Tool based approach for Integration Effort Estimation in Component Based Software Development Projects

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Abstract: Effort estimation is process of predicting most practical or tropical use of effort required to develop or maintain a software project. Estimation provides clear vision to the management to decide whether the proposed project is feasible or not under specified cost and time constraints. As there is change in paradigm from structured programming to object oriented and then component based development, there is always in demand to develop new technologies of effort estimation to keep pace with the change in paradigm. Various models have been suggested by number of scientists for component based software development. The most popular model is Cocots model which is amalgam of three sub-models i.e. assessment effort, integration effort and tailoring effort estimation models. Many researchers have proposed formulas for evaluating assessment and tailoring costs theoretically. Major problem found in the existing work is calculation of integration cost. This cost cannot be evaluated through some formula or theoretical calculations as the amount of code required as glue code is not predictable using these methods. This paper proposes the evaluation of the glue code cost using UML diagrams. A Java Parser Tool has been developed to evaluate the glue code by parsing through the XMI file which can be used in calculating integration effort of the component based software. For the support of the proposed system an existing UCRS system used to evaluate cost through implementation of it.

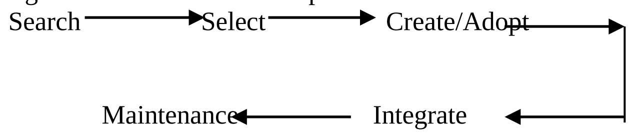
Keywords: Software Metrics, Glue code, Component-based software systems, Integration cost, Assessment Cost, Tailoring Costs, effort multiplier

I. INTRODUCTION

To meet the requirements of high quality software at low cost, new development paradigm have been introduced that facilitate the creation of reliable, flexible and reusable systems. One of such paradigm is component based software development that relies on the concept of building system using independent and reusable components.

CBSD is a reused based approach for designing, implementing and developing loosely coupled, independent, flexible and reliable components into the system.

Component based development collects requirements from the users, selects a suitable architectural approach to get up the objectives of the system to be built and then following the sequences (Khera, 2009)



CBSD requires focus on integration-centric activities names, searching and identifying candidate components, assessing and selecting components based on system requirements and architectural and project constraints, tailoring and integrating the selected components into a seamless software system and upgrading the system as components evolve over time with newer versions.

Component based software engineering has been widely accepted as a new and latest approach to software development. Various models have been suggested by number of scientists for component based software development. The most popular model is Cocots model which is amalgam of three sub-models i.e. assessment effort, integration effort and tailoring effort estimation models.[1]

$$\mathrm{CAE} = \sum (\mathrm{CCF\ X\ MIEF}) + \sum (\mathrm{CCA\ X\ MDAE})$$

$$\mathrm{CTE} = \sum (\mathrm{NCT\ X\ MTE\ X\ TCQ})$$

$$\mathbf{CIE=A\ (SIZE)^{B}\ \Pi\ EM}$$

Total Effort = CAE+CTE+CIE

Where CAE is efforts of component assessment

CTE is efforts of component tailoring

CIE is efforts of component integration

II. CALCULATION OF INTEGRATION EFFORT

The USC-CSE COTS Integration Cost Estimation Model Equation (Abts C.M.,2000)

$$\boxed{\mathbf{PM = A \times [SIZE]^{B} \times \prod_{i=1}^{13} EMi}}$$

Where-

A = 2.0 (A Multiplicative conversion constant Scale Factor)

B=1.00 + (0.04 × **SF)**

$$\mathrm{SIZE} = \mathrm{LOC} \times \left(1 + \frac{\mathrm{BRAK}}{100}\right)$$

Symbols	Descriptions
PM	Integration Effort in Person-month.
A	Constant, provisionally set to 2.0
LOC	Size of COTS component glue code expressed in source lines of code or function points.
BRAK	Brakage of the glue code due to change in requirements or component voltality.
EM	Effort Multipliers: ACIEP, ACIPC, AXICP, APCON, ACPMT, ACSEW, APCPX, ACPPS, ACPTD, ACREL, AACPX, ACPER, ASPRT
SF	Scale Factor: AAREN

2.1 Evaluation of Glue code size:-A Java parser tool has been developed to evaluate the glue code by parsing through the xmi file. Integration cost is the cost of generating glue code for adding two or more components to acquire a new workable system. The effort estimation in this work is pre-implementation so that the organization can predict the cost beforehand. The cost of integration through generation of glue code is calculated by analyzing the UML diagram through xmi files. Case study of UCRS (University Course Registration System) has been taken to evaluate the integration effort. The step-by-step method is as follows (Jain Rajul et al., 2017)

Step-1 : Case study of University Course Registration System(UCRS) (Jawwad W.Shareef et al.,2012) has been taken and deployment diagram of same has been designed using ArgoUml version 0.34 which is open source software and available over the internet.

