Intra-Similarity And Inter-Similarity Analysis Of Steel Structure MTO's

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Abstract— In this research investigation, the real world MTO's (Material Take Off)'s of two different Steel Structures, namely LQUM's (Leaving Quarter Utility Member)'s were considered. For each one, the Intra-Similarity and Intra-Dissimilarity were computed using the definitions given in [1]. Also, Inter-Similarity between the two aforementioned respective entities were computed using standard Cosine Similarity Measure. Such Intra-Similarity and Intra-Dissimilarity describe how strongly units in the same group resemble each other. Such a study is useful in our context for assessing the Structural Steel Grade homogeneity or non-homogeneity throughout a structure. Furthermore, the advantage of such an Intra measure is that using this measure we can clearly distinguish the contribution of Intra aspect variation and Inter aspect variation when both are bound to occur in a given phenomenon of concern.

Keywords— Intra-Similarity, Intra-Dissimilarity

I. INTRODUCTION

The following paragraphs of this section detail the concepts similar to Intrasimilarity & Dissimilarity [1] used for analysis by the author in this thesis.

In [1], the author has detailed a novel method of finding the '*Total Intra Similarity And Dissimilarity Measure For The Values Taken By A Parameter Of Concern*'. The advantage of such a measure is that using this measure we can clearly distinguish the contribution of Intra aspect variation and Inter aspect variation when both are bound to occur in a given phenomenon of concern.

Also, in most literature, this concepts is referred to as the Intra-Class Correlation [2].

II. R.C. BAGADI INTRASIMILARITY & INTRADISSIMILARITY OVERVIEW

In [1] R.C. Bagadi gave a detailed treatment of IntraSimilarity & IntraDissimilarity. An overview of the paper is presented in this section.

Given any Sequence of the kind,
$S = \{y_1, y_2, y_{3,} ...., y_{n-1}, y_n\}$ which represent the (ordered) values taken by a Parameter of concern. We first consider the Cartesian Cross Product of S with itself, i.e. $R = S \times S = \underset{i=1}{\overset{n}{C}}\underset{i=1}{\overset{n}{C}}\{y_i, y_j\}$ where C denotes a Collection. We now consider elements of the kind $\{y_i, y_j\}$ and $\{y_j, y_i\}$ as same and therefore will consider only one among them in the sum terms shown below in the next line, which appears as

$$LB = \underset{i=1}{\overset{n}{C}}\underset{i=1}{\overset{n}{C}}\{y_i, y_j\} - \underset{j:j>i}{\overset{n}{C}}\ \underset{i=1}{\overset{n}{C}}\{y_i, y_j\} \qquad \text{Equation 1}$$

We now consider the smaller of each of the 2 tuple in the above set LB and add these values to give us

$$SLB = \sum\left\{Smaller\left\{\underset{i=1}{\overset{n}{C}}\underset{i=1}{\overset{n}{C}}\{y_i, y_j\} - \underset{j:j>i}{\overset{n}{C}}\ \underset{i=1}{\overset{n}{C}}\{y_i, y_j\}\right\}\right\}$$

Equation 2

For the terms of the kind $\{y_i, y_i\}$, the Smaller Operator detailed above selects y_i itself. The spirit behind considering the smaller number is that it represents the congruence part of the two numbers. The logic behind removing the $\underset{j:j>i}{\overset{n}{C}}\ \underset{i=1}{\overset{n}{C}}\{y_i, y_j\}$ terms is that when their congruence part is evaluated it is the same as their places juxtaposed counterparts of themselves in $S \times S$.

We now consider the larger of each of the 2 tuple in the above set LB (RHS of Equation 2) and add these values to give us

$$LLB = \sum\left\{L\arg er\left\{\underset{i=1}{\overset{n}{C}}\underset{i=1}{\overset{n}{C}}\{y_i, y_j\} - \underset{j:j>i}{\overset{n}{C}}\ \underset{i=1}{\overset{n}{C}}\{y_i, y_j\}\right\}\right\}$$

Equation 3

Now, we call the Total Intra Similarity Measure as

$$AD = \frac{SLB}{LLB} = \left\{ \frac{\sum \left\{ Smaller\left\{ \overset{n}{\underset{i=1}{C}} \overset{n}{\underset{i=1}{C}} \{y_i, y_j\} - \overset{n}{\underset{j:j>i}{C}} \overset{n}{\underset{i=1}{C}} \{y_i, y_j\} \right\} \right\}}{\sum \left\{ Larger\left\{ \overset{n}{\underset{i=1}{C}} \overset{n}{\underset{i=1}{C}} \{y_i, y_j\} - \overset{n}{\underset{j:j>i}{C}} \overset{n}{\underset{i=1}{C}} \{y_i, y_j\} \right\} \right\}} \right\}$$

Equation 4

For the terms of the kind $\{y_i, y_i\}$, the Larger Operator detailed above selects y_i itself. The advantage of such a measure AD is that using this measure we can clearly distinguish the contribution of Intra aspect variation and Inter aspect variation (with respect to their similarity) when both are bound to occur in a given phenomenon of concern.

