pace with that of the more developed countries in the world. This is dramatically borne out by the trajectories shown in Figures 2 and 3. Huge investments in just two instititutions in Singapore, NUS and NTU have taken them far ahead of all the IITs put together.

Indian universities rarely turn up in world university rankings such as Quacquarelli Symonds (QS), Times Higher Education (THE) and the Shanghai Jiao Tong ARWU. Even when they do, the best from India are invariably the five oldest IITs which take their turn as if in a game of musical chairs in the various league tables. Very much more has to be done for India to be able to claim that its higher technological institutes can rank with the best in the world.

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Metrological performance evaluation of force standard machines using intercomparison as a measure at National Physical Laboratory, India

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National Physical Laboratory, India has been maintaining the standards of force from 1 N to 3 MN. There are various force machines of capacities ranging from 50 N to 3 MN. A new 1 MN force standard machine has been established to provide better traceability up to 1 MN. In order to establish the validity of metrological capabilities of the existing 50 kN dead weight force machine (BMC 0.003% at *k* = 2), it has been compared to 1 MN force standard machine having force realization between 1 and 100 kN using dead weights (best measurement capability (BMC) 0.002% at *k* = 2) and 10 kN–1 MN with 10 kN incremental using lever multiplication (BMC 0.009% at *k* = 2) through the precision force transducers of relative repeatability 0.005%. The intercomparison has been used to evaluate the normalized error (*En* value) and it has been found within the permissible limit during the whole range of the 50 kN dead weight force machine.

Keywords: Force standard machine, intercomparison, metrological performance, normalized error.

NATIONAL Physical Laboratory, India (NPLI) has been the custodian of maintaining and dissemination of national standards at the apex level in the country. The force and hardness standard group of NPLI has the responsibility to maintain and disseminate the standards of force, torque and hardness. The group has various force machines of different capacities from 50 N to 3 MN (ref. 1). For realization of force with utmost precision at the apex level, the 50 kN dead weight force machine and the newly established 1 MN force standard machines have been employed. The former was developed by More House Corporation, USA, according to the instructions of NPLI and has been used for about a decade (Figure 1); it has been already discussed elsewhere. The expanded uncertainty associated with the force applied is 0.003% (*k* = 2) (ref. 2).

Figure 1. The 50 kN dead weight force machine.

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In order to realize the need of having lower uncertainty associated with force standard machines in higher range (preferably 100 kN to 1 MN) and to provide traceability of force measurement to the user industries and calibration laboratories in compliance with the latest international standards like ISO 376/ASTM E-74/EURAMET and to have international compatibility of the standards established in the different National Metrology Institutes (NMIs) by reproducing degree of equivalence of the force standards in the key/bilateral comparison of the force, a new 1 MN force standard machine has been established by Grassmann Testing Metrology Gmbh (GTM), Germany, at NPLI. The machine has also been evaluated for its metrological characteristics and its calibration and measurement capability within the framework of inter-laboratory inter-comparison with Physikalisch-Technische Bundesanstalt (PTB), Germany (Figure 2). The expanded uncertainty associated with the force applied is 0.002% ($k = 2$) for force up to 100 kN using dead weights and 0.009% ($k = 2$) for forces from 10 kN to 1 MN using lever multiplication system (Figure 2). The 1 MN force standard machine has already been discussed elsewhere[3].

One of the major tasks of metrology is to provide a unified basis for the measurements. Hence, the comparison of two different measurements of the same measurand has special importance. For validation of the compatibility of the results of two different measurements, a suitable criterion needs to be developed and has to be applied in practice. To cater to the need, some efforts have been made and suitable procedure has been suggested[4,5]. The method discussed earlier has been used at NPLI as a measure to compare the metrological capabilities of 1 MN force standard machine and 50 kN dead weight force machine using precision force transducers of capacity 5, 10, 20 and 50 kN of relative repeatability 0.005% (Figure 3). The procedure used was based on ISO 376:2004 and suitable factors have been taken into account. Now, ISO 376:2004 has been revised to ISO 376:2011 and broadly, has a similar procedure for the calibration of force transducers. According to ISO 376:2011, creep measurements are a must, if hysteresis measurements have not been taken into account. The force transducers are calibrated strictly according to ISO 376:2004 and hysteresis measurements have already been taken into account. The process adopted is in accordance with ISO 376:2011. Hence, intercomparison between the 1 MN force standard machine and 50 kN dead weight force machine may be considered according to ISO 376:2011 and the results have been reported[6]. The uncertainty related calculations have been done on the basis of standard practices. The normalized error (*En* value) has been computed and found to be within permissible limits[6–10].