Step-2: After designing the deployment diagram , its XMI (XML metadata interchange) file is generated using ArgoUml export to xmi option. XMI file contains each and every information regarding all the components that integrated into the system.

Step-3 : A Java based parser Netbeans version 7.1.2 to parse the xmi file and extract the information such as components, interfaces, operations, parameters etc.

Step-4: The information collected from the xmi file has been analyzed and amount of glue code required for each interface has been evaluated based on parameter processing.

Step -5: Some weight values has been applied with these amount of glue code values to increase the accuracies.

Step-6: The average of weighted glue code amount for all the interface is taken to calculate final glue code size.

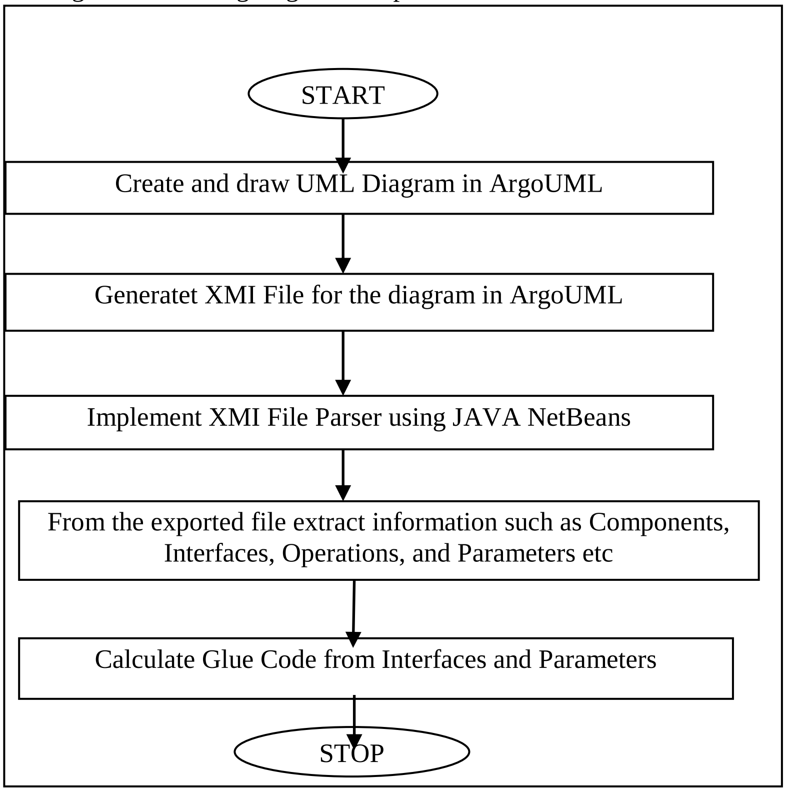

START
Create and draw UML Diagram in ArgoUML
Generatet XMI File for the diagram in ArgoUML
Implement XMI File Parser using JAVA NetBeans
From the exported file extract information such as Components, Interfaces, Operations, and Parameters etc
Calculate Glue Code from Interfaces and Parameters
STOP

Fig-1 Flowchart for Glue code size estimation

III. GLUE CODE CALCULATION

Glue code is measured in this work as lines of code required to integrate two components based on per interface per parameter. For including the possibilities all parameters are taken to be both single values parameters and multi-valued parameters. The assumption is justifiable as during the integration a component may need to receive a simple value or a compound value from other components. Since evaluation of these parameters might be complex therefore it is being assumed further that the component implementation handles these complexities during further processing but do not provide any type of conversions required between two components in respects of values and types. For reducing the possible error, weighted processing has been considered.