Furthermore, we can even write the Total Intra Similarity Vector as

$$TISV = \sum_k \left\{ Smaller\left\{ \overset{n}{\underset{i=1}{C}} \overset{n}{\underset{i=1}{C}} \{y_i, y_j\} - \overset{n}{\underset{j:j>i}{C}} \overset{n}{\underset{i=1}{C}} \{y_i, y_j\} \right\} \right\} \hat{e}_k$$

Equation 5

where $k = n^2 - \left(\frac{n^2 - n}{2} \right) = \frac{n^2}{2} + \frac{n}{2}$

We can use this Total Intra Similarity Vector to compare the Total Intra Similarity Measure of two Parameters that take the same number of values. Such a comparison can be achieved using any popular type of Inner Product scheme. These two Parameters could be different or could be the same Parameter whose observation is repeated again.

In a similar manner, we can define the Total Intra Dissimilarity Measure as

$$AD^- = \left(\frac{LLB - SLB}{LLB} \right)$$

$$= \left\{ \frac{\sum \left\{ Larger\left\{ \overset{n}{\underset{i=1}{C}} \overset{n}{\underset{i=1}{C}} \{y_i, y_j\} - \overset{n}{\underset{j:j>i}{C}} \overset{n}{\underset{i=1}{C}} \{y_i, y_j\} \right\} - Smaller\left\{ \overset{n}{\underset{i=1}{C}} \overset{n}{\underset{i=1}{C}} \{y_i, y_j\} - \overset{n}{\underset{j:j>i}{C}} \overset{n}{\underset{i=1}{C}} \{y_i, y_j\} \right\} \right\}}{\sum \left\{ Larger\left\{ \overset{n}{\underset{i=1}{C}} \overset{n}{\underset{i=1}{C}} \{y_i, y_j\} - \overset{n}{\underset{j:j>i}{C}} \overset{n}{\underset{i=1}{C}} \{y_i, y_j\} \right\} \right\}} \right\}$$

Equation 6

The spirit behind considering the difference between the larger and smaller number is that it represents the non-congruence part of the two numbers.

The advantage of such a measure AD^- is that using this measure we can clearly distinguish the contribution of Intra aspect variation and Inter aspect variation (with respect to their dissimilarity) when both are bound to occur in a given phenomenon of concern.

Furthermore, we can even write the Total Intra Dissimilarity Similarity Vector as

$$TIDSV = \sum \left\{ \begin{array}{l} Larger\left\{ \overset{n}{\underset{i=1}{C}} \overset{n}{\underset{i=1}{C}} \{y_i, y_j\} - \overset{n}{\underset{j:j>i}{C}} \overset{n}{\underset{i=1}{C}} \{y_i, y_j\} \right\} \\ - Smaller\left\{ \overset{n}{\underset{i=1}{C}} \overset{n}{\underset{i=1}{C}} \{y_i, y_j\} - \overset{n}{\underset{j:j>i}{C}} \overset{n}{\underset{i=1}{C}} \{y_i, y_j\} \right\} \end{array} \right\} \hat{e}_k$$

Equation 7

where $k = n^2 - \left(\frac{n^2 - n}{2} \right) = \frac{n^2}{2} + \frac{n}{2}$ and the summation is over the k terms.

III. RESULTS OF R.C. BAGADI ALGORITHM FOR COMPUTING INTRASIMILARITY & INTRADISSIMILARITY

We consider the Material Take-Off of two Steel Structures (namely MTO Structure1 and MTO Structure2) and compute the Total Intrasimilarity of Steel Grade for each of them. We use the concepts stated in [1] for the Total Intrasimilarity computation. We calculate such Total Intrasimilarity of Steel Grade for each of them for the cases of Plates, Tubulars, Rolled Sections for Primary

Structural Steel MTO and Plates, Grating, Tubulars and Rolled Sections for Secondary Structural Steel MTO. We then form a Universal Total Intrasimilarity Vector for each of the MTO's of Structure1 and Structure 2 and compare them using standard Cosine Similarity Measure.
We use the simplified form of [1] where we consider the Ordered Pair (a, b) as separate from the Ordered Pair (b, a) while computing the Total Intrasimilarities and Total IntraDissimilarities.