The 1 MN force standard machine and 50 kN dead weight force machine have been used for the intercomparison to validate the metrological performance of the latter. The precision force transducers of 5, 10, 20 and 50 kN having relative repeatability better than 0.005% have been used for the studies and are found to have stable values. The force transducers have also been used for establishing the traceability of force calibrating machines at NPLI from the primary force standard machines. A high-resolution indicator has been used for recording the observations. The digital indicator used is precise enough and has resolution as fine as 0.000001 mV/V.

Figure 2. The new 1 MN force standard machine with precision digital indicator.

Figure 3. A typical precision force transducer (force transfer standard; Interface Inc. USA).

The procedure for calibration of force transfer standard adopted is based on ISO 376:2011 guidelines (Figure 4). The procedure includes the following steps[8,9]:

- The digital indicator is switched on for 30 min. The no-load output (before taring) and the calibration signal are noted.
- Before application of the calibration forces, the force transfer standard is preloaded thrice to its maximum capacity and kept at full load for 90 sec.
- Calibration of the force transfer standard has been done in compression mode.
- Calibration is carried out by applying two series of calibration forces in ascending order at initial position, considered 0° (series 1 and 2).
- Two series of calibration forces have been applied at rotation positions 120° and 240° (series 3 and 4).
- The force transducer is subjected to the full load once for about 90 sec each time before starting the calibration to the new position.
- Between the loadings, readings corresponding to no load after waiting at least 30 sec for the return to zero are noted.
- The same procedure is adopted for both the force transducers and calibration is carried out at 1 MN force standard machine and 50 kN dead weight force machine.

The relative repeatability and relative reproducibility have been evaluated (eqs (1) and (2)) and plotted (Figures 5 and 6). The relative deviation (RD) between the average values of force transducers obtained over the 1 MN force standard machine and 50 kN dead weight force machine has been evaluated (eq. (3)) and plotted (Figure 7). The deviation is further used to evaluate the normalized error (*En* value; eq. 4)) and plotted (Figure 8).

Relative repeatability deviation (%)

$$= 100 \times \left(\frac{\max(x1;\, x2) - \min(x1;\, x2)}{\mathrm{mean}(x1;\, x2)} \right), \qquad (1)$$

where $x1$ and $x2$ stand for series 1 and 2 at 0°.

Relative reproducibility deviation (%)

$$= 100 \times \left(\frac{(\max(x1;\, x3;\, x4) - \min(x1;\, x3;\, x4)}{\mathrm{mean}(x1;\, x3;\, x4)} \right), \qquad (2)$$

where $x3$ and $x4$ stand for series 3 and 4 at 120° and 240° respectively.

Relative deviation (%)

$$= 100 \times \left(\frac{\mathrm{FTS}_{1\ \mathrm{MN\ FSM}} - \mathrm{FTS}_{50\ \mathrm{kN\ DWFM}}}{\mathrm{FTS}_{1\ \mathrm{MN\ FSM}}} \right), \qquad (3)$$

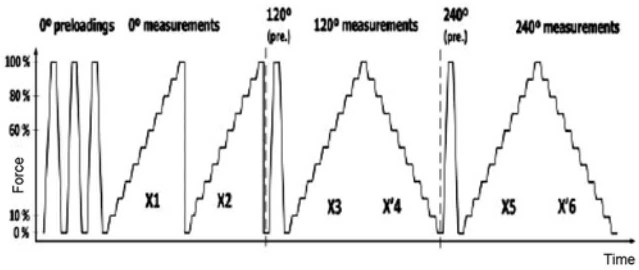

Figure 4. Schematic calibration procedure.

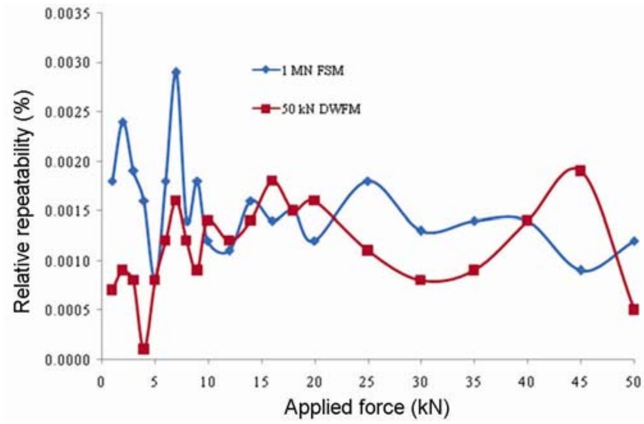

Figure 5. Relative repeatability of force transducers.