The processing cost of the single values parameters is taken as follows:

Every single value will be either assigned to receiving parameter directly which will include a single assignment statement. If type conversion is required then every language provides a set of statements for converting types of values, which is found to be between 2-3 additional statements e.g, in JAVA we have wrapper classes to convert types which requires two statements to convert from one type to another. Most involved type conversion is from String type to any primitive type which requires parsing of String i.e. O(c) processing time where c is number of digits, hence requiring n number of statements in conversion.

The processing cost of compound values is a combination of the ingredients of the compound types which themselves are single values or compound values. Therefore cost of these can be k * cost of single values where k is number of single values involved in each compound values.

After summing up we get the following formula for evaluating the glue code cost:

Glue Code Cost:

$n1 + n2*c + n3 * s + k1 + k2 * s + k3 * c;$

Where

n1 is number of single values parameters

n2 is number of single values requiring type conversion

c is cost of conversion

n3 is number of single values requiring conversion from String to numeric values

s is cost of conversion from String to numeric

k1 is number of single values requiring no conversion and involved in multi-values parameter

k2 is number of single values requiring conversion and involved in multi-values parameter

k3 is number of single values requiring conversion from String to numeric and involved in multi-values parameter

Application of weight mechanism:

Since glue code cost evaluated using parameters may involve some complex processing during assignment on receiving parameters therefore we need to apply some weight to reduce the possible error. The weight value should be higher than one always and must be kept as small as possible. As the weight is increased the value is considered to be more on assumption based then on the actual cost i.e. Weight 1/α Accuracy

Calculation of weight in this work is being done again on the basis of the number of parameters and it is being found that as the numbers of parameters are increased weight value is reduced.

2.2 Evaluation of Effort Multipliers (EMs)

Step-1: A Java form has been designed to capture the appropriate rating (ranging from very low to very high) for each of the thirteen effort multipliers and one scale factor from the user.

Step-2: After the rating of all the effort drivers, numerical value of each parameter corresponding to the assigned rating is determined using calibration table 1.

Step-3. All thirteen values of effort drivers are multiplied to get Π EM.

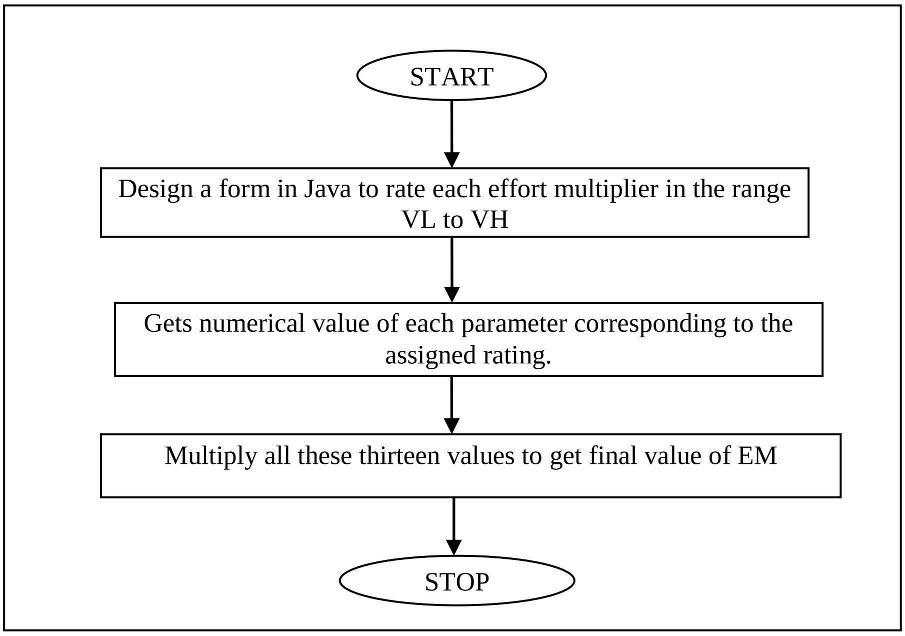

START
Design a form in Java to rate each effort multiplier in the range VL to VH
Gets numerical value of each parameter corresponding to the assigned rating.
Multiply all these thirteen values to get final value of EM
STOP

Fig-2 Flowchart for Evaluation of Effort Multiplier

Integration Personnel Drivers (Abts C.M.,2000)

1) **ACIEP - COTS Integrator Experience with Product**

How much experience does the development staffs have with COT product such as running, maintaining and integrating the product?

