Convertibility Between IFPUG and COSMIC Functional Size Measurements

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Abstract. Since 1984 the International Function Point Users Group (IFPUG) has produced and maintained a set of standards and technical documents about a functional size measurement methods, known as IFPUG, based on Albrecht Fuction Points. On the other hand, in 1998, the Common Software Measurement International Consortium (COSMIC) proposed an improved measurement method known as Full Function Points (FFP). Both the IFPUG and the COSMIC methods both measure functional size of software, but produce different results. In this paper, we propose a model to convert functional size measures obtained with the IFPUG method to the corresponding COSMIC measures. We also present the validation of the model using 33 software projects measured with both methods. This approach may be beneficial to companies using both methods or migrating to COSMIC such that past data in IFPUG can be considered for future estimates using COSMIC and as a validation procedure.

Keywords: Functional Size measurement, IFPUG, COSMIC, Software Estimation.

1 Introduction

Function Point Analysis or FPA is one the oldest and most widely used software functional size measurement method. It was proposed by Albrecht and his colleagues at IBM in 1979. Since 1984 this method is promoted by the International Function Point Users Group (IFPUG) [7]. In 1994, the International Organization for Standardization (ISO) set up a working group to establish an

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international standard for functional size measurement. This group did not produce a measurement standard, but a set of standards and technical documents about functional size measurement methods, known as the ISO/IEC 14143 series [1,2,3,4,5]. The FPA method became the standard ISO/IEC 20926 [11] in 2003, its unadjusted portion being compliant with the ISO/IEC 14143 [1]. Starting in 1998, a set of experts in software measurement created the Common Software Measurement International Consortium or COSMIC, and proposed an improved measurement method known as Full Function Points (COSMIC FFP) [6]. This method became the standard ISO/IEC 19761 in 2003 and is also ISO/IEC 14143 compliant. Both IFPUG and the COSMIC-FPP methods measure functional size of software, but produce different results. For this work, we briefly compare IFPUG and COSMIC definitions and propose a model to convert functional size measures obtained with the IFPUG method to the corresponding COSMIC FFP measures. To do so, we have used a repository of 33 projects measured using both methods.

The organisation of the paper is as follows. Section 2 provides a high level view of the mapping between both methods. Section 3 presents and analyses our approach and its empirical validation. Finally, Section 4 concludes the paper and future work is outlined.

2 Analysis of Correspondence Between Definitions

This section presents a very high level view of the components and relationships for IFPUG and COSMIC measurement methods needed to obtain correspondences between the concepts defined by such components and relationships to determine under which conditions it would make sense to compare the measurements obtained with both methods.

There are three initial concepts in the measurement of software functionality size shared for both methods: the purpose of a measurement, the scope of a measurement and the application boundary. Such concepts define what is measured and what it is measured for. In it possible to have a mapping between both methods for the key terms: (i) the *purpose of a measurement*; (ii) the *scope of a measurement* and (iii) the definition of *boundary*. The same happens with other key concepts in the software functional size measurement that must be considered; three are related to data (the *object of interest* or *entity*, the *data group* or *file* and the *data attribute* or *data elements*) and two to its transformation processes (the *functional process* or *transactional function*). Table 1 summarizes the correspondence of concepts between COSMIC and IFPUG.

After analyzing both methods, it can be concluded that: (i) the software functional size measures obtained shall be comparable when the purpose and the scope of the measurement coincide, as well as the application boundary; obviously, the application to be measured also has to be the same. These concepts are practically identical in both methods; (ii) both methods coincide when they divide the user data processing requirements into units, using practically the

Table 1. Correspondence of concepts between COSMIC and IFPUG

COSMIC	*IFPUG*
Purpose of a measurement	Purpose of the count
Scope of a measurement	Scope of the count
Boundary	Application boundary
User	User
Object of interest	Entity
Data group	File
Data attribute	Data elements
Functional process	Transactional function

same criterion. Consequently, functional processes in COSMIC will be transactional functions in IFPUG and vice versa; and (iii) both methods also coincide in grouping data sets using practically the same criterion. Consequently, data groups in COSMIC will correspond to files in IFPUG and vice versa.