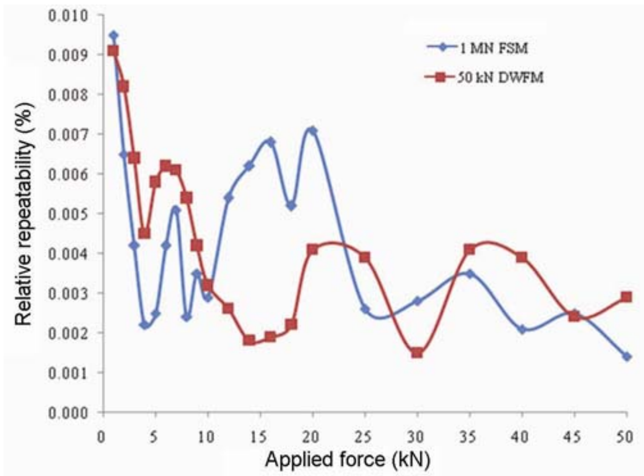

Figure 6. Relative reproducibility of force transducers.

where 1 MN FSM stands for 1 MN force standard machine, while 50 kN DWFM stands for 50 kN dead weight force machine.

$$En = 100 \times \left(\frac{\left(\dfrac{X_{1\ \mathrm{MN\ FSM}} - X_{50\ \mathrm{kN\ DWFM}}}{X_{1\ \mathrm{MN\ FSM}}} \right)}{\sqrt{W^2_{1\ \mathrm{MN\ FSM}} + W^2_{50\ \mathrm{kN\ DWFM}}}} \right), \qquad (4)$$

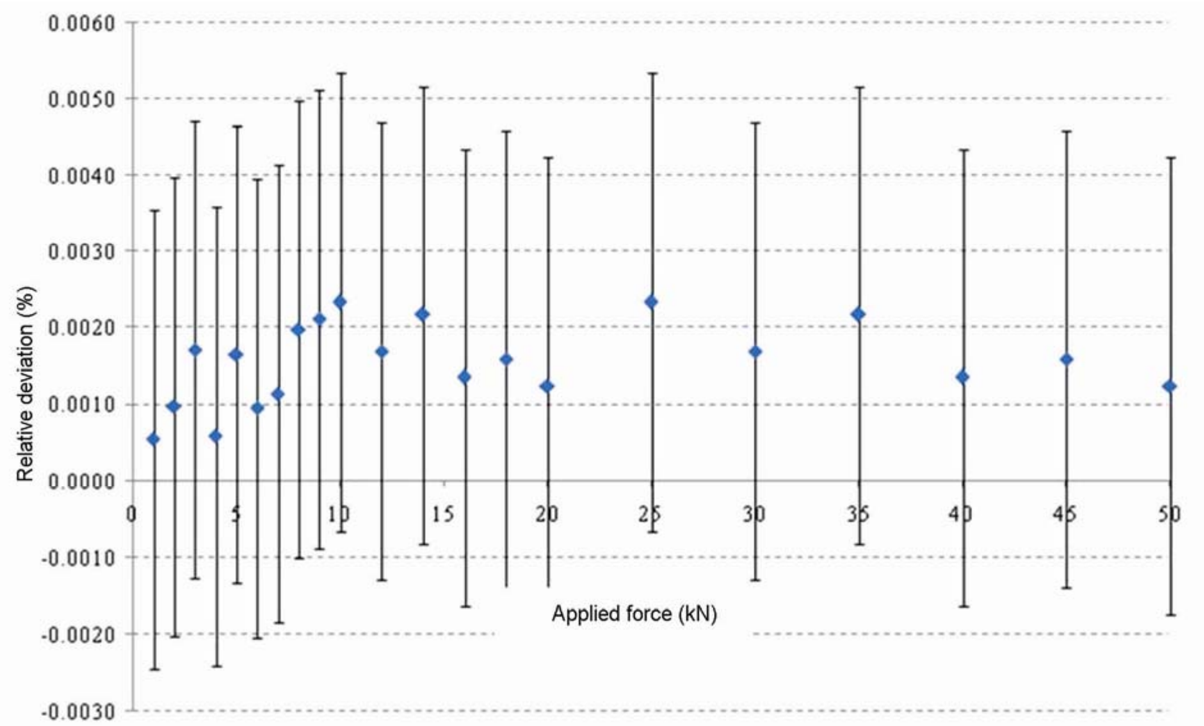

Figure 7. Relative deviation of force transducers.