Metric: months/years of experience with product.

Very Low	**Low**	**Nominal**	**High**	**Very High**
No experience with the product	*< 6months Experience with the product.*	*6months-1year exp. with the product*	*1year- 2 years experience with the product.*	*>=2 years experience with the product.*

2) ACIPC – COTS Integrator Personnel Capability

What are the overall abilities, software development skills and experience of the development team with the specific platform, tool, language and programming language?

Metric: months/years of experience

Very Low	**Low**	**Nominal**	**High**	**Very High**
No experience with the product	*< 6months experience with the product.*	*6months-1year exp.with the product*	*1year- 2 years experience with the product.*	*>=2 years experience with the product.*

3) AXCIP - Integrator Experience with COTS Integration Processes

Does a validated and formal integration process exist in the organization and how experienced is the development staff?
Metric: a mix of conditions including SEI CMM level, ISO 9001 certification, and number of times integration team as a whole on average has used the defined COTS integration process.

Very Low	**Low**	**Nominal**	**High**	**Very High**
	CMM level =1 OR ISO 9001 certified AND No experience	CMM level =2 OR ISO 9001 certified AND No experience	CMM level =3 OR ISO 9001 certified AND Some experience	CMM level >=3 OR ISO9001certified AND More experience.

4) APCON - Integrator Personnel Continuity
How stable is your integration team? Are the experienced people staying around or leave the organization for the duration of the task?
Metric: annual integration personnel turnover rate.

Very Low	**Low**	**Nominal**	**High**	**Very High**
>=48%	*24% - 47%*	*12% - 23%*	*6% - 11%*	*<=5%*

5) ACPMT - COTS Product Maturity
How much time the previous versions were available on market ? Was the version thoroughly used by others ?
Metric: time on market.

Very Low	**Low**	**Nominal**	**High**	**Very High**
Pre-released Beta version	*Version available for <6 months*	*Version available for <6 months*	*Version available for 6 months–1 year*	*Version available for 1 year- 2year*

6) ACSEW - COTS Supplier Product Extension Willingness
How willing the supplier of the COTS product to modify the software design by adding or removing functionalities?
Metric: Nature and number of changes supplier will make.

Very Low	**Low**	**Nominal**	**High**	**Very High**
	Will not make any changes.	Will make a few changes	*Will make 1 major and many minor changes*	*Will make 2 major and many minor changes*

7) APCPX - COTS Product Interface Complexity
What are the complexity issues regarding the interfaces between the COTS component and the glue code connecting it to the main application?
Metric: the scale for this driver uses a subjective average of the three equally weighted facets of interface complexity described in table 2.

Very Low	**Low**	**Nominal**	**High**	**Very High**
	Point value is Between 5 - 7	*8-10*	*11-13*	*14-15*

8) ACPPS - COTS Supplier Product Support
What is the nature of the technical support that is available for the integration team for the COTS product during the development?
Metric: the level of support available and procured

Very Low	**Low**	**Nominal**	**High**	**Very High**
	No support	*Help desk support*	*Technical support*	*Consulting support*

9) ACPTD - COTS Supplier Provided Training and Documentation
How much training or documentation for the COTS component is available for the integration team during the development ?
Metric: the amount of training or documentation available.

Very Low	**Low**	**Nominal**	**High**	**Very High**
No training	*About ¼ of needed training is provided*	*About ½ of needed training is provided*	*About ¾ of needed training is provided*	*As much needed training is provided*

APPLICATION/SYSTEM Drivers
10) ACREL - Constraints on System/Subsystem Reliability
How severe are the reliability constraints on the system or subsystem into which the COTS component is being integrated?
Metric: the potential threat if the component fails to perform as expected

Very Low	**Low**	**Nominal**	**High**	**Very High**
	Threat is low.	*Threat is moderate.*	*Threat is high.*	*Threat is very high*

11) AACPX - Application Interface Complexity
What are the complexity issues regarding the interfaces between the main application system and the glue code used to connect the system to the COTS component?
Metric: the same subjective averaging of the items in table 2 as used for the driver APCPX.