MATERIAL TAKE-OFF (STRUCTURE 1)
Primary Structural Steel MTO Summary
Summary of primary structural steel is tabulated in the following table.

Structure	Category	Steel Type	Grade	Weight (MT)			Total Weight (MT)
				Plates	Tubulars	Rolled Sections	
LQUM Topsides	Primary	I	Fy = 345MPa (t ≤ 63mm)		88.90		88.90
			Fy = 325MPa (t > 63mm)				
		II	Fy = 345MPa (t ≤ 63mm)	432.71	162.27	99.58	694.56
			Fy = 325MPa (t > 63mm)				
		II-X	Fy = 414MPa (t ≤ 63mm)	12.27			12.27
			Fy = 405MPa (t > 63mm)				
		III	Fy = 345MPa (all "t")		3.80	3.8	7.6
				A. Total Primary Structural Steel			791.06

Table 1- Primary Structural Steel MTO Summary (Structure 1)

Constructing the Set S

We need to construct the Set S for each of the Plates, Tubulars and Rolled Sections Aspects for Primary Steel Structure MTO of Structure 1. The Set S is the distribution of Steel by weight w.r.t the Steel grade.
As can be noted from the above table, for Plates, a grade of $F_y = 345MPa$ is used for 432.17kg~433kg and again a steel grade of $F_y = 414MPa$ is used for 12.27kg~12kg. Therefore according to [1] the Set S to begin with here is

$$\left\{ \overbrace{345,345,.......,345}^{433\,times}, \overbrace{414,414,.......,414}^{12\,times} \right\}$$

From here on, we follow the procedure detailed in II to compute the IntraSimilarity and IntraDissimilarity. We use R Program to compute the same.
For Plates, the R Program is

R Program For Primary Steel Structure MTO Plates

```
rm(list = ls())
setwd("C:/Users/VinodMTechAITAM/Desktop/Vinod")

##### Cartesian Cross Product #######
xs=read.csv("psmtop.csv",header = T)
ys=xs
xys <- expand.grid(xs$var, ys$var)
for (i in 2 : nrow(xys)) {
xy <- as.vector(xys[i, ])
```

```
# x <- xy[1], y <- xy[2]
}
write.csv(xys,"xys.csv")
##########Direct Similarity#######################################
SL=matrix(0,198025,1)
for (i in 1:198025)
{SL[i]<-min(xys[i,])}
write.csv(SL,"SL.csv")

####################Direct Dissimilarity###############################
DSL=matrix(0,198025,1)
for (i in 1:198025) {
DSL[i]<-max(xys[i,])-min(xys[i,])
}
write.csv(DSL,"DSL.csv")
TSI=sum(SL)/(sum(SL)+sum(DSL))
TDSSI=sum(DSL)/(sum(SL)+sum(DSL))
TSI
TDSSI
res <- c(TSI,TDSSI)
write.csv(res,"res.csv")
```

We need to construct the Set S for each of the Plates, Tubulars and Rolled Sections Aspects for Primary Steel Structure MTO of Structure 1, and then compute the Intrasimilarity & IntraDissimilarity.

In a similar fashion, we compute the IntraSimilarities and IntraDissimilarities for all the component types (Plates, Tubulars, Gratings, Rolled Sections) for Primary Structural Steel, for Secondary Structural Steel for the MTOs of Structure 1 and 2. To this end we analyse 14 cases using 14 written R Programs.

Secondary Structural Steel MTO Summary
Summary of secondary structural steel is tabulated in the following table.

Structure	Category	Steel Type	Grade	Weight (MT) Plates	Grating	Tubulars	Rolled Sections	Total Weight (MT)
LQUM Topsides	Secondary	II	Fy = 345MPa (t ≤ 63mm)				21.86	21.86
			Fy = 325MPa (t > 63mm)	2.83		9.31	140.47	152.61
		III	Fy = 345MPa (all "t")					
		IV	Fy = 345MPa (all "t")	229.94		1.25	1.22	232.41
		V	Fy = 240MPa (all "t")		12.67			12.67
							B. Total Secondary Structural Steel	419.55

Table 2 - Secondary Structural Steel MTO Summary (Structure 1)

MATERIAL TAKE-OFF (STRUCTURE 2)
Primary Structural Steel MTO Summary
Summary of primary structural steel is tabulated in the following table.

