EXPANDED SCOPE OF TRAFFIC-FLOW ANALYSIS: ENTITY FLOW-PHASE ANALYSIS FOR RAPID PERFORMANCE EVALUATION OF ENTERPRISE PROCESS SYSTEMS

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ABSTRACT

This paper describes entity-flow phase analysis (EFA) which is a method for fast performance analysis of organisational process systems. EFA, similarly to traffic-flow analysis for communication systems (TFA), uses the combined approach of simulation and numerical methods. In simulation projects initiated to support the design of Information and Communication Technology (ICT) system and Business Process (BP) system in an organisation the parallel analysis of different systems may be efficient. EFA is a promising evaluation method to be applied for systems with determined BP and ICT subsystems in an organisational environment.

INTRODUCTION

Mixed simulation projects

Simulation projects aimed to support the design of Information and Communication Technology (ICT) and Business Process (BP) systems in an organisation traditionally are independent, separate projects, in spite of the fact that these systems may have significant influence on each other. Common analysis of these systems may have advantages but in this case we need to have methods appropriate for both types of systems.

Process system definition

There are some known, basic definitions of business processes:

By the definition given in (Davenport 1993) processes are structured, measured sets of activities designed to produce a specified output for a particular customer or market.

According to another definition a business process is a partially ordered set of Enterprise Activities which can be executed to realise a given objective of an enterprise or a part of an enterprise to achieve some desired end-result (Savén 2002).

In enterprise (organisational) modelling business process is defined as a network of actions performed in context of one or more organisational roles in pursuit of some goal (Koubarakis and Plexousakis 1999)

According to the above requirements we give a <u>definition</u> to be used to our modelling purposes:

Business processes are related to enterprises and they define the way in which the goals of the enterprise are achieved.

Business Process is a set of Enterprise Activities linked together to form a process with one or more kinds of input to produce outputs.
A <u>process system</u> is a set of business processes linked together to perform some Enterprise Function or Subfunction.
(Processes of an enterprise can be identified using process mapping (Graesley 2000)).

The Traffic-Flow Analysis

The <u>*traffic-flow analysis*</u> (TFA) (Lencse 2001, about the convergence of TFA: (Lencse and Muka 2006)) is a simulation-like method for the fast performance analysis of communication systems. TFA uses statistics to model the networking load of applications.

In the <u>first part</u> the method distributes the traffic (the statistics) in the network, using routing rules and routing units.

In the <u>second part</u> the influence of the finite capacities (line and switching-node capacities) is calculated.

The important features of TFA:

The results are approximate but the absence and the place of <u>bottlenecks</u> is shown by the method.

The execution time of TFA is expected to be significantly less than execution time of detailed simulation of the system.

TFA describes the steady state behaviour of the network (there is no need for <u>warm-up time</u> definition).

IDENTIFYING EFA MODEL ELEMENTS

EFA: A new evaluation method

In this paper we introduce a new method, EFA for the fast process analysis. EFA is based on the experience of TFA.

We introduce two versions of EFA:

1. In the first version the analysis is performed in two steps: first the spatial distribution of entity-load is determined, then the time distribution is calculated (One-phase Method)
2. In the second version the analysis is performed by repeating the steps of determination of spatial distribution of entity-load and the time distribution is calculation for activity groups featured with equal distance from entity-load source (Multi-phase Method)

We may have a promising capability of common analysis of BP and ICT systems using EFA-TFA methods.

An overview of TFA model elements

Now, before identifying EFA model elements we summarise TFA model elements:

Network model of TFA consists of nodes (routers, switches, etc.) and lines (transmission lines).

Traffic model: TFA uses probability density functions (PDF) to model the traffic load: PDF of throughput and PDF of delay. (The traffic is generated by applications (application models)). The delay distributions are calculated when the influence of finite line and node capacities are taken into account.

(Any traffic model can be used in TFA (mathematical or statistical) that satisfies the requirements described in (Lencse 2001)).

Throughput is the number of packets or bits arrived in a time interval ***T***. It is clear that the value of ***T*** has significant influence on the distribution.

Bit-throughput and packet-throughput distributions are used to describe the traffic on the lines and in the nodes.

The routing model (which can be any) of the network is used to distribute the traffic.

EFA model elements: Activity model-element, linking activities

By definition the process is a set of activities which are linked together.

