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Automated Functional Size Estimation using Business Process Models with UPROM Method

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***Abstract*—Estimating functional size in early phases of software projects is essential for accurate effort and cost planning. When an organization requires its business processes to be automated by a business application software, business processes are analyzed in the initial phases and utilized in various ways through software development life cycle. In previous studies we presented a unified business process modeling methodology, UPROM for the practices of business process and user requirements analysis, COSMIC based functional size estimation (FSE) and process documentation. Applying UPROM notation, process and guidelines to implement these practices in an integrated way, a set of models are developed that can be used to generate related artifacts. As one of the artifacts, UPROM tool is used to automatically estimate the early COSMIC functional size conforming to UPROM FSE method. The procedures and rules of UPROM FSE method are described in this paper. The results of multiple case study and validation activities indicate that UPROM can be used to achieve reasonably accurate size estimation results in early phases and decreased subjectivity without significant extra work for estimation.**

Keywords—business process modeling, requirements analysis, early functional size estimation, COSMIC

I. INTRODUCTION

Software functional size measurement (FSM) methods utilize functional user requirements to identify the size of the software [1]–[3]. Usually accurate size measurement is not available to be utilized as a basis for project effort estimation until the end of software requirements specification phase. However, project managers need to estimate the effort in earlier phases of the software development life cycle by using methods like early size estimation and expert judgment. Due to scarce and unstructured information in early phases, this estimation is usually unreliable, subjective and unrepeatable [4]. Therefore, methods are needed to achieve reasonably accurate size estimation of the software in early phases and without requiring excessive effort.

Process-aware information systems (PAIS) have become popular in the last decades [5]. A PAIS is a software that automates business process workflows and is developed with any method including general purpose coding languages or process automation infrastructures. Regardless of the development method, an organization needs to analyze and define its business processes in an early phase, and usually does this in the form of business process models.

The knowledge embedded in business process models is utilized in many practices in software development life cycle though usually not transferred to those practices in a systematic way. Such practices we identified during our previous studies are business process and user requirements analysis, functional size estimation (FSE) and process documentation [6]. The outputs of these practices are usually developed independently, thus they end up to be inconsistent and unmaintainable. Additionally, excess effort is spent for developing these outputs. We developed a unified business process modeling (BPMod) methodology, UPROM, to analyze business processes and user requirements in an integrated way in early phases of software development life cycle [6]. The models developed by applying UPROM are then utilized to automatically generate artifacts of user requirements document containing natural language requirements sentences, process definition document conforming to a template, business glossary and process metrics list. UPROM notation is used to represent user requirements in a systematic way. Though these user requirements are not yet as mature as software requirements, model constructs and operations conducted on conceptual system entities logically correspond to FSE concepts and data movements. We defined rules to map FSE concepts of COSMIC method [7] to the models and automatically calculate an estimated size of the related business application (or PAIS) in COSMIC function points (CFP).

In this paper we present UPROM notation, then describe UPROM FSE method which includes the conversion and mapping rules to achieve estimated software size in CFP from the models. UPROM tool is utilized to conduct BPMod in conformance to the methodology and automatically generate FSE report conforming to the rules. We also present the validation activities for the UPROM FSE method. By using UPROM, one can obtain early and reasonably accurate size estimation of a PAIS by spending almost no extra effort. As the models already developed for business process and user requirements analysis are utilized in an automated way, subjectivity and non-repeatability problems in applying the method are overcome.

Unlike other early FSE methods, UPROM method does not enforce users to follow any instruction specific to size estimation. It provides rules to automatically calculate

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estimated size from the models already developed for business process and user requirements analysis. Users just need to analyze business processes and user requirements as guided by UPROM, then they automatically obtain early FSE for the PAIS. Details of analysis activities and generation of other artifacts are left out of scope of this paper. We focus solely on FSE aspect of UPROM.

The rest of the paper is organized as follows. In section 2, a summary of the related research is provided. Section 3 briefly describes UPROM. Section 4 explains the details of UPROM FSE method. Section 5 presents two applications and validation activities. Section 6 concludes the study.

II. Related Work

There are a few methods for early software FSE. Jones' very early size predictor method can be used for estimation only by providing scope, class and type of a project [8], though it provides rough prediction for very early phases. Standard component sizing and proxy based estimating methods [9] rely on historical data. Wideband Delphi, statistical sizing [10] and FPAi [9] methods enhance expert judgment by using group of estimators and statistical methods. Early & Quick COSMIC-FFP [11] is used by breaking down the software objects and estimating data movement ranges for different object types. The method relies on the estimator's ability to identify software objects and leads to subjectivity. A comparison of these models for early FSE of a system can be seen on [12].

Automation of FSM brings the benefits of decreased measurement variation, prevention of subjectivity, continuous measurement and effort reduction. FSM automation methods mostly utilize software models. Survey studies reveal that model based FSM procedures utilized Unified Modeling Language (UML) diagrams, object oriented and conceptual models to define formal COSMIC measurement procedures [13]. Other methods automating the measurement utilized data models, use cases, sequence and class diagrams and other object oriented models [14]–[19].