Structure	Category	Steel Type	Grade	Weight (MT)			Total Weight (MT)
				Plates	Tubulars	Rolled Sections	
LQUM Topsides	Primary	I	Fy = 345MPa (t ≤ 63mm)		110.23		110.23
			Fy = 325MPa (t > 63mm)			120.56	120.5 6
		II	Fy = 345MPa (t ≤ 63mm)	336.52	154.67		491.19
			Fy = 325MPa (t > 63mm)				
		II-X	Fy = 414MPa (t ≤ 63mm)	12.27			12.27
			Fy = 405MPa (t > 63mm)				
		III	Fy = 345MPa (all 't')		5.0	5.89	10.89
					A. Total Primary Structural Steel		745.14

Table 3 - Primary Structural Steel MTO Summary (Structure 2)

Secondary Structural Steel MTO Summary
Summary of secondary structural steel is tabulated in the following table.

Structure	Category	Steel Type	Grade	Weight (MT)				Total Weight (MT)
				Plates	Grating	Tubulars	Rolled Sections	
LQUM Topsides	Secondary	II	Fy = 345MPa (t ≤ 63mm)					
			Fy = 325MPa (t > 63mm)	3.45		11.23	23.56	38.24
		III	Fy = 345MPa (all 't')				147.87	147.87
		IV	Fy = 345MPa (all 't')	225.67		1.55	1.15	228.37
		V	Fy = 240MPa (all 't')		14.56			14.56
					B. Total Secondary Structural Steel			429.04

Table 4 - Secondary Structural Steel MTO Summary (Structure 2)

We summarize the results as

Structure 1 MTO	*TSI, TDSSI*
Primary Structural Steel MTO - Plates	TSI=0.9896149 TDSSI=0.01038514
Primary Structural Steel MTO - Tubulars	TSI= 1 TDSSI= 0
Primary Structural Steel MTO – Rolled Sections	TSI= 1 TDSSI= 0
Secondary Structural Steel - Plates	TSI=0.9985264 TDSSI= 0.001473609
Secondary Structural Steel - Gratings	TSI= 1 TDSSI= 0
Secondary Structural Steel - Tubulars	TSI= 0.9890511 TDSSI= 0.01094891

Secondary Structural Steel – Rolled Sections	TSI= 0.9853208 TDSSI= 0.01467923

Table 6- Results Of MTO of Structure 1

Total Intrasimilarity Vector for Structure1 MTO (for Steel Grade w.r.t Weight)

$$TSVS1 = \begin{bmatrix} Plates\ (Primary) \\ Tubulars(Primary) \\ RolledSections\ (Primary) \\ Plates\ (Secondary) \\ Grating(Secondary) \\ Tubulars(Secondary) \\ RolledSections\ (Secondary) \end{bmatrix} = \begin{bmatrix} 0.9896149 \\ 1 \\ 1 \\ 0.9985264 \\ 1 \\ 0.9890511 \\ 0.9853208 \end{bmatrix}$$

Total IntraDissimilarity Vector for Structure1 MTO (for Steel Grade w.r.t Weight)

$$TDSVS1 = \begin{bmatrix} Plates\ (Primary) \\ Tubulars(Primary) \\ RolledSections\ (Primary) \\ Plates\ (Secondary) \\ Grating(Secondary) \\ Tubulars(Secondary) \\ RolledSections\ (Secondary) \end{bmatrix} = \begin{bmatrix} 0.01038514 \\ 0 \\ 0 \\ 0.001473609 \\ 0 \\ 0.01094891 \\ 0.01467923 \end{bmatrix}$$

Structure 2 MTO	*TSI, TDSSI*
Primary Structural Steel MTO - Plates	TSI=0.9868964 TDSSI= 0.01310356
Primary Structural Steel MTO - Tubulars	TSI= 1 TDSSI= 0
Primary Structural Steel MTO – Rolled Sections	TSI=0.9944913 TDSSI= 0.005508675
Secondary Structural Steel - Plates	TSI=0.998501 TDSSI= 0.001499008
Secondary Structural Steel - Gratings	TSI= 1 TDSSI= 0
Secondary Structural Steel - Tubulars	TSI=0.9842534 TDSSI=0.01574662
Secondary Structural Steel – Rolled Sections	TSI=0.9861315 TDSSI= 0.01386855