The links are connections with a direction showing the performance order (time-precedence) of activities. Internal links are connecting the activities of one process; external links are connecting processes forming a process system. The links are only logical connections with no capacity limit.

Performing an activity takes time which can be better described by a probability distribution (service time profile, activity time-consumption), than by an exact value because many factors are influencing the performance-time (for example the learning process of the assigned process resource). In many cases it is enough to use normal distribution and the expected value of activity time:

T_{Cons}(activity, entity type) Time-Consumption of an Activity – expected value of time necessary to perform the given activity, that is necessary to process the entering entity-type.

EFA model elements: Entity-load model

The entity-load in the model is produced by programmable entity-generator, the source of incoming entities. There may be different types of entities entering the process, which are produced by different sources, generators.

Entity-load models to be used:

1. An entity ***arrival profile*** describes the arrival time distribution of entity-load for an entity of a given type.

2. TFA-like ***entity-throughput*** model uses the probability distribution describing the entity-load intensity: the probability that ***k*** entities directed to an activity to be processed in a time interval of ***T*** length is $p_T[k]$. In the steady state $p_T[k]^*$ denotes that exactly ***k*** entities need to be serviced in ***T*** time. (Consideration about the value of ***T***, see below.)

The entity-load model is taken as an input for the model, while the delay-time is calculated.

The delay caused by the resource capacity limit can be calculated for the entity-throughput model using a formula similar to TFA delay-time calculation:

$$D_T[i] = \begin{cases} \sum_{k=0}^{R_n} p_T[k]^*, i = 0 \\ \sum_{k=iR_n+1}^{(i+1)R_n} p_T[k]^*, i \geq 1 \end{cases}$$

where $D_T[i]$ is the probability of an ***i*T*** delay, R_n is the resource capacity limit for activity ***n***.

(Remark: a more precise calculation can be done using the Bayes' theorem and the probability distribution of resource accessibility.)

The destinations of entities are exit (result) points of the process. The output observations of the process can be made and the necessary output statistics can be created at these points.

EFA model elements: The T interval

The ***T*** interval is the resolution of our examination.

(It is also clear that the entity-load intensity distribution influenced by the determination of ***T***.)

In process analysis a typical value of ***T*** is an hour, but in the assessment of Callcenters the typical value is one minute. In examination of ICT-BP connections it may be necessary to use seconds.

EFA model elements: Entity routing, process decisions

Similarly to communication systems there is a routing of entities in the process. Entity routing depends on process decisions.

A routing decision may be made using different algorithms:

Percentage distribution: the destination of an entity is decided by the probability distribution of the possible entity outputs.

Entity-feature distribution: output for an entity is chosen by some feature of an entity (type, priority, etc.).

Load-balancing distribution: output for an entity is chosen on the basis of some load-balancing algorithm (including some quantity-limit consideration too).

Other details

There are some other elements influencing the generation and routing of entities:

Fork element makes copies of an entity (this is a parent-child relationship) and routes the copies to outputs in a parallel way. The Fork's pair is the Join element that collects the entities divided by Fork element into one entity. The delay of an entity collected by Join equals the maximum delay of entities routed by Fork.

Split element also makes copies of an entity and routes the copies according to the output links of the element but the splitted entities will not be collected into one entity again. Split generates entities, which will have separate ways in the process.

Transform element may change the entity's features in the process.

A CAPACITY-LIMIT MODEL

In the following, we determine a Resource Capacity-Limit Model (RCLM) to be used by EFA method.

RCLM has two important basic features:

1. RCLM should describe different groups of resources, where a group functions as a pool of resources, having a summary limit for the resources in the pool.
2. If a given resource element is engaged in one activity of the process it cannot be used by another one at the same time.

The RCLM elements and parameters:

List of resource types describing the resources required in the process

- N_{Res} ***(type)*** Number of Resource-Elements of a given type – the number is the capacity limit of the resource group (pool)

List of activities using a given type of resource

- P_{ARes}***(type, month, week, day, time)*** Resource Accessibility – the probability that a resource of the given type is accessible at the given point of time for a given activity, in an interval of ***T length***. (For the correct description of the "resource behaviour" we should examine longer periods, to take into consideration the seasonality.)
- R_n - expected value of accessible resource capacity of a given type for an activity ***n*** (non-negative integer). We may use R_n to decrease the amount of calculations.