The studies utilizing business process models as input to FSM activities are scarce. An earlier study is for IFPUG method [2] and focuses on reuse. Other two examples use business process models but don't provide rules for mapping FSM method concepts [12], [20]. The study of Monsalve et al. supports our ideas that business process knowledge can be utilized to measure the size of the software [21]. In their method Qualigram and BPMN notation constructs are mapped to COSMIC concepts. This method introduces notation elements specific to size estimation purposes (like read and write annotations), embeds all information on the control flow and requires modeling of business processes in workflow level.

A recent work [4] maps COSMIC constructs to the extended Event Driven Process Chain (eEPC or shortly EPC) models [22] and automates the estimation procedure. The study returned positive results in a case study. This study was utilized and extended to develop UPROM FSE method described in this paper. This method is specialized in FSE of business application systems that automate business processes, or PAIS.

III. UPROM Background

UPROM is a unified BPMod methodology for practices of business process improvement, analysis and modeling, user requirements analysis, software FSE and process documentation in an integrated way. As a result, a set of models is developed that embeds all required information to generate the artifacts of the user requirements document, software FSE report, process definition document, business glossary and process metrics list. Details of the methodology can be found in [6] and [23].

BPMod is conducted based on UPROM metamodel that includes six diagram types. EPC is the core diagram type of UPROM metamodel focused on representing the control flow. EPC, disseminated by ARIS framework, is a common BPMod notation in literature and practice for analyzing processes and ensuring communication in business domain [22]. Alternative to EPC, BPMN is another well-known and popular BPMod notation. Although BPMN aims to be a common notation for both business and technological perspectives, such a goal brings complexity problems for business users [24]. To enable usage of BPMN in business domain, usually modeling is conducted with a restricted model element set in practice [25]. EPC and the restricted element set of BPMN have indeed similar expressive power and transformation of EPC models to BPMN is possible [26], [27]. We plan to integrate BPMN notation to UPROM as an alternative diagram type to EPC.

All diagram files of the same scope developed by using UPROM notation are placed in a "modeling project". The folder structure of the modeling project is organized according to their hierarchy of sub-diagram relations. Objects in the same modeling project with identical names are assigned to be unique. Attributes of each instance of a unique object are updated together. The metamodel elements and possible connection types for each diagram type are given below.

- **Value Chain (VC) Diagram:** Value Chain, Risk, Objective, Product. Connections: is predecessor of, is process-oriented superior (between value chain symbols), relation.
- **Function Tree (FT) Diagram:** Function, Technical Term. Connections: directed relation, relation.
- **EPC Diagram:** Event, Function, Process Interface, Business Rule, Application, Organizational Elements (Organizational Unit, Group, Location, Position, Internal Person, External Person), Information Carriers (Document, List, Log, File, Reference, Product), Technical Term, Improvement, Key Performance Indicator (KPI), Risk, Objective, Connectors (And, Or, Xor). Connections: control flow, information flow, relation.
- **Organization Chart (OC) Diagram:** Organizational Elements (same with the ones in EPC diagram). Connections: directed relation.
- **Function Allocation (FA) Diagram:** Organizational Elements, Function, Entity, Cluster, Application, Constraint, Improvement. Connections: information flow, relation.

- **Conceptual Entity Relationship (ER) Diagram:** Entity, Cluster, Attribute, Key Attribute, Generalization, Relationship. Connections: relation, aggregation.

UPROM analysis activities are summarized in the following sections.

A. Analyze Processes and Develop BPMod Diagrams

UPROM guides users to analyze business processes from functional, behavioral and organizational perspectives. VC and FT diagram types are utilized for functional and EPC for behavioral perspective. Any of these diagrams can be placed at the top level of the folder structure as the process map diagram. Each VC, FT and EPC diagram is associated to any other VC, FT and EPC diagram by one and only one sub-diagram relation. EPC diagrams exist at the lowest level. OC diagram is utilized to analyze the organizational elements placed on EPC diagrams.

B. Analyze User Requirements and Develop Analysis Diagrams

Each leaf function object on EPC diagrams is analyzed to determine if it is to be automated by PAIS. If so, an FA diagram is assigned as a sub-diagram of that function. FA diagram enables analysis of user requirements related to the execution of that function. FA diagrams are identified based on business processes. Thus, no function that is not placed in the business process can be allocated to PAIS to automate the related processes. In this way, in UPROM it is assured that business processes guide the analysis of user requirements and they are strictly related to each other.

An example FA diagram can be seen in Fig. 1. Object types placed on this FA diagram are: Function (rounded rectangle), entity (light-colored rectangle), application (rectangle with double stripes), position (rectangle with single stripe), external person (white rectangle), constraint (dark-colored rectangle).

An FA diagram expresses three different requirement types. The first is for identifying responsibilities for executing the function. This is modeled by organizational element-function relation. This relation can indicate the following responsibility types: "carries out, approves, supports, contributes to, must be informed on completion".

The second requirement type is used for specifying the entities to be read and manipulated by applications. This is modeled by function-entity and entity-application relations. Function-entity relation indicates the CRUDL-based operation conducted on the entity while the function is executed. Operation types can be: "reads, changes, lists, creates, deletes, views, uses". Entity-application relation specifies the application on which the entity resides on. Third requirement type is for defining constraints ruling on the function. This is modeled by application-constraint relation.