Very Low	**Low**	**Nominal**	**High**	**Very High**
	Total point value is 5 - 7	*Total point value is 8 - 10*	*Total point value is 11 -13*	*Total point value is 14-15*

12) ACPER - Constraints on System/subsystem Technical Performance
How strict are the technical performance constraints (e.g. memory, reserve,capacity, etc.) on the application system that the COTS component needed ?
Metric: the presence or absence of constraints.

Nominal	**High**	**Very High**
There are no technical constraints or real time processing needs.	Real time processing must be performed OR other technical constraints exist.	Real time processing must be performed AND other technical constraints exist

13) ASPRT - System Portability
What are the overall system or subsystem portability requirements that the COTS component needed to meet?
Metric: the nature of portability requirements.

Nominal	**High**	**Very High**
There are no portability requirements at the system level	*System must be portable across platforms*	*System must be portable across divergent platforms*

Complexity Elements	**Very Low** **(point value 1)**	**Low** **(point value2)**	**Nominal** **(point value 3)**	**High** **(point value 4)**	**Very High** **(point value5)**
Interface Conventions		All API *conventions are clear and consistant* .	Most API *conventions are clear and consistant*	Few API *conventions are clear and consistant*	API *Conventions are non consistant*
Control Aspects		*All control aspects are well-defined and consistent.*	*Most control aspects are well-defined and consistent.*	*Few control aspects are well-defined and consistent.*	*No control aspects are well-defined and consistent.*
Data	*No data conversion required*	*Little data conversion required*	*some data conversion required*	*Significant data conversion required*	*Extensive data conversion required*

Table- 2 Interface complexity criteria

Table – 1 Calibration table for parameters (Abts C.M., 2000)

Glue Code Parameters					
Non-Linear Scale Factor					
	VL	L	N	H	VH
AAREN	4.00	3.00	2.00	1.00	0.00

Glue Code Parameters					
Cost Drivers	VL	L	N	H	VH
Personnel Drivers					
ACIEP	1.34	1.16	1.00	0.86	0.75
ACIPC	1.60	1.27	1.00	0.79	0.62
AXCIP	-	1.12	1.00	0.89	0.79
APCON	1.58	1.26	1.00	0.80	0.63
COTS Component Drivers					
ACPMT	1.45	1.20	1.00	0.83	0.69
ACSEW	-	1.07	1.00	0.94	0.88
APCPX	-	0.82	1.00	1.22	1.48
ACPPS	-	1.14	1.00	0.88	0.77
ACPTD	1.20	1.09	1.00	0.91	0.84
Application/System Drivers					
ACREL	-	0.88	1.00	1.14	1.30
AACPX	-	0.84	1.00	1.19	1.42
ACPER	-	-	1.00	1.11	1.22
ASPRT	-	-	1.00	1.07	1.14

IV.ABOUT UCRS

UCRS (Jawwad W. Shareef et al.,2012) is a automation system for the universities and provides various facilities to the students, faculties and staff. Within this system, a student registers for classes. Once given access, the students may select a term and build a class schedule from the offered classes. The system passes information about a student's schedule to the billing system. A student can also register, add, or drop a course. An instructor may use the registration system to print a student class list and to submit grades for her/his class. The administrator may maintain student and teacher information.

This model provides an overall view of the system and helps to demonstrate the extraction of existing component assembly complexity metrics. The component, RegistrationSystem, has seven provided interfaces namely, IMakeSchedule, IUpdateSchedule, IDisplaySchedule, IRegisterCourse, IViewResult, ISubmitGrades and ILogin which in ArgoUML tool are linked by an arrow known as (Abstraction). Similarly there are four required interfaces of component 'RegistrationSystem', linked by an arrow known as (Dependency). These required interfaces serve as provided interfaces for the following.

- ICourseMgt by component 'Course Management'
- ITermMgt by component 'Term Management'
- IPersonMgt by component 'Person Management'
- IBillMgt by component 'Billing System'

After the modeling of UCRS is completed, the metrics are derived using ArgoUML tool, the XMI 1.2 file is generated with the help of Export XMI option (ArgoUML using Netbeans XMI Writer version 1.0). Using this XMI file, the metrics are derived by parsing the XMI 1.2 file. The UCRS model in XMI is identified by a unique id (UML:Model xmi.id). The XMI file contains information of all components by assigning a unique (UML:Component xmi.id) to each component.

