Integrating Organizational Knowledge into Embedded Systems: Introducing ETIC

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Abstract

Enterprise-oriented Task-specific Integrated Circuits (ETIC) is a reconfigurable embedded system designed and owned by icDNA Pty. Ltd. in Sydney Australia where the first author is affiliated. ETIC architecture introduces a breakthrough in the field of embedded systems architecture in the sense that it is capable of transforming the user-defined business algorithms into the hardware specification. This is done by the ETIC’s special feature called Arbitrary Superword Level Parallelism (ASLP). This paper investigates variables as well as their relationships within the two worlds of embedded systems and enterprise-oriented business processes, with the aim of identifying new missions for ETIC within the domain of enterprises. A knowledge representation methodology is introduced for storing the knowledge of business processes within the instruction-set of the ETIC. Simulated results from a working prototype of ETIC are also presented.

1. Introduction

1.1 A Historical Background

Despite recent improvements in the area of systems analysis, design and development still hardware issues such as execution optimization, processor speed and capacity and many other hardware parameters are dictated to the business world by the hardware world. This is so because there still exists a large layer of abstraction from say a C program or a database schema to the instruction-set of a microprocessor. This paper extends the territory of both business and hardware worlds so that many of their tasks can be performed collaboratively. It demonstrates how the enterprise knowledge can be directly mapped into the instruction-set of the ETIC in a way that allows users in the business world to bring under their control many of the hardware-oriented variables. As this may not be possible without an appropriate business process model that can link the two worlds together, an existing business process model suitable for this purpose is also introduced in this paper. Hardware details of ETIC are not discussed as they fall outside the scope of this paper.

1.2 A Hardware Breakthrough That Puts Smile on the Face of Business Managers

Providing the business managers with the capability of designing embedded systems for their use will enhance the effectiveness of business processes in the following ways:

1. Business managers can provide direct input to the design process rather than using what is available by the hardware industry. This will greatly reduce the training efforts, as well as the system failure and rejection rates in both worlds.

2. Changes made in the user’s requirements do not necessarily need to pause at the flowchart-level, pass a thick abstraction layer called compiler, and then reach the computer architects’ world. In the past this has been a major factor in creating hostility and expensive reconstruction efforts in the two worlds. With ETIC changes can
be mapped directly to the instruction set of the microprocessor; and if the resulting hardware does not perform well it can easily be changed.

3. ETIC can assist in defining global policies and parameters such as overall process security, task standardization, Key Success Factors (KSF) etc. As an example, when discussing the KSFs of an embedded system the user world may be interested in measures such as relative response-time (depending on the culture, context, market conditions, etc.), dollar value of the system output, effects of the system on the organization’s global market-share, etc. On the other hand the hardware world will interpret KSFs of the same embedded system as being the absolute response-time (as relative, culture-oriented response time is meaningless in this world), processor speed, error-free/reliable software, etc. Ideally, a direct mapping of the business tasks into the instruction-set will also create direct and correct mappings between these two sets of KSFs. In fact, there will be only a single larger world instead of two smaller and possibly, hostile worlds, as may be the case today.

4. ETIC maintains a balanced growth between the complexity of the business tasks and the computing power of the hardware. Currently, and according to the Shannon’s Law, as the complexity of a task algorithm increases there is no guarantee that the computing power also increases proportionately [1]. With ETIC, due to its embedded context-awareness ability, the dynamic mapping of emerging tasks can be taken care of by its embedded execution engine.

In Section 2 relevant knowledge engineering issues in relation to the ETIC are discussed. An existing high-level business process model/framework is introduced that is used to be loaded in the ETIC in order to demonstrate ETIC’s ability to store business rules that (theoretically) may require infinite word-length (see [6] for a typical application of the framework in networked business communities). A methodology is also introduced that facilitates seamless mapping of the business users’ requirements into the executable codes of the hardware. In Section 3 one generic methodology for applying ETIC in enterprise environments is discussed, followed by a conclusion and future works in Section 4.

