images decreases the noise effects which is one cause of loss of accuracy.

These actions however involves a computation duration. Thus the consumer could ask for this duration to be limited. In the next subsection, a structure is proposed to integrate the consumer needs based on the model presented in the last section.

3.2 Structure to integrate consumer needs/strategy

Here time variation represented by p function in Eq. (1) is assumed to be known. Consumer has to be able to send, over the network, the request identifier of desired information and its corresponding strategy in terms of uncertainty and response time. To express the strategy, the consumer gives the bounds of the maximum accepted uncertainty and maximum value of the reply delay.

The receiver (i.e. the supplier of the information) of the consumer request has to deliver the information entity *ie* according to the expressed constraints on uncertainty and response time.

In the proposed approach, the supplier knows the information $<ie_{ti}, p , r, t_i>$ and is able to compute the information entity $ie(t)$, that is actually a confidence interval. If propagation time is considered as negligible or known *a priori*, the information entity does not have to be computed by the consumer. If propagation time is only known *a posteriori*, the consumer has to know the information $<ie_{ti}, p , r, t_i>$ in order to evaluate $ie(t)$ itself by computing the confidence interval. In this case, either the first time that consumer invokes an information entity, it must first request the corresponding p; or, for each sending of ie_{ti}, the supplier systematically sends also the p function.

3.2.1 Exchange between a consumer and a supplier of measurement

Fig. 17 illustrates exchanges between one consumer and one supplier. This supplier can be for example an intelligent sensor. Note that in the context of an intelligent instrument network, exchanges are usually made in diffusion mode; which supposes the use of a label for each nature of exchange. In the following description, the knowledge of p by the consumer is assumed to be done, or not necessary if propagation time is considered as negligible.

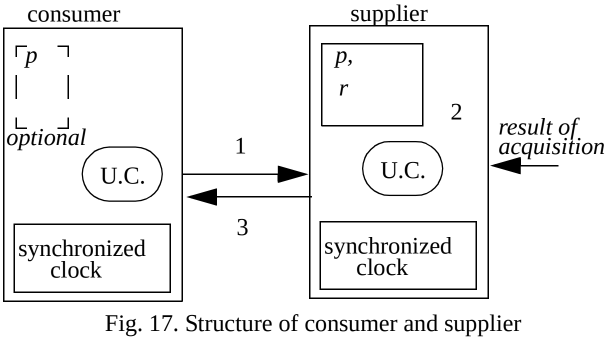

Fig. 17. Structure of consumer and supplier

Step 1: the consumer sends
- a ’measurement request’ label
- the identifier of the desired information,
- the current *date*
- the bounds of the maximum accepted uncertainty,
- the maximum value of reply delay.

Step 2: the supplier computes the uncertainty from information delivered by the last acquisition process results (which have been memorized by the supplier) - see section 2.5. If necessary, a new acquisition process will take place, especially if the sensor is configured to perform an acquisition on demand. Specific methods will also be used if needed in order to respect the accuracy constraints. If it is not possible to respect accuracy constraints in the assigned time, either the supplier will provide the best information measurement possible in accordance to the assigned time or supplier will indicate the impossibility to supply the result according to the accepted uncertainty, using for example a special message-id.

Step 3: the supplier send, over the network,
- a ’measurement sent’ label
- an identifier of the provided information,
- the *date* t_i of the refreshment,
- the information entity ie_{ti} at time t_i (or a label to indicate the impossibility to supply the result according to the accepted uncertainty).
- if the need arises, i.e. if the consumer is able to compute the uncertainty without asking for another measurement, the supplier also sends the p functions.

3.2.2 Exchange between a consumer and several suppliers of a single entity measurement

In this last section, the case of interfaces dedicated to the management of information entities is discussed. Each interface manages all information entities representing the same physical phenomenon. Also, several suppliers of information entities representing the same physical phenomenon are considered here.

The interface role is to receive the request of the consumer and to provide to the consumer the measurement in accordance to the request constraints given by the consumer (i.e. bounds of maximum accepted uncertainty and maximum reply delay). The concerned suppliers are all able to provide the measurement, as presented in section 3.2.1. From the information entities provided by the many suppliers, the interface has to determine the information entity to be sent to the consumer.

For each supplier, the interface computes the confidence interval for the current date as presented in section 2.5. Then, the interface is able to choose or to mix these results to provide a result that complies with the consumer constraints. Several strategies are possible to determine the result to be delivered: for example, the first measurement having an uncertainty smaller than the maximum accepted uncertainty, or the measurement with the smallest uncertainty, etc... These strategies are integrated inside the interface.

To avoid increasing traffic on the bus, this interface memorizes the information entity provided by each supplier. This is especially the case for sensors that supply measurements at a fixed time period.

This interface is able to request a new acquisition process of measurement to one or more suppliers. This would be the case for sensors supplying measurements on demand.

Fig. 18 illustrates a possible structure for one consumer (or more), several suppliers and the interface based on the modeling measurement proposed in section 2.

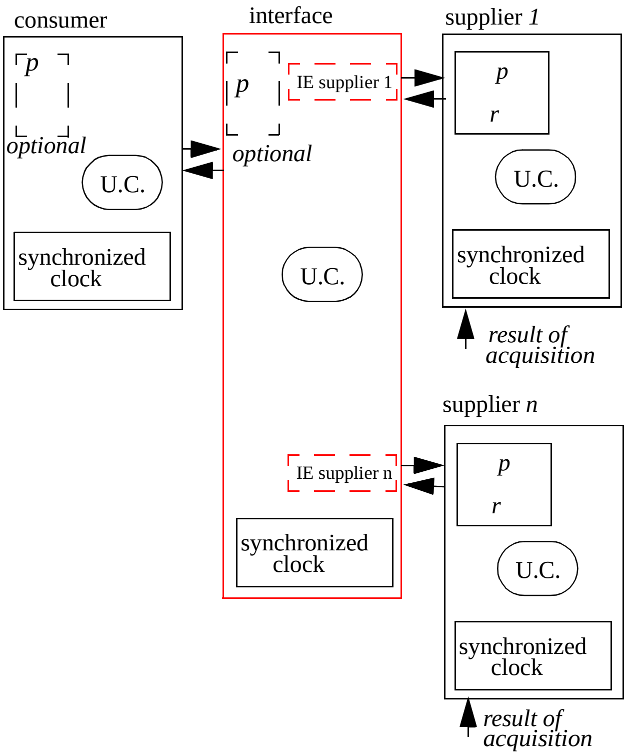

Fig. 18. Structure of consumer, suppliers and interface

Subscription functionalities can be added. The entity information subscription allows a consumer to send its needs including the period of desired refreshment. This stage is then performed only once. Then, the interface takes the initiative to send measurement to the consumer(s).

4. CONCLUSION

Measuring accuracy is currently the subject of many investigations. In this paper, a model has been presented that makes possible the computation of the uncertainty associated with each information entity, especially measurement information. In addition, taking into account information refreshment in the model constitutes an interesting way to improve the quality of the decision in many problems.

We have shown that the proposed information model allows the consumer to modify the production of the required information in accordance to its own strategy, i.e. its needs in terms of accuracy and delay.

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