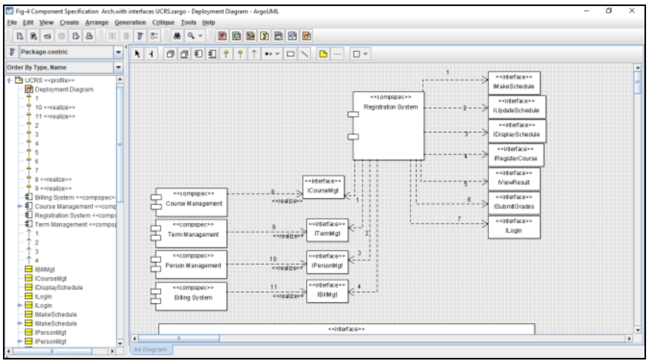


Fig-4 Component Specification Arch.with interfaces UCRS.zargo - Deployment Diagram - ArgoUML
File Edit View Create Arrange Generation Critique Tools Help
Package-centric
Order By Type, Name
<<compspec>> Registration System
<<compspec>> Course Management
<<compspec>> Term Management
<<compspec>> Person Management
<<compspec>> Billing System
<<interface>> IMakeSchedule
<<interface>> IUpdateSchedule
<<interface>> IDisplaySchedule
<<interface>> IRegisterCourse
<<interface>> IViewResult
<<interface>> ISubmitGrades
<<interface>> ILogin
<<interface>> ICourseMgt
<<interface>> ITermMgt
<<interface>> IPersonMgt
<<interface>> IBillMgt
<<realize>>
As Diagram

Fig.1. Component Diagram of UCRS Registration System (Jawwad W.Shareef et al.,2012)

The component provided and required interfaces are shown as a link pointed to a stereotype <<interface>>, here in XMI file the component which provides an interface to other components is identified by (UML:Dependency.client) by assigning a unique (UML:Component xmi.idref) to each component, the link which carries this dependency to the stereotype <<interface>> is identified by (UML:Abstraction) assigning a unique (xmi.idref), similarly for a required interface of a component the link which carries this dependency to the stereotype <<interface>> is identified by (UML:Dependency.supplier) in the system.

The XMI files stores all necessary information regarding UCRS model. This file is parsed Java Parser tool developed with the help of ArgoUML parser; to derive different metrics related to component assembly, using a Java API tool.