3 Conversion Rule Proposed

There are several situations in which it is possible to know reasonably the resulting data movements for each object of interest. Some of those objects of interest will correspond to Internal Logical Files (ILF) or External Interface Files (EIF), according to the equivalences established so that it is possible to express the number of data movements according to the number of File Types Referenced (FTR) between IFPUG and COSMIC. There is a data movement for each FTR in the External Outputs where an object of interest is deleted: the application writes when deleting the corresponding data group. In this case, there is usually an error or confirmation message. Preliminarily, we could generalize that the minimum number of data movements in an elementary process is equal to the number of FTRs adding one:

$$CFSU_{MIN} = FTR + 1 \tag{1}$$

where $CFSU_{MIN}$ (COSMIC Function Size Unit) is the minimum size of the functional process measured in COSMIC and FTR is the number of File Type Referenced in IFPUG. However, in COSMIC, the minimum number of data movements in a functional process is 2 CFSU. When the number of FTR is zero, Eq. (1) only returns 1 data movement. We need to reformulate Eq. (1) to consider this case:

$$CFSU_{MIN} = Max(2, FTR + 1) \tag{2}$$

The theoretical maximum of data movements cannot be determined from the number of FTRs. Even if there are four data movements at the most for each file type referenced, there could be other data movements that will not imply persistent data groups; for example, commands, parameters, etc. However, from the above analysis it is possible to assume the maximum number of data movements according to the elementary process type:

- In external inputs (EI), there are usually no more than two data movements in the same functional process for each file type referenced: there are two data movements, one for the input and the other for the writing of the data of an object of interest.
- In external outputs (EO) and External Queries (EQ), where data of an object of interest are read and shown, neither is there usually more than two data movements in the same functional process for each file type referenced, one for reading and one for the output of the object of interest.
- In all elementary processes there is usually an error or confirmation message.
- In EO, generally, there is also an output of data created during the elementary process, or an entry command or parameter.

We could generalize that the maximum number of data movements in an elementary process is equal to the double number of file types referenced plus one, for external entries and inquiries, and plus one for external outputs. Considering that the number of file types referenced could be zero, and that the size measured in COSMIC cannot be lower than 2, the above is expressed as follows:

$$CFSU_{MAXEI/EQ} = Max(2, 2 \cdot FTR + 1) \tag{3}$$

$$CFSU_{MAXEO} = 2 \cdot FTR + 2 \tag{4}$$

where $CFSU_{MAXEI/EQ}$ is the maximum size of the external input or external queries functional process measured in COSMIC, $CFSU_{MAXEO}$ is the maximum size of the external output functional process measured in COSMIC and as before FTR is the number of file types referenced.

In short, given the measurement of an application with IFPUG, of which the number of transactional functions and the number of FTRs in such functions are known, we propose as a hypothesis that such application will have a COSMIC size within the interval given by the following equation:

$$\begin{array}{c}\sum_{i=1}^{EI} Max(2, FTR_i + 1) + \sum_{i=1}^{EO} Max(2, FTR_i + 1) + \sum_{i=1}^{EQ} Max(2, FTR_i + 1) \\ \leq CFSU \leq \\ \sum_{i=1}^{EI} Max(2, 2 \cdot FTR + 1) + \sum_{i=1}^{EO} Max(2, 2 \cdot FTR + 1) + \sum_{i=1}^{EQ} Max(2, 2 \cdot FTR + 1)\end{array} \tag{5}$$

4 Experimental Validation of the Conversion Rules

The data used in this qualitative analysis come from 33 software applications, measured with IFPUG version 4.1 and COSMIC version 2.2. Out of these 33 software applications, one is a case study documented by IFPUG [7]. Data from IFPUG were taken as such and only the measurement with COSMIC was carried out. Another application is a case study provided by IBM Rational as example RUP [8]; this application was already measured with COSMIC and only the measurement with IFPUG was performed. Another application is a case study described in Fetcke [9]; the data from IFPUG and COSMIC were obtained as such from a case study used to compare different software measurement methods. The remaining 30 applications were final projects of students attending the Software Engineering course at the University of Alcalá, Madrid, Spain. These software development projects included the description of the application and the measurements with both methods. These measures were obtained by a team of three junior measurers, which later were verified by another senior measurer and finally by the authors. Some projects from the Software Engineering courses at the University of Alcalá were discarded when the description of the application did not enable the validation of the measures obtained. The differences in the measures were generally due to different interpretations of user requirements and furthermore, rules of IFPUG and COSMIC methods are stated in a natural language and thus, subject to ambiguity and interpretation. However, all differences were exhaustively revised and reconciled.

The intervals in our set of measures vary between 78 and 462 function points, with a mean of 291.2 function points, and a standard deviation of 98.6 function points. The summary of the results of the measurement appears on Table 2. IFPUG is the size measured in function points without adjustments with IFPUG 4.1; ILF+EIF is the number of data functions, internal logical files plus external interface files in each project; EI+EO+EQ are the number of transactional functions in each project, external inputs plus external outputs plus external inquiries; FTR is the total number of file types referenced in all functional processes of each project. Lastly, COSMIC is the functional size measured in COSMIC units.