THE EFA METHOD

The work of the EFA method, similarly to TFA, can be divided into two parts:

1. Distribution of the entity-load in the process
Sending entity-load statistics to the process activities according to the routing conditions
At this point summation of statistics must be performed.

2. Calculation of time influences of finite capacities of resources

We may use the expected value of a resource for an activity or the probability distribution of resource accessibility can be used to get more precise result.

Remark: if there are feed-back loops in the process first they should be eliminated: it may be done by adding a calculated portion of entity-load of the output point of feed-back to its input point and then cutting-off the loop.

M1 One-phase method

M1.1 Sending statistics to every process activity according to the routing
M1.2 Calculate the processing-time of activities parallel.
(The execution of the second step is expected to require much more processing power then the exection of the first step, that's why the second step may worth executing parallel by multiple processors.)

M2 Multi-phase method

M2.1 Sending statistics to all process activities which are in equal distance from process entity-load source (starting with the nearest group of activities). Sending statistics is performed according to the routing rules.
M2.2 Calculate the processing-time for activities in the group in a parallel way.
M2.3 Repeat cycle M2.1 and M2.2 for the next nearest group of activities.
Remark: if there are feed-back loops in the process, first a One-phase method run should be applied to eliminate feed-back.

TESTING THE EFA APPROACH: AN APPLICATION EXAMPLE

Let us see an example to compare process analysis methods: the application of Event-driven Discrete-Event Simulation (DES) and EFA.
The test-process topology (elements and links) is shown in Figure 1. The process has two sources for generation of entity-load: Source 01. and Source 02. There are 7 activities in the process: Activity 01-07. There is one exit-point in the process: Result 01.

The entity-load model is described by two arrival profiles with normal distributions. The Activities 01-07 have different service profiles which are also described by normal distributions.

The resources for all activities are placed into one pool of resources with high capacity limit: the expected value of accessible resource capacity is higher than the number of incoming entities require.

The routing decision may be made using percentage distribution at outputs of Activity 02.

The resolution (T) is 0.01 day. The interval of observation (simulated time) is 365 days.

There are two process models built: a Flow-DES simulation model (F-DES) and a Multi-phase EFA model (EFA-M).

(Both process models (F-DES and EFA-M) are created in an Event-driven Discrete-Event Flow-Simulator, ImiFlow™ of Elassys Consulting Ltd.)

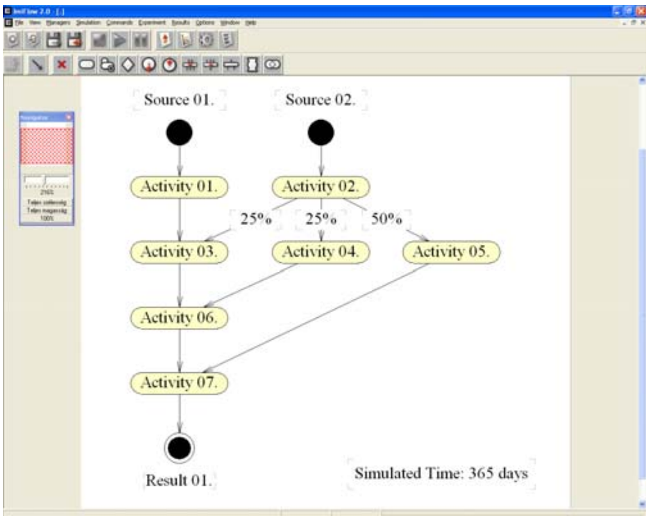

Figure 1. The examined test enterprise process

The comparison results are summarised in Figure 2., Figure 3. and Table 1.

Figure 2. shows the delay time (measured in days) of entities at Activity 05. for DES and EFA methods. There is a higher dynamics in DES but the moving averages (thick dashed lines) are closer to each other.

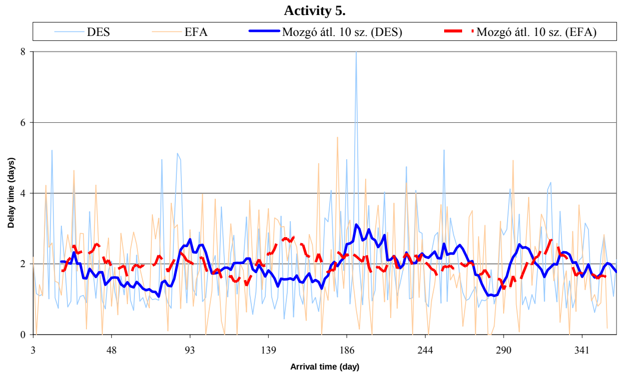

Figure 2. The output delay at Activity 05.