By using FA diagram requirements are analyzed in user level. Thus, unlike mature software requirements used as input to FSM methods, these requirements are identified in early business analysis by modelers and end users. Entities placed on FA diagrams are conceptual definitions that cannot be directly utilized to generate a database schema. Still, higher level relations between those entities are identified in UPROM's conceptual ER diagram. Generalization, named relationship and aggregation relations can be specified between entities on an ER diagram. An example can be seen in Fig. 6.

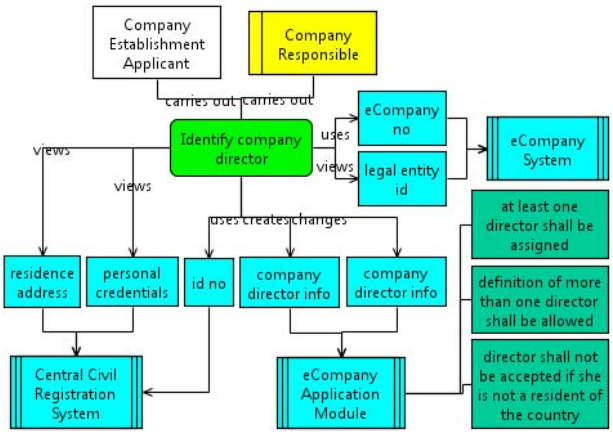

Fig. 1. Example Function Allocation (FA) Diagram

IV. UPROM FSE METHOD

A. Measurement Strategy Phase

The purpose of using UPROM FSE method is to measure the size of user requirements for the PAIS in early phases of SDLC. The level of granularity is higher than the functional user requirement (FUR) level defined by COSMIC, though the concepts are the same. As defined by [28], FURs are related to transfer, transformation, storage and retrieval of data. Same concepts are represented in FA diagrams of UPROM. But granularity of the requirements is higher, covering more than single event. The higher granularity is defined to be acceptable by COSMIC method. In this study, the term user requirements is used for the functional requirements defined in UPROM in higher granularity and in an early phase of SDLC. To indicate FURs defined in the granularity level required by COSMIC, the term software requirement is used.

The software to be developed is represented by application object in UPROM. If multiple applications are placed on the models, all are in the scope of the measurement. If a system is decomposed and components are placed on the models as applications, each component is measured separately and results are summed up.

Functional users are the organizational elements connected to the functions. External applications on FA diagrams from which data is used and to which data is sent are also functional users. Thus, system boundary lies between these functional users and applications to be measured.

B. Mapping Phase

1) Functional Processes (FP): A functional process is a "unique, cohesive and independently executable set of data movements" [1]. Thus, as UPROM procedure, lowest level

functions in EPC diagrams which are assigned an FA sub-diagram for automation are functional processes. Due to a higher level of granularity, the coverage of a functional process may be broader compared to COSMIC. EPC notation requires the event that activates the function be modeled before the related function. Thus, triggering events are also specified in EPC diagram. Considering the COSMIC rule that a functional process must have at least two DMs; an FA diagram must also contain at least an entity and application in addition to function.

2) Object of Interests (OOI) and Data Groups (DG): Operations on entities are modeled on an FA diagram, each entity depicting an object that is processed by the software. Thus, each entity is an OOI on which DMs are applied. Entities are mostly persistent, showing objects existing in the system after the function is completed. Transient objects are also modeled as entities, to show outputs that are created for that function. DGs are not explicitly specified, but usually realized by the explanation provided by constraint objects.

C. The Measurement Phase

COSMIC measurement method calculates the size of a system by adding up all DMs [1]. DMs are basic components moving a single data group with Entry (E), Exit (X), Read (R) and Write (W) movement types. In UPROM, as the user requirements analysis is conducted at a higher level, individual DMs are not yet identified in user requirements. However, as modeled on FA diagram, CRUDL-based operations conducted on each entity during the execution of the function provides information about DMs of the related functional process. Using CRUDL operations to determine the life-cycle and DMs of OOIs in a functional process is also suggested by COSMIC business application guideline [7]. In UPROM, seven operation types based on CRUDL operations are determined to express user requirements. In Table 1 below, operation types used in UPROM, the related base CRUDL operations and DM conversions for each operation are provided.

TABLE I. UPROM CONVERSION FROM OPERATION TYPE TO DM

Operation Type	Base CRUDL Operation	Data Movements
Create	create	E, W
Change	update, list	E, R, W, X
Delete	delete	E, W
View	list	E, R, X
List	list	E, R, X
Read	read	R
Use	read	R

The interpretation of each operation type in Table 1 is provided below. It should be kept in mind that these operations also aim to analyze and express user requirements.