2. An Enterprise Process Model for ETIC

2.1 Characteristics of an Ideal Process Model

To the opinion of the writers an ideal business process model for ETIC will have at least the following attributes:

1. It must be representative of the process culture so that cultural/organizational variations can be directly reflected into the instruction set of the ETIC embedded system.

2. Almost all business processes are collaborative by nature; and as a result multiple human agents may be involved at the same/different times/places. An ideal enterprise process model for ETIC must satisfy such requirements. The proposed framework is capable of dealing with collaboration issues.

3. The proposed business process clearly identifies the boundaries between the Business process, between the business process and the tasks within the process, and between the task and the actions that make up the task. Such hierarchical structure facilitates integration of the rules in the two worlds.

4. And finally, the business process model must not be restricted to a certain class of knowledge, and must be capable of dealing with all types that currently within the taxonomy of knowledge. These types currently are ‘know-what’, know-who’, ‘know-how’ [2] and the ‘contextual knowledge’ [3] with an added dimensions of ‘tacit’ and ‘explicit’ [Ibid]. In this paper one’s contextual knowledge is simplified as being someone else’s ‘know-how-when-who-etc.’ knowledge and vice versa. The proposed business model is capable of achieving this goal as well.

2.2. A Process Awareness Model for ETIC

This model has been developed with an intention to address the awareness and knowledge-sharing needs of today’s enterprise environments [4] & [5]. An outline of the model is described below.

Using the formalism of applied mathematics and particularly the ‘graph theory’ a business process can be described by a connected graph called process net shown in Figure 1. This graph consists of the following ‘nodes’ and ‘arcs’ each representing a collaborative semantic object:
(i) A non-empty set of role/actor vertices (filled circles in Figure 1) and simple task vertices (normal circles). Actors are human agents that assume one or more roles within the business process.

(ii) A set of edges or arcs that connect above vertices together. These arcs represent various artifacts in the form of resources (e.g., knowledge, documents, tools, programs etc) used by the roles in order to perform their simple task (or task, for short).

In their direct/indirect interface with the above artefacts, roles execute one or more interaction acts (such as creating an artefact, using or modifying an existing artefact, exchanging an artefact, etc.) when performing various tasks. There are two kinds of artefacts. One is called the role artefact and has a role and a simple task as its endpoints. This artefact, among other things, encapsulates knowledge expected from the relevant role for the successful execution of the relevant task. Some examples of the role artefacts include: technical skills, personal databases, spreadsheets, previous experience in similar jobs, etc. This represents one category of knowledge that is engineered within the proposed process awareness model.

The other kind of artefact is called the task artefact, which has two (simple) tasks as its endpoints. These two simple tasks together constitute a collaborative task. Each simple task is performed by a role, hence the collaboration between the roles. Two collaborating roles use/exchange/create a task artefact for their collaboration. Task artefacts, among other things, encapsulate the common/public knowledge (as opposed to the personal knowledge within the role artefacts) that is expected from the actors in order to execute their collaborative task successfully. Some examples of the task artefacts are organizational/public databases, shared workspaces, e-mails, shared applications, collaboration-aware applications, etc.

2.3 Interaction with the ETIC

A task artefact is naturally ‘collective’ and it is always shared by two roles. Therefore, knowledge within a task artefact must ideally be codified and then stored in a computerized system to be made available on demand. This will portray the first generic responsibility/missions for the ETIC under the proposed process model. That is, to enable knowledge sharing throughout the organization. In this mission, ETIC may even go as far as assisting individual knowledge seekers (say a role) to identify the, and communicate with, the knowledge sources (other roles) within the process that in turn will enhance collaboration. One ideal system design directive is that although the process model allows reuse of knowledge (and therefore allows its separation from the sources), it must not lose sight of its original context. As will be shown in 3.2, engineering the awareness knowledge of business tasks into the instruction-set of ETIC using the proposed process awareness model will provides such facility.