Figure 3. shows the delay time of entities at Activity 07. which is the exit point of the process. Here, the arrival frequency of entities is higher than in Figure 2. DES and EFA moving averages are again close to each other.
The average delays for DES and EFA for every Activity and for the whole observation period are collected in Table 1. The results in columns F-DES and EFA-M are highly correlated.

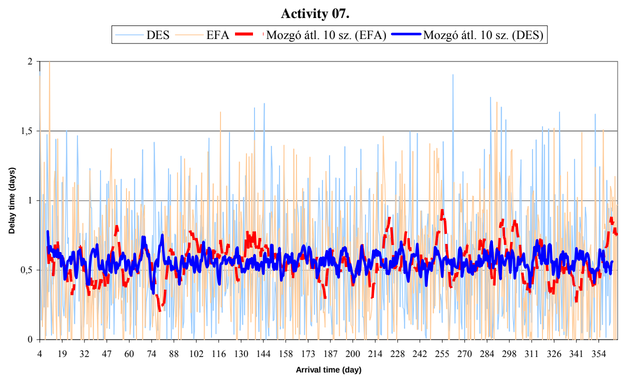

Figure 3. The output delay at Activity 07.

Name	F-DES	EFA-M
Activity 01.	1.52 day(s)	1.50 day(s)
Activity 02.	1.30 day(s)	1.30 day(s)
Activity 03.	3.21 day(s)	3.19 day(s)
Activity 04.	3.18 day(s)	3.46 day(s)
Activity 05.	2.21 day(s)	2.16 day(s)
Activity 06.	4.46 day(s)	4.73 day(s)
Activity 07.	5.89 day(s)	5.85 day(s)

Table 1. Comparison of DES and EFA delays

CONSIDERATIONS ABOUT THE APPLICATION OF EFA FOR PARALLEL ANALYSIS

In the case of information system design in an organisation, after identifying the ICT and BP subsystems to be examined (using the meta-methodology developed by the authors) we may have different situations:

If we have one ICT and one BP subsystem, depending on the focus of the simulation there can be three basic parallel simulation decisions: (1) detailed simulation of both ICT and BP subsystems; (2) detailed simulation of ICT system with simulated BP as process environment; (3) detailed simulation of BP with simulated ICT system as environment. The BP and ICT parts can act as the two segments of parallel discrete event simulation. They can be executed parallel by two interconnected processors. For all the three situations the use of the Statistical Synchronisation Method (Pongor 1992) can be considered as an inter-processor synchronisation method if there is a relatively slow speed of changes in subsystems' states. ***In situation (2) the use of EFA may be considered.*** In situation (3) the method of TFA may be appropriate.

Methods for the ***parallel execution of the Combined DES and TFA*** (Lencse 2004) can be found in (Lencse 2005); similar considerations can also be made for ***EFA*** application. (Combined application of DES, TFA and EFA should be the object of future research work.)

CONCLUSIONS

We have introduced a new method for the fast performance analysis, EFA in this paper.

We have defined model elements for EFA:

- we have described activity model-element and linking of activities,
- we have defined entity-load models: the usual arrival profile, and the entity-throughput model,
- we have given a formula and a method for delay-time calculation,
- we have examined the problem of entity routing depending on process decisions.

Using the introduced elemets we have outlined two versions of EFA method: One-phase method for rapid analysis and Multi-phase method for a more precise fast evaluation.

We have given solution to the problem of possible feed-back loops in the examined process.

In the end we have tested the EFA method on an example of an enterprise process.

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BIOGRAPHY

GÁBOR LENCSE received his M.Sc. in electrical engineering and computer systems at the Technical University of Budapest in 1994 and his Ph.D. in 2000. The area of his research is (parallel) discrete-event simulation methodology. He is interested in the acceleration of the simulation of communication systems. Since 1997, he works for the Széchenyi István University in Győr. He teaches computer networks and networking protocols. Now, he is an Associate Professor. He does R&D in the field of the simulation of communication systems for the Elassys Consulting Ltd. since 1998. Dr Lencse works part time at the Budapest University of Technology and Economics (the former Technical University of Budapest). There he teaches digital design and computer architectures.

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