- **Create**: It indicates the creation of an entity into a persistent storage. It is also used when data of an entity is sent to an external application.
- **Change**: It is used when the attributes of an entity need to be changed. In COSMIC method, change is usually considered as two separate functional processes: “Retrieve for update” and “update”. As UPROM handles them as only one operation, 1 E and 1 X DM less is measured compared to COSMC. COSMIC mentions that these two can also be taken as a single functional process. Considering that functional processes are analyzed at a higher granularity in UPROM, these two are considered single operation, and single E and X DMs are added. When there is a change operation in an FA diagram, it is common that the entity to be changed also needs to be listed or queried. So, it is suggested that the existence of list, search or query shall also be considered when change operation is used.
- **Delete:** When an instance of an entity needs to be deleted, this operation is used.
- **View:** This operation is used when the attributes of a specific entity, usually a previously selected one, are obtained and shown to the user.
- **List:** It is used for situations where an entity is listed for all of its values, or it is queried by one or more of its attributes and the resulting limited set of entities are shown. Listing operation is also used when a listing (like drop-down list) is populated during the operations pertaining to other entities.
- **Read:** When it is required just to obtain the attributes of an entity, this operation is used. This happens together with other entity operations. Usage of read and list can sometimes be mistaken. The difference is that, read is used when a single entity needs to be retrieved and used in other operations, and doesn’t need to be shown to the user.
- **Use:** This operation is only used together with list or view to express the information utilized for those operations. For example, if a query is conducted on an entity, some attribute is utilized to make the search. That attribute is shown connected with a use operation so that in the user requirements, we can understand the basis for the query.

DMs are calculated for each entity, then added up for each application based on entity-application connection on FA diagram. Further rules are utilized to adjust DM values calculated by converting operations based on Table 1. Before introducing these rules, we provide an example conversion below for the FA diagram in Fig. 1.

- eCompany System: 1 Uses + 1 Views: 1E + 2R + 1X
- eCompany Application Module: 1 Create + 1 Change: 2E + 1R + 2W + 1X: 7 DMs
- Central Civil Registration System: 1 Uses + 2 Views: 2E + 3R + 2X: 7 DMs

The rules applied to fine-tune DMs identified by the conversion and identify total estimated functional size for each application are described below. The DMs in an FA

diagram are calculated separately for each application system on the diagram. Thus, the following rules are applied separately for each application.

1) ***Rule 1****:* If there is a create or delete operation in a functional process but no X DM is introduced, one X DM is added. The rule is applied taking of list and view operations. The rationale for this rule is that, there shall be one X for all create and delete operations in a functional process, but not an X for each operation to prevent the improper accumulation of X DMs. Apart from that, each list and view operation shall have its own X DMs caused by basic COSMIC rules. Each change operation inherently contains retrieve and update, thus having an X DM in the conversion table. This rule also ensures that there is at least one X DM in a functional process.

The rule is illustrated in Fig. 2. Before applying Rule 1, total DM of the FP would be: 1 Create + 1 Delete: 2 E + 2W = 4 DM. By applying Rule 1, 1 X DM is added and resulting DM is 5.

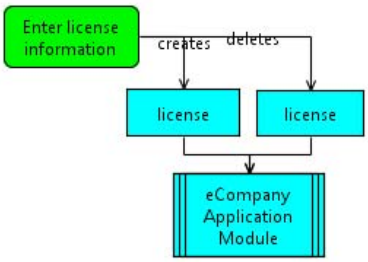

Fig. 2. Illustration of Rule 1

2) ***Rule 2****:* To prevent unnecessary accumulation of E DMs in FPs, the sub-rules described below are applied. At COSMIC method, when an OOI is listed, viewed, created, changed or deleted, DMs of type R, W and X may be applied for other related OOIs depending on the E-R model of the system. If this is the situation, usually E DM is only one in the functional process, as there is only one triggering entry. But considering UPROM conversion table (Table 1), multiple E DMs will be added up for each such operation. To prevent such occurrences, ER diagram of UPROM is used to identify "related entities" and remove extra E DMs for those entities.

To illustrate how this rule is applied, consider a part of the ER diagram for a simple celebrity system in Fig. 3. Fig. 4 expresses a requirement of this system, where a paparazzi enters a record of a catch he discovers for a celebrity in a certain place. When direct conversion is applied for this FA diagram, functional process should have 3 E DMs caused by one create and two list operations. However, celebrity and place entities are listed only because the user requests to enter a catch record, thus no other E DMs are added with respect to COSMIC rules. To comply with this, UPROM method removes extra E DMs when they are introduced in the same FA diagram because of the operations on related entities.

E DMs are removed for operations on the entities that are assigned to be "related" by the following rules.

- Any entities connected with generalization, relationship or aggregation are related.
- Entities need to be directly connected and they should be on opposite sides of the connection (decided by the direction of connections on diagrams). Only one relation needs to exist in between. Multiple levels of relations are not accepted.
- Entity is not accepted to be related to itself. Thus, separate E DMs are added for multiple operations on the same entity.

We are aware that not all of the operations on related entities are applied due to the triggering effect of the main entity. Some of the operations on the related entity may be applied because of any other independent reason, thus the application of the rule may result in inappropriate removal of E DMs. Considering that each activity and the related FA diagram is focused on some specific functionality of the system, we assume that such cases will occur rarely enough and will not introduce a big diversity in size estimation results.

We also assume that operations on all sub entities and their aggregate entity relevant for the functional process are explicitly modeled on FA diagram. If the modeler analyses the processes by only placing the aggregate entity and assumes that the same operations will also be valid on sub entities, the size needs to be automatically multiplied for all sub entities. If this is the practice, this rule must be implemented in UPROM tool to calculate size in this way.