We used two complementary techniques for our experimental research (i) the direct verification on a relatively large number of cases, where we evaluated our hypothesis; and (ii) statistical analysis to generalize the findings. The first technique consists of evaluating a model in a relatively large set of cases and confirming that the expression in Eq. (5) is always verified. In each case, the same software application is measured both with the IFPUG method and with the COSMIC method. If in any of such cases, the expression in Eq. (5) is not verified, we would be able to affirm that the corresponding model does not enable any conclusion regarding the size of an application measured with COSMIC from the intermediate measures resulting from the measurement of such application with COSMIC. On the contrary, if the expression in Eq. (5) is verified in all cases, we will be able to state that the corresponding model adequately describes the cases considered, but we will not be able to make general statements for other applications not included in the cases considered.

We now describe the statistical analysis. To do so, we defined two random variables: one as the difference of the value measured with COSMIC and the minimum value given by Eq. (5), and the other as the difference between the maximum given by Eq. (5) and the value measured with COSMIC. The former represents the distance between the lower extreme of the range and the value measured with COSMIC, while the latter represents the distance between the

Table 2. Project Measurement Results

Proj ID	*IFPUG*	*ILF+EIF*	*EI+EO+EQ*	FTR	*COSMIC*
1	95	5	16	27	68
2	126	10	14	37	80
3	78	3	16	27	72
4	329	25	44	71	177
5	340	14	72	108	195
6	324	6	82	87	267
7	177	9	33	33	108
8	381	12	65	163	278
9	360	12	62	139	210
10	286	14	46	58	191
11	462	14	65	169	286
12	283	7	53	122	263
13	109	5	21	21	65
14	432	19	79	149	294
15	326	12	74	91	200
16	331	13	62	84	234
17	236	9	42	88	158
18	324	10	62	132	297
19	311	6	63	126	310
20	346	14	63	91	263
21	410	19	88	88	215
22	395	14	84	97	279
23	279	14	52	65	166
24	324	13	61	91	224
25	412	19	64	163	248
26	315	11	66	123	313
27	157	9	20	107	215
28	307	14	45	155	264
29	167	8	22	89	125
30	299	11	54	111	267
31	269	19	39	66	144
32	299	12	57	114	277
33	320	15	47	103	155

value measured with COSMIC and the upper extreme of the range. To accept statistically that the value measured with COSMIC is always within the interval, both variables must have a known distribution with positive mean. The second and fourth columns in Table 3 show the maximum and the minimum given by Eq. (5) in relation to the COSMIC measure.

The significance level chosen for these statistical tests is 98%, corresponding to $\alpha = 0.02$, because, as the affirmations about the variables are independent among them, the significance level resulting from the combination of both will be equal to $98\%^2 \geq 95\%$, corresponding to $\alpha = 0.05$.

The first step in the statistical analysis is to characterize these random variables, calculating some of their descriptive statistics and determining their

Table 3. Measurements Minimum and Maximum calculated according to the Model

Proj ID	*Minimum*	*CFSU*	*Maximun*	$D\downarrow$	$D\uparrow$
1	43	68	73	25	5
2	51	80	88	29	8
3	43	72	73	29	1
4	115	177	198	62	21
5	180	195	301	15	106
6	169	267	278	98	11
7	66	108	114	42	6
8	228	278	403	50	125
9	201	210	352	9	142
10	112	191	200	79	9
11	208	286	357	78	71
12	175	263	312	88	49
13	42	65	68	23	3
14	228	294	392	66	98
15	165	200	436	35	236
16	146	234	244	88	10
17	130	158	236	28	78
18	194	297	342	103	45
19	189	310	329	121	19
20	156	263	268	107	5
21	178	215	278	37	63
22	181	279	292	98	13
23	117	166	199	49	33
24	152	224	260	72	36
25	227	248	400	21	152
26	189	313	324	124	11
27	129	215	249	86	34
28	200	264	375	64	111
29	111	125	208	14	83
30	165	267	295	102	28
31	105	144	180	39	36
32	171	277	285	106	8
33	150	155	269	5	114

distributions with the respective distribution parameters. Table 4 shows descriptive statistics for variables $D\downarrow$ and $D\uparrow$.

As we can see in Table 4, the mean between both variables is positive. After several tests with different distributions, we found that both variables follow an exponential distribution, the first with $\lambda = 0.017$ and the second with $\lambda = 0.019$. The data adjustment with exponential distribution was performed using the Kolmogorov-Smirnov test [10]. In this test, the null hypothesis H_0 is that variables follow an exponential distribution; the alternative hypothesis H_A is that they do not follow an exponential distribution. The test results for both variables appear in Table 5.