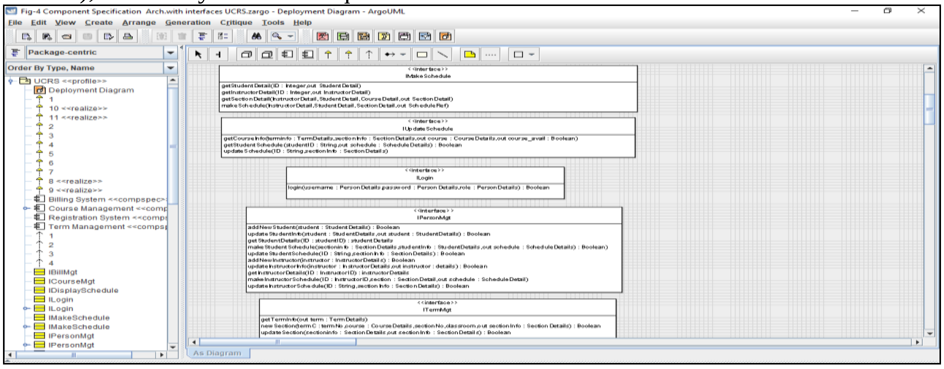


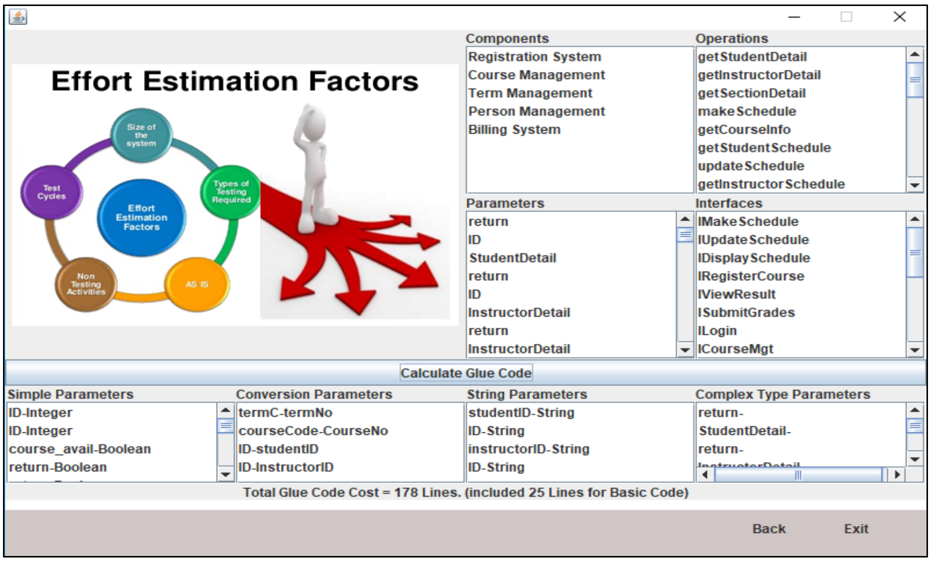
Fig-4 Component Specification Arch.with interfaces UCRS.zargo - Deployment Diagram - ArgoUML
File Edit View Create Arrange Generation Critique Tools Help
Package-centric
Order By Type, Name
As Diagram

```
<<interface>>
IMakeSchedule
getStudentDetail(ID : Integer,out StudentDetail)
getInstructorDetail(ID : Integer,out InstructorDetail)
getSectionDetail(InstructorDetail, StudentDetail, CourseDetail,out SectionDetail)
makeSchedule(InstructorDetail,StudentDetail, SectionDetail,out ScheduleRef)

<<interface>>
IUpdateSchedule
getCourseInfo(terminfo : TermDetails,sectionInfo : SectionDetails,out course : CourseDetails,out course_avail : Boolean)
getStudentSchedule(studentID : String,out schedule : ScheduleDetails) : Boolean
updateSchedule(ID : String,sectionInfo : SectionDetails)

<<interface>>
ILogin
login(username : PersonDetails,password : PersonDetails,role : PersonDetails) : Boolean

<<interface>>
IPersonMgt
addNewStudent(student : StudentDetails) : Boolean
updateStudentInfo(student : StudentDetails,out student : StudentDetails) : Boolean
getStudentDetails(ID : studentID) : studentDetails
makeStudentSchedule(sectioninfo : SectionDetails,studentInfo : StudentDetails,out schedule : ScheduleDetails) : Boolean)
updateStudentSchedule(ID : String,sectionInfo : SectionDetails) : Boolean
addNewInstructor(instructor : InstructorDetails) : Boolean
updateInstructorInfo(instructor : InstructorDetails,out instructor : details) : Boolean
getInstructorDetails(ID : InstructorID) : instructorDetails
makeInstructorSchedule(ID : InstructorID,section : SectionDetail,out schedule : ScheduleDetail)
updateInstructorSchedule(ID : String,section Info : SectionDetails) : Boolean

<<interface>>
ITermMgt
getTermInfo(out term : TermDetails)
newSection(termC : termNo,course : CourseDetails,sectionNo,classroom,out sectionInfo : SectionDetails) : Boolean
updateSection(sectioninfo : SectionDetails,out sectionInfo : SectionDetails) : Boolean
```

Fig. 2. Various Interfaces with Operations and Parameters of UCRS Registration System

IV. IMPLEMENTATION & RESULTS

A JAVA based application has been developed to evaluate the glue code for the case study of UCRS to estimate the cost of glue code. The implementation has been done to list all the components, interfaces, operations and parameters in the system by parsing the XMI file. As proposed in section above for evaluation of glue code formula, various statistics regarding the parameters, their types and their requirement of lines of codes has been calculated as stated.