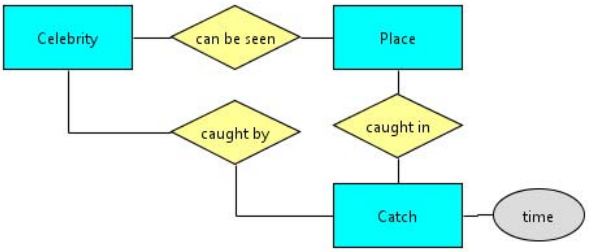

Fig. 3. A part of ER diagram for Celebrity System

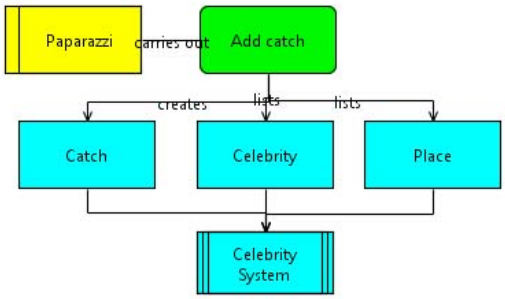

Fig. 4. An FA diagram representing the requirement for adding a catch

3) ***Rule 3****:* If a function on an FA diagram is executed by more than one organizational element, the measured size

of the functional process shall be multiplied by the number, as there will be two separate functional users that can conduct the function. However, if FA diagram is referenced more than once in the models, the size is not added up again.

4) ***Rule 4****:* According to COSMIC method, a functional process shall comprise at least two DMs, an E plus either an X or a W. Thus, at least one operation of type create, change, delete, view and list must exist on an FA diagram. Read and use operations cannot exist alone.

The rules 1 to 4 are applied to operations conducted on entities residing on a single application in an FA diagram. The following rules are applied on the whole modeling project.

5) ***Rule 5:*** The whole modeling project is scanned for applications for which only the following operations are conducted on its entities: list, view, read, use. It is concluded that this is an external application from which data is only requested and viewed. There may be also other external applications shown on FA diagrams to which data can be provided, like external web services. Only create operations are conducted on those applications to indicate that data of an entity are sent. Both types of external applications are functional users of the system. DMs calculated for such applications are added up to the size of the main application in the related FA diagram.

6) ***Rule 6:*** Any entity in the modeling project must be created in at least one functional process during its lifecycle. This means that at any place through all business processes, we should be observing a create operation for each entity. This is not applicable to entities residing on external applications identified by the previous rule.

To exemplify detailed application of the method and depict how rules are applied, an FA diagram is provided in Fig. 5. Constraint objects are removed from this diagram as they are not used in FSE. To implement the rules, a part of ER diagram related to the FA diagram is given in Fig. 6.

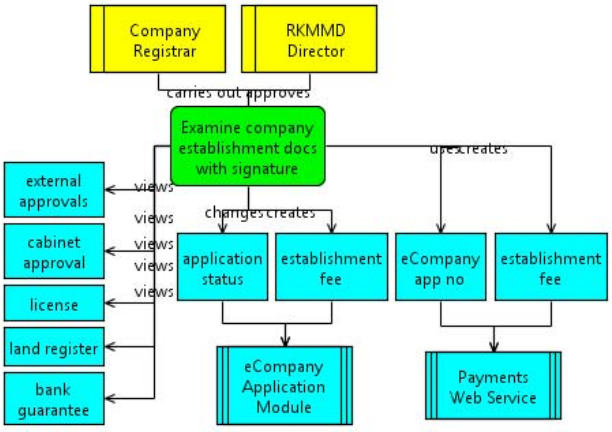

Fig. 5. A more detailed FA diagram example

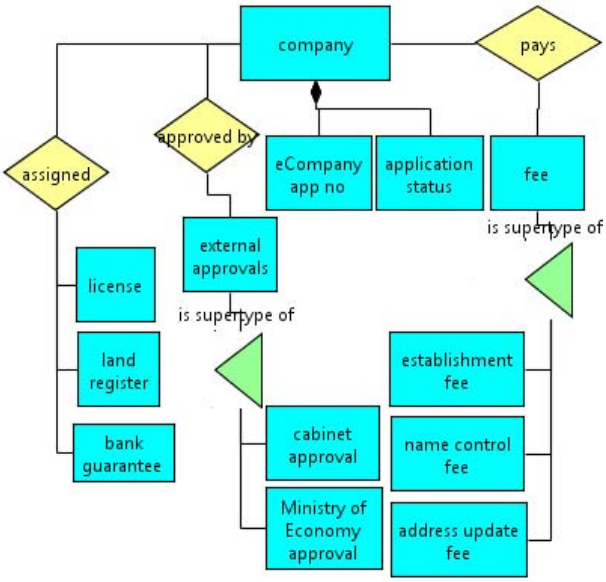

Fig. 6. Part of ER diagram for the example FA diagram in Fig. 5

The application of UPROM FSE method phases for eCompany system and the calculation of estimated size for FA diagram in Fig. 5 is explained below in a stepwise manner.