Table 4. Statistics for the random variables $D\downarrow$ and $D\uparrow$

Statistic	$D\downarrow$	$D\uparrow$
Mean	60.36	53.64
$\sum$	35.68	55.75
σ^2	1272.99	3108.05
Median	62	34
Min	5	1
Max	124	236

Table 5. Kolmogorov-Smirnov test for variables $D\downarrow$ and $D\uparrow$

	$D\downarrow$	$D\uparrow$
D	0.173	0.148
p-value	0.254	0.431
a	0.02	0.02

We accept the null hypothesis H_0 that samples follow an exponential distribution, as the *p*-value calculated is higher than the significance level $\alpha = 0.02$ in both cases. The risk of rejecting the null hypothesis H_0 when it is true is 25.36% and 43.09% for the below and above differences, respectively. Figures 1 and 3 show the histograms for the variables $D\downarrow$ and $D\uparrow$ respectively. Figures 2 and 4 show the distributions accumulated for both variables. In these graphs it is possible to visually check the test results, in the sense that the adjustment in both cases is good, but it is better for variable $D\uparrow$.

The fact that both variables $D\downarrow$ and $D\uparrow$ have exponential distribution not only confirms our hypothesis, but further corroborates our hypothesis. On the one hand, it means that the probability of obtaining smaller differences

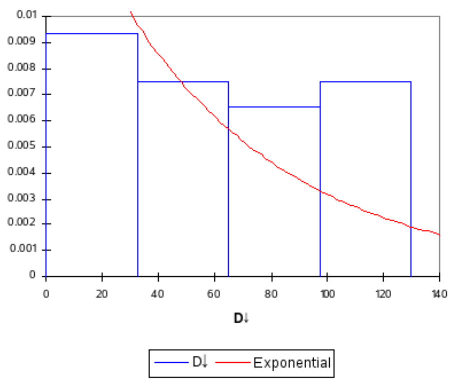

Fig. 1. Histogram for D↓

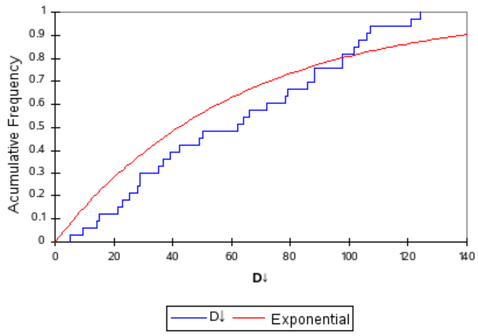

Fig. 2. Accumulative distribution for D↓

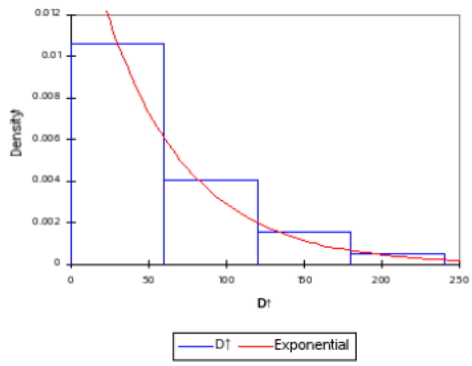

Fig. 3. Histogram for D↑

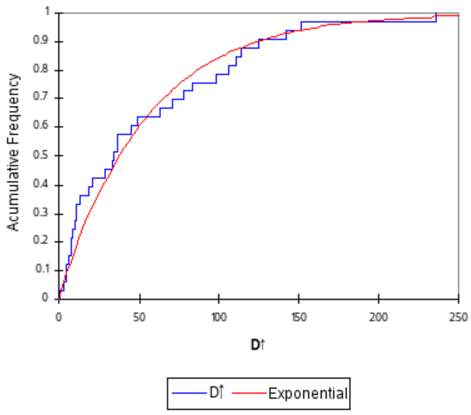

Fig. 4. Accumulative distribution for D↑

between measures and extremes is higher, and the probability of obtaining larger differences between measures and extremes is lower. Also, on the other hand, it also means that the distances are always positive, i.e., measures using COSMIC will never be outside the interval calculated according to our model.

5 Conclusions and Future Work

In this paper, we proposed a method to convert from IFPUG Function Points defined by the International Function Point Users Group (IFPUG) to COSMIC Full Function Points (COSMIC FFP) defined by the Common Software Measurement International Consortium (COSMIC). Although both methods produce different results, we have empirically shown an equation that limits interval of the conversion to be within a range. Such approach can be beneficial to companies using both methods or in the process of migrating to COSMIC such that past data measured using IFPUG can be considered for future estimates using COSMIC. Also, when organizations used both methods to improve their estimates, the approach of this paper can be used as an additional validation procedure.

Future work will consist in performing further case studies and validations within academia and industrial organizations.

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