Components
Registration System
Course Management
Term Management
Person Management
Billing System

Operations
getStudentDetail
getInstructorDetail
getSectionDetail
makeSchedule
getCourseInfo
getStudentSchedule
updateSchedule
getInstructorSchedule

Parameters
return
ID
StudentDetail
return
ID
InstructorDetail
return
InstructorDetail

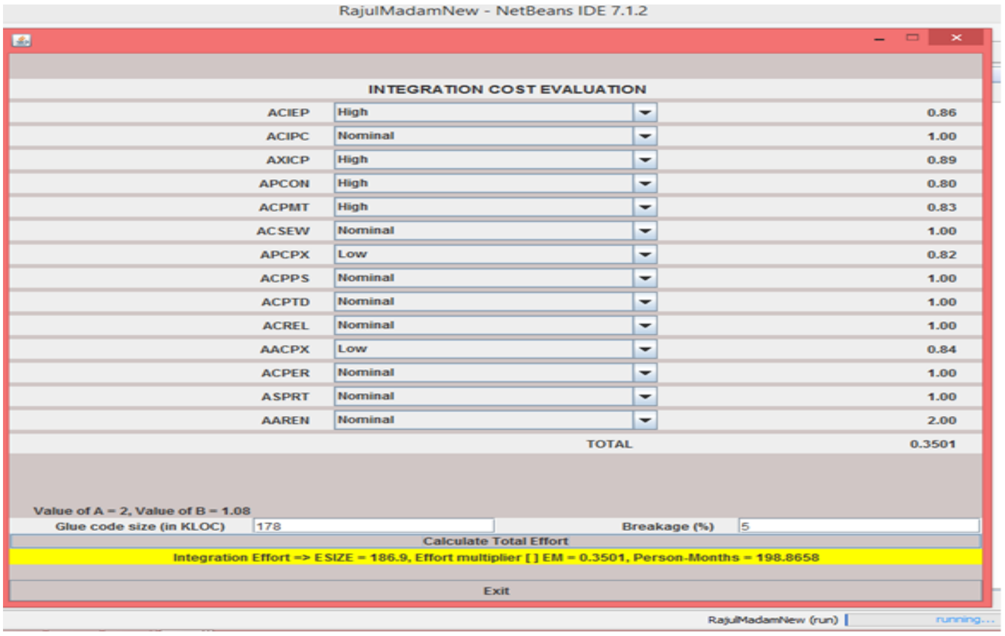
Interfaces
IMakeSchedule
IUpdateSchedule
IDisplaySchedule
IRegisterCourse
IViewResult
ISubmitGrades
ILogin
ICourseMgt

Simple Parameters	Conversion Parameters	String Parameters	Complex Type Parameters
ID-Integer	termC-termNo	studentID-String	return-
ID-Integer	courseCode-CourseNo	ID-String	StudentDetail-
course_avail-Boolean	ID-studentID	instructorID-String	return-
return-Boolean	ID-InstructorID	ID-String	

Total Glue Code Cost = 178 Lines. (included 25 Lines for Basic Code)

Figure 5: Java Tool showing the various types of parameters evaluated from the parsing of XMI file and estimated lines of code required for glue code generation for the components of the registration system of UCRS.

From the figure 5 above, it is shown that estimated lines of code to be written for integration of the components of registration system of UCRS are 178.



INTEGRATION COST EVALUATION

ACIEP	High	0.86
ACIPC	Nominal	1.00
AXICP	High	0.89
APCON	High	0.80
ACPMT	High	0.83
ACSEW	Nominal	1.00
APCPX	Low	0.82
ACPPS	Nominal	1.00
ACPTD	Nominal	1.00
ACREL	Nominal	1.00
AACPX	Low	0.84
ACPER	Nominal	1.00
ASPRT	Nominal	1.00
AAREN	Nominal	2.00
	TOTAL	0.3501

Value of A = 2, Value of B = 1.08

Glue code size (in KLOC) 178 Breakage (%) 5

Integration Effort => ESIZE = 186.9, Effort multiplier [ ] EM = 0.3501, Person-Months = 198.8658

V. LIMITATION AND FUTURE RESEARCH

- BRAK % is assumed. A well-defined guideline needs to be developed which assist the developer in estimating the Brakage of the glue code due to change in requirements or component volatility
- A well- defined guideline should also be developed for providing rating to various attributes

VI. FUTURE RESEARCH

- The tool can be further upgraded for estimation of tailoring cost for component-based systems.
- Other metrics related to Component-based systems can be included in enhanced version of the tool proposed.

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