- The initial phase is the measurement strategy phase to be identified for the whole software to be developed. The scope of measurement is the process automation software defined by the modeling project in which FA diagram in Fig. 5 resides. This is eCompany; an online system for managing life cycle processes of companies. eCompany system is decomposed into software modules, which are all in the scope. eCompany Application Module depicted in the figure is one of them. Functional users in Fig. 5 are Company Registrar and RKMMD director. Payments Web Service, which is an external application, is also a functional user.
- In the mapping phase, functional processes, OOIs and DGs are identified. For the FA diagram in Fig. 5, the functional process is: Examine company establishment docs with signature. OOIs in this diagram are the entities of external approvals, cabinet approval, license, land register, bank guarantee, application status, establishment fee and eCompany app no. DGs for this functional process are not explicitly specified.
- The third phase is the measurement phase. The size is calculated for applications in each FA diagram and added up to find the overall size. The calculations are exemplified below for FA diagram in Fig. 5.
- For each application, convert operations to DMs according to Table 1:
  Payments Web Service: 1 creates + 1 uses = 1E + 1R + 1W

eCompany Application Module: 5 Views + 1 Create + 1 Change = 7E + 6R + 5W + 6X

- Apply Rule 1: The rule is applicable only to "Payments Web Service" DMs, as no X DM exists for it although there is a create operation. Thus, total DMs for this application is updated as:
  Payments Web Service: 1E + 1R + 1W + 1X
- Apply Rule 2: This rule is not applicable to Payments Web Service, as the two entities "eCompany app no" and "establishment fee" are not related. For eCompany Application Module, we observe ER diagram considering the rules and conclude that only two entities "external approvals" and "cabinet approval" are related. One E DM is removed for this and the resulting DMs for this application are updated as:
  eCompany Application Module: 6E + 6R + 5W + 6X
- Apply Rule 3: The function is executed by more than one organizational element (one with "carries out" and the other with "approves" responsibility). Thus, we multiply all DMs by two:
  eCompany Application Module: 12E + 12R + 10W + 12X
  Payments Web Service: 2E + 2R + 2W + 2X
- Apply Rule 4: FA diagram conforms to the constraint as there are view, change and create operations. No action is required.
- Apply Rule 5: Considering the whole modeling project, we understand that Payments Web Service is an external user of the system. The main application of this FA diagram is eCompany Application Module. If there were more than one other application, the main application would be the one connected to the function on EPC diagram level. Thus, we add up all DMs to only one application and end up with the following result:
  eCompany Application Module: 14E + 14R + 12W + 14X
- Apply Rule 6: For eCompany Application Module, the entities which are viewed and changed in this FA diagram must be created in other diagrams. Thus, we need to check that create operation is conducted for "external approvals, cabinet approval, license, land register, bank guarantee, application status" entities in any other FA diagrams of the modeling project.

D. Aggregation and Reporting of Results

DMs for the applications placed in the modeling project are found by processing all FA diagrams as explained in the previous section. According to COSMIC method, the size in CFP for an application is calculated by adding up all DMs. In the same manner, UPROM adds up all DMs for each application calculated in individual FA diagrams. UPROM automatically prepares an FSE report. The report is organized according to hierarchical headings of EPC diagrams. Result of size estimation for each FA diagram under the related EPC diagram is listed in subheadings as exemplified in Fig. 7. At the end of this report, total CFP for each application is given.

Considering all procedures including conversion and rules, one can think that UPROM FSE is complex to apply. However, the users do not need to deal with any of these procedures. They only need to focus on analyzing the user requirements conforming to UPROM guidelines. Estimated size in CFP for each application in the modeling project is automatically calculated and presented to user as a report exemplified in Fig. 7.

1. Process Name: Company.ftd

Process Address: eCompany

1.1. Pocess name: EstablishCompany.epc

Process Address: eCompany/01-EstablishCompany

1.1.1. MSR1. ApplyforCompanyEstablishment

Company Establishment Application:

Entry Function Point: 1

Read Function Point: 0

Write Function Point: 2

Exit Function Point: 1

Total: 4 CFP

1.1.2. MSR2. SelectCompanyType

Company Establishment Application:

Entry Function Point: 2

Read Function Point: 1

Write Function Point: 2

Exit Function Point: 1

Total: 6 CFP

Fig. 7. An excerpt from UPROM FSE report

V. APPLICATIONS AND VALIDATION

UPROM was applied in a multiple case study. Case study research is a common qualitative method used in information systems [29] applied to investigate a phenomena in its natural setting and analyze the individual cases to generate theories from practice [30], [31]. Case study research was appropriate to apply UPROM in cases and analyze the results in detail in its own context. To evaluate the applicability of UPROM in different cases, collect more data and deal with validity problems, multiple case study research was applied. The sources of evidences utilized are existing documents, interviews, direct and participant observation and physical artifacts. The following research questions were addressed in this study:

Research Question 1: Can UPROM FSE method be used for estimating the size of the system from business process models developed conforming to UPROM notation?

Research Question 2: Is there a significant deviation between the identified FSE and COSMIC FSM results?

We proposed that UPROM FSE method can be used to estimate the size of the systems in the cases and reasonably accurate results can be achieved, considering that the estimation is conducted in an early phase of SDLC.

The first case study specifically aimed to validate UPROM FSE method. In the other case, UPROM was utilized in projects in real life settings and the generated artifacts were utilized as project deliverables. The case studies and the validation approach are described below.

Detailed descriptions of the cases and the generated artifacts can be found in [32].