On the other hand, role artefacts are more personal. They either reside in people’s minds or, in certain situations they may reside in their personal databases or private workstations. Therefore, a second mission for the ETIC in enterprises would be to assist the knowledge seekers to facilitate creation, organization and utilization of knowledge in order to perform simple (or non-collaborative) tasks. This we call the ‘knowledge utilization role of the ETIC’.

And finally, the third mission for the ETIC in the enterprise communities would be the mission of the traditional/1st generation embedded systems where the system is mainly used to execute/automate a context-less, simple, business task in isolation from other tasks, other roles, and other artifacts within the process. The context-aware attribute of the ETIC arises from the following facts:

1. ETIC is application-specific as opposed to the task-specific nature of the 1st generation embedded systems. As explained before, business applications/processes can be modeled as a mesh of roles each performing one or more tasks. With ETIC the ‘role’ becomes processor itself. Each role is assigned to one ETIC processor. Tasks of the role constitute the instruction-set of that ETIC. Actions within the task are transformed into the hardware specifications. This will enable the user to store context-specific knowledge within the instruction set of the ETIC. More on this in Section 3. High-level languages ‘VHDL’ and VERILOG are used to create ETIC. For full details about the process net and formalized definitions of its semantic concepts refer to [5].

2. Both the instruction set and the hardware architecture are patents registered by icDNA Pty
Ltd, Australia. As a result of using a high-level language in ETIC the existing various levels of parallelism used by the business analysts to describe business applications are now available to the ETIC. This provides ETIC with (theoretically) infinite capabilities in dealing with the task complexity, with the emerging tasks and with the speed of the processor. More on this is provided in Section 3.

Figure 1 shows a connected graph representing a hypothetical process with four roles X, Y, T and V. Filled circles represent role vertices, and plain circles represent task vertices. Thick lines represent role artefacts and narrow lines represent task artefacts.

![Process Net Diagram](image)

Figure 1: Example of a Process Net with four roles and 14 tasks

The actors who participate in a business process need to have certain level of process awareness called required level of awareness that is expected from them in order to perform the task successfully. We refer to this knowledge as contextual/organizational knowledge. To avoid lengthy discussion in the area of ‘process awareness’ only a summary of five awareness levels that a role may have in any business process are discussed below. For more details refer to [5].

**Level-0 awareness:** A role is at level-0 awareness if s/he possesses knowledge about the objects that lead the role to an understanding of the tasks that the actor performs within the process. A role’s level-0 awareness will enable him to initiate lowest level of knowledge sharing transactions with other roles within the process (in this case nil, as the role knows nobody else within the process yet). The mathematical representations of this level for the two roles X and T are:

\[ A0('X') = \{ \{X,1\}, \{1\}, \{X,2\}, \{2\}, \{X,3\}, \{3\}, \{X,4\}, \{4\} \} \]

\[ A0('T') = \{ \{T,5\}, \{5\}, \{T,6\}, \{6\}, \{T,7\}, \{7\} \} \]

**Level-1 Awareness:** A role that reaches level-1 awareness will possess level-0 awareness plus a knowledge about all the objects that leads the role to an awareness about some of the other roles within the process. The ‘some of the roles’ here means those with whom the role has a direct task dependency. According to the Figure 1 role ‘V’ happens to have task dependency with one other role, that is, role ‘X’. Level-1 awareness allows ‘V’ to initiate a limited level of knowledge-sharing transactions with others (here, ‘X’ only). The mathematical representation of level-1 visibility for the role V is:

\[ A1(V) = \{ A0(V), \{b,c\}, \{c\}, \{c,X\}, \{X\} \} \]

Or, alternatively,

\[ A1(V) = \{ A0(V), \{b,a\}, \{a\}, \{a,X\}, \{X\} \} \]