Table 6- Results Of MTO of Structure 2

Total Intrasimilarity Vector for Structure2 MTO (for Steel Grade w.r.t Weight)

$$TSVS2 = \begin{bmatrix} Plates\ (Primary) \\ Tubulars(Primary) \\ RolledSections\ (Primary) \\ Plates\ (Secondary) \\ Grating(Secondary) \\ Tubulars(Secondary) \\ RolledSections\ (Secondary) \end{bmatrix} = \begin{bmatrix} 0.9868964 \\ 1.0 \\ 0.9944913 \\ 0.998501 \\ 1 \\ 0.9842534 \\ 0.9861315 \end{bmatrix}$$

Total IntraDissimilarity Vector for Structure2 MTO (for Steel Grade w.r.t Weight)

$$TDSVS2 = \begin{bmatrix} Plates\ (Primary) \\ Tubulars(Primary) \\ RolledSections\ (Primary) \\ Plates\ (Secondary) \\ Grating(Secondary) \\ Tubulars(Secondary) \\ RolledSections\ (Secondary) \end{bmatrix} = \begin{bmatrix} 0.01310356 \\ 0 \\ 0.005508675 \\ 0.001499008 \\ 0 \\ 0.01574662 \\ 0.01386855 \end{bmatrix}$$

Inner Product Of Normalized Total IntraSimilarity Vectors & IntraDissimilarity Vectors For Structures 1&2

R Program

```
TISVS1=c(0.9868961, 1,0.9944913,0.998501,1,0.9842534,0.9861315)
NTISVS1=TISVS1 / sqrt(sum(TISVS1^2))
TIDSVS1=c(0.01310356,0,0.005508675,0.001499008,0,0.01574662,0.01386855)
NTIDSVS1=TIDSVS1 / sqrt(sum(TIDSVS1^2))
TISVS2=c(0.9896149, 1,1,0.9985264,1,0.9890511,0.9853208)
NTISVS2=TISVS2 / sqrt(sum(TISVS2^2))
TIDSVS2=c(0.01038514,0,0,0.001473609,0,0.01094891,0.01467923)
NTIDSVS2=TIDSVS2 / sqrt(sum(TIDSVS2^2))
SIS1and2<-NTISVS1%*%NTISVS2
SIDS1and2<-NTIDSVS1%*%NTIDSVS2
SIS1and2
SIDS1and2
```

We can note that simple Euclidean Inner Product of Normalized Total Intrasimilarity Vectors & IntraDissimilarity For Structures 1&2 give us a value of 0.9999971 and 0.9598244 respectively. This tells us that both are quite similar steel grade wise with respect to their weights.

IV. Conclusions

Advantages of Intra-Similarity & Dissimilarity Measure

Intra-Similarity and Intra-Dissimilarity describe how strongly units in the same group resemble each other.

The advantage of such an Intra measure is that using this measure we can clearly distinguish the contribution of Intra aspect variation and Inter aspect variation when both are bound to occur in a given phenomenon of concern.

Intra-Similarity and Intra-Dissimilarity measures can be used to assess the consistency between measures of the same class (i.e., measures of the same thing).

The Intra-Similarity and Intra-Dissimilarity measures assesses rating reliability by comparing the variability of different ratings of the same subject to the total variation across all ratings and all subjects.

The Intra-Similarity and Intra-Dissimilarity measures allows estimation of the reliability of both single and mean ratings.

The Intra-Similarity and Intra-Dissimilarity measures can be used to compare the reliability of different instruments.

Advantages of Intra-Similarity & Dissimilarity Measure w.r.t our research study

Intra-Similarity and Intra-Dissimilarity describe how strongly units in the same group resemble each other. Such a study is useful in our context for assessing the Structural Steel Grade homogeneity or non-homogeneity throughout a structure.

Also, using these we can design Steel Structures to have high Intra-Dissimilarities (but well above the safety factors) such that in fire resistant design, the possible fire based destruction of such structure is slow (because of Grade Dissimilarity) leaving us enough time to evacuate occupants to safety.

Such aforementioned Intra-Similarity and Intra-Dissimilarity vectors of two different structures can be compared using cosine similarity measure, thereby helping one in estimation and budgetary aspects of similar structures.

Lastly, we conclude that the two MTO's of LQUMs are quite similar, with their IntraSimilarities and IntraDissimilarities varying a little bit.

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