A. Case Study for Three Simple Applications

The first case study research was applied on three simple business application systems. Our research group [33] already defined the requirements of these systems and utilized them for different size measurement experiments [34], [35] in previous studies. Thus, the requirements and COSMIC size measurement results were peer reviewed many times. These are simple applications that do not execute long business processes, but have enough functionality for us to apply UPROM and compare the estimated and measured results.

The first system is Celebrity Information System where celebrities, relationships between celebrities, places and the catches where at least one celebrity is seen are managed. Fig. 3 and Fig. 4 are example models of this application. The second system is Veterinary Record System used to manage the record of pets, their owners and applied vaccines. Movie Manager System keeps the information on movies together with its directors, producers, writers and actors/actresses. The inquiries and listings are conducted for the movies.

To answer the research questions, the planned and conducted case study activities included the development of process models for three systems conforming to UPROM notation and system requirements, automated generation of FSE report by using UPROM tool and comparison of FSE results with the COSMIC measurement values.

An external expert checked the FSE report to verify that UPROM tool generates the size estimation in conformance with UPROM FSE generation procedures. She stated that "process models fit with the requirements properly" and "by using EPC, FT and FA diagrams, one can easily understand the related requirements". She manually calculated the size from FA diagrams following UPROM procedures and approved that the generated report gives the correct output.

Considering that early FSE conducted by UPROM is based on immature data compared to software requirements achieved in later phases, we don't expect the estimated size to completely correspond to the measured size. Even when a system with mature software requirements is measured by trained measurers using COSMIC method, measured size can deviate largely because of individual interpretations and assumptions. Experimental results show that more than 20% deviation is observed in most of the measurements caused by different interpretations [34]–[36]. Santillo and Meli suggested 10% deviation benchmark [37]. Adding up two aspects of deviation; individual interpretations, assumptions and benchmark; we accept that up to 30% deviation is reasonably accurate for an early FSE method.

TABLE II. METRICS ON BUSINESS PROCESS MODELS OF T

	Celebrity System	**Veterinary System**	**Movie Manager**
# EPC & FT diagrams	5	4	3
# FA diagrams	8	7	11
# entities	4	4	6

Metrics on business process models of the three applications are given in Table 2. The estimated sizes for three systems as generated by UPROM tool and COSMIC size measurement results as measured by previous certified measurement experts are provided in Table 3.

TABLE III. COSMIC FSM AND UPROM FSE RESULTS FOR THREE APPLICATIONS

	Celebrity System	**Veterinary System**	**Movie Manager**	**Average**
COSMIC FSM Size	36 CFP	37 CFP	85 CFP	53 CFP
UPROM FSE Size	38 CFP	36 CFP	83 CFP	51 CFP
Deviation of UPROM FSE size	5,6%	-2,7%	-2,4%	3,6%

As seen in the table above, UPROM FSE results deviated at most by 5,6% for the three cases, which is far below the accepted deviation range specified above. We need to keep in mind that business process models for these systems are developed using software requirements which specified system needs in detail. Applications are also quite small, making them easier to analyze. Thus, little room was left for interpretations and assumptions. When business process models are developed for complex systems in early analysis phase, we don't expect to end up with that "good" results. Still, this case study shows us that UPROM FSE method provides a good approximation to COSMIC method. Moreover, after the completion of models, almost no effort was expended to end up with the estimated size. The only operation conducted is to initiate the "FSE generation" functionality on the tool for the selected modeling project, and the results were achieved under a minute.

B. Case Study for Two e-Government Projects

Another UPROM case study was conducted in two projects as part of an e-government program. Project activities included the analysis of processes and user requirements in business perspective for Company (eCompany) and Trademark (eTrademark) Central Registration Systems to be developed. They aimed to provide an online workflow system to automate the lifecycle processes of companies and trademarks.

UPROM methodology was followed to analyze the as-is processes and define the to-be processes, prepare technical contract document, estimate the software size to plan the software development tender, and prepare the business process documents and business glossary for the users. 90% of the user requirements statements in the technical contracts were prepared from the user requirements document generated by UPROM tool. Process definition document and business glossary as generated by UPROM tool are directly delivered to the customer. The estimated COSMIC functional sizes by UPROM were used to make an estimate of required development effort and evaluate the tenders. All figures in this paper other than Fig. 3 and Fig. 4 are examples of these cases. Table 4 presents basic metrics on the business process models of eCompany and eTrademark systems.

TABLE IV. METRICS ON BUSINESS PROCESS MODELS OF E-GOVERNMENT SYSTEMS

	eCompany	eTrademark
# FT diagrams	3	3
# EPC diagrams	15	6
# FA diagrams	82	36
# Entities	106	58

Similar to the previous case study, this case study aimed to examine if we can achieve reasonably accurate estimation results for two real life projects by estimating the size with UPROM. This case study had research questions pertaining to other aspects of the methodology, which are outside the scope of this paper. 5 modules are identified for each system in their business process models. CFP size is calculated by UPROM separately for each module. Total size and distribution of the size to 4 DM types are shown in Table 5.