**Level-2 Awareness:** A role’s level-2 awareness is his/her level-1 awareness plus knowledge about the objects that lead the role towards an understanding of all other roles within the process whether or not the role has task dependency with them. The mathematical representation of level-2 awareness for the role X is:

\[ A2('X') = \{ A1('X'), \{g,h\}, \{h\}, \{h,T\}, T \} \]

**Level-3 Awareness:** A role’s level-3 awareness is his/her level-2 awareness plus knowledge about the objects that lead the role towards an understanding of all interactions that occur between any pair of roles within the process. The mathematical representation of the role Y is:

\[ A3(Y) = \{ A2(Y), \{X,a\}, \{a\}, \{a,b\} \} \]

**Level-4 Awareness:** A role with level-4 awareness will possess the highest level of awareness within the context of the business process (higher levels of awareness within the enterprise are not discussed in this paper). It is knowledge about the objects that lead that role to an understanding of how all the objects within the process (that is, roles, tasks, role artefacts and task artefacts) fit together to make the process. Graphically, the process net in its entirety can represent this level of awareness. Contrary to the previous levels, the
graphical representation of this level for all the roles will then be the same:

3. Knowledge Engineering Issues: Introducing the ETIC/ASLP Capability

Each role within the business process can now be allocated to one ETIC processor. Each task that is performed by this role constitutes one unique instruction element within the ETIC. Each instruction element will carry knowledge related to the actions within the task (‘know-what’) as well as the role artifact that is used to perform the task (that is, ‘know-how’). In addition, the contextual knowledge represented in the form of various awareness levels can also be embedded directly into the ETIC as follow:

ETIC’s equivalent level-0 awareness for ‘X’ is:

\[ 0ET(X) = \{ \text{BUS(ET(X)-inst(1))}, \{\text{inst(1)}\}, \{\text{BUS(ET(X)-inst(2))}, \{\text{inst(2)}\}, \{\text{BUS(ET(X)-inst(3))}, \{\text{inst(3)}\}, \{\text{BUS(ET(X)-inst(4))}, \{\text{inst(4)} \} \}
\]

ETIC’s equivalent level-1 awareness for ‘V’ is:

\[ 1ET(V) = \{0ET(V), \{\text{BUS(instr(b)-inst(c))}, \{\text{inst(c)}\}, \{\text{BUS(instr(c), ET(X)}, ET(X)\} \}
\]

ETIC’s equivalent level-3 awareness for ‘Y’ is:

\[ 3ET(Y) = \{2ET(Y), \{\text{BUS(ET(X)-inst(a))}, \{\text{inst(a)}\}, \{\text{BUS(instr(a)-inst(b))} \}
\]

ETIC’s equivalent level-4 awareness for ‘X’ is:

\[ 4ET(X) = \{3ET(X), \{\text{BUS(ET(V)-inst(5))}, \{\text{BUS(ET(V)-inst(6))}, \{\text{inst(5)}, \{\text{inst(6)}\}, \{\text{BUS(ET(T)-inst(3))}, \{\text{BUS(ET(T)-inst(4))}, \{\text{inst(3)}, \{\text{inst(4)}\}, \{\text{BUS(ET(Y)-inst(2))}, \{\text{inst(2)} \}
\]

4. Conclusion and Future Works

This paper introduced three major enterprise roles for ETICS. It then proposes a methodology for the integration of ETIC into the business processes (or vice-versa) using an existing business process framework. We believe that this is only the first step in this direction and work needs to be done in the following areas:

1. Currently, the business user needs to take the first initiative by supplying their business requirements in the form of an algorithmic procedure (say, a ‘C’ program) to the ETIC before collaboration between the two can start. Further improvement would be for the ETIC to take the first initiative by monitoring the business environment in search of a business problem to solve. This we would call the 3rd generation of the enterprise-oriented embedded systems.

2. The current high-level programming interface between the business user and the ETIC can be improved to incorporate more friendly styles of interface such as GUI and Natural Languages.

Further experimentations need to be done in order to validate the suitability of the proposed Process Awareness Framework to the ETIC.

References