TABLE V. UPROM FSE RESULTS FOR E-GOVERNMENT SYSTEMS

Entry	Read	Write	Exit	Total
eCompany				
332	290	200	296	1118 CFP
30%	26%	18%	26%	
eTrademark				
119	112	89	117	437 CFP
27%	26%	20%	27%	

The distributions of DM types for eCompany and eTrademark systems are compatible with the ISBSG data set findings for business application domain [38], [39]. Write DMs are less, and the rest is close to each other. Only the number of entries is higher than the averages.

There is no benchmark size measurement value in this case study which we can utilize to compare UPROM FSE results, like in the previous case. Also, it is not possible to conduct a complete FSM conforming to COSMIC method, because the user requirements are not yet mature enough. To evaluate the estimation results, we selected a sample set of functional process from eCompany system. The selection aimed to cover different types of functionalities of the system such as company establishment application, entering information regarding the company to be established and approval operations. Samples from these processes were selected randomly, aiming about 10% coverage. We provided the business process models and generated requirements to an external certified measurement expert. She measured the functional processes using COSMIC and identified DMs. External expert also needed to make assumptions due to higher abstraction level of user requirements. Thus, her COSMIC measurement results can also be regarded as "estimation" and is not expected to be as accurate as a proper COSMIC FSM.

Number of DMs identified by the expert and estimated by UPROM are compared to each other for each functional process and total size. An example comparison for 4 functional processes are provided in Table 6. The total size of the sample is 110 CFPs, which is about 10% of the total estimated size of eCompany system. For the whole sample, the deviation of the absolute error of each FP is 27%, and deviation in total size is 6%. Considering the reference limits identified in the previous section, even the deviation for absolute error for each FP is below the limits. Considering that in practice total estimated value is used, we can conclude that size estimation for this case study is reasonably accurate.

According to interview results, the analysts agreed that the effort spent to identify user requirements with UPROM was about the same with conventional approaches; though a more complete and consistent set of requirements was achieved. However while extra effort needs to be spent in conventional approaches for estimating the functional size, the only operation conducted in UPROM was to initiate the size generation functionality of UPROM tool, which took under a minute.

TABLE VI. COMPARISON OF UPROM FSE AND COSMIC EXPERT MEASUREMENT

FP Name	Measurer	DM Type				Total	Difference
		E	R	W	X		
Apply for Establishment	Expert	1	0	2	2	5	1
	UPROM	1	0	2	1	4	
Identify free zone status	Expert	2	1	2	2	7	1
	UPROM	2	1	2	1	6	
Approve establishment fee	Expert	1	1	2	1	5	2
	UPROM	1	2	2	2	7	
Define company name	Expert	2	1	2	3	8	2
	UPROM	4	1	3	2	10	
Total	**Expert**	**6**	**3**	**8**	**8**	**25**	**2**
	UPROM	**8**	**4**	**9**	**6**	**27**	
	Deviation for absolute error of each FP (6/25)						24%
	Deviation in total size (2/25)						8%

VI. CONCLUSION

In this paper, we present UPROM FSE method used to automate early COSMIC based size estimation of a business application software that aims to automate business processes. This FSE method is part of the unified BPMod methodology, UPROM, to conduct analysis of business processes and user requirements in an integrated way. User requirements analysis is conducted in early business analysis phase, discovering the needs of the users from a business perspective based on business processes. The notation covers 6 different diagram types. If the diagrams are developed conforming to UPROM notation, rules and guidelines, one can automatically generate artifacts of user requirements document, early FSE report, process definition document, business glossary and process metrics list.

We focus on the rules and procedures of UPROM FSE method in this paper. Function allocation (FA) diagram, which is the diagram type to analyze the functions for automation, is utilized to calculate the estimated size. An FA diagram is created for each function in EPC diagrams that is to be automated by the PAIS. This ensures that user requirements analysis is guided by and conducted in tight relation with the business processes. FA diagram specifies

the CRUDL-based operations conducted on the entities that resides on the applications. According to UPROM size estimation procedure, these operations are converted to DMs, and then adjusted by applying various rules. However, the user does not need to learn and apply any of these procedures, as they are implemented automatically by UPROM tool.

UPROM FSE method brings various benefits. Estimated size in CFP is calculated with virtually no effort by means of automation. A reasonably accurate estimation of functional size is achieved in early phases of software development, as shown by the two cases. Variation of measurement and subjectivity due to the measurer are decreased by means of model usage and automation. Lastly, measurement can be repeated easily whenever the user requirements are updated.

UPROM FSE method is applicable for business application systems which aim to automate business processes, in other terms PAIS. Also, UPROM must be followed as the unified methodology to analyze both business processes and user requirements so that one can apply UPROM FSE method.

We evaluated UPROM FSE method in a multiple case study. The first case study aimed to compare UPROM FSE results of three small applications to their COSMIC function point sizes which are already measured in previous studies. The second case study is conducted for two e-government systems in real life settings. For this case, a sample functional process set is selected and manually measured according to COSMIC method. UPROM FSE results are compared to manually measured size in CFP. In both cases, the results are observed to be reasonably accurate compared to previous COSMIC FSM comparison studies.

To generalize the results and applicability of UPROM FSE method, more case studies need be conducted in different domains. To validate the results in a more comprehensive way, the estimated size will be compared to the measured COSMIC size using the software requirements in later phases of the projects and the correlation between the realized effort and estimated sizes will be examined.

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