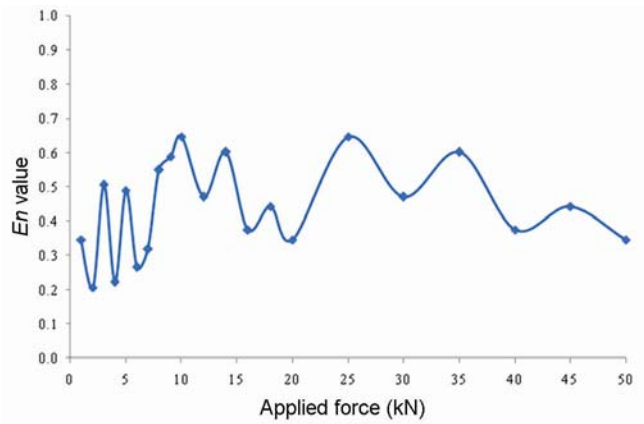

Figure 8. Normalized error (*En* value).

where $X_{1\ \mathrm{MN\ FSM}}$ stands for average value of force transducers at 1 MN force standard machine, while $X_{50\ \mathrm{kN\ DWFM}}$ stands for average value of force transducers at 50 kN dead weight force machine.

$W_{1\ \mathrm{MN\ FSM}}$ stands for BMC of 1 MN force standard machine, while $W_{50\ \mathrm{kN\ DWFM}}$ stands for BMC of 50 kN dead weight force machine.

$W_{1\ \mathrm{MN\ FSM}} = 0.002\%$ ($k = 2$) for dead weight forces (1 kN – 100 kN).

$W_{50\ \mathrm{kN\ DWFM}} = 0.003\%$ ($k = 2$) for dead weight forces (1 kN – 50 kN).

The 5 kN force transducer has been used for the range 1–5 kN, 10 kN force transducer for the range 6–10 kN, 20 kN force transducer for the range 12–20 kN and the 50 kN force transducer for the range 25–50 kN. Though the 50 kN dead weight force machine may apply force as minimum as 0.5 kN, the 1 MN force standard machine can realize force as minimum as 1 kN using dead weights. Hence, the 5 kN force transducer has been calibrated at 1, 2, 3, 4 and 5 kN only. For 10 kN for transducer, observations are not taken into account for evaluation of relative deviation and normalized error (*En* value) respectively, for observations up to 5 kN. Similarly, for 20 and 50 kN force transducer, observations up to 10 and 20 kN are not taken into account for evaluation of relative deviation and normalized error (*En* value) respectively. The findings of Figures 5–8 have also been summarized in Table 1.

For more rigorous validation of the findings, the study has been further extended according to the guidelines of the international comparisons and the time interval between the readings has been kept 360 sec. Rest of the calibration procedure is as discussed earlier. The mean values of the force transducers obtained at 50 kN DWFM and 1 MN FSM have been used to evaluate the relative deviation and *En* value. The results have been summarized in Figure 9.

The force transducers of 5, 10, 20 and 50 kN have been calibrated according to the calibration procedure based on the guidelines of standard ISO 376:2011 using 1 MN force standard machine and the 50 kN dead weight force machine, and average values have been obtained. Relative repeatability and relative reproducibility for 5, 10, 20 and 50 kN force transducers obtained while calibrating using 1 MN force standard machine and 50 kN dead

Table 1. Summary of comparison

Applied force (kN)	1 MN Force Standard Machine: Relative repeatability deviation (%)	1 MN Force Standard Machine: Relative reproducibility deviation (%)	50 kN Dead Weight Force Machine: Relative repeatability deviation (%)	50 kN Dead Weight Force Machine: Relative reproducibility deviation (%)	Relative deviation (%)	Normalized error (*En* ratio)
1	0.0019	0.0115	0.0002	0.0105	0.0005	0.15
2	0.0022	0.0049	0.0004	0.0085	0.0010	0.27
3	0.0015	0.0020	0.0003	0.0044	0.0017	0.48
4	0.0006	0.0033	0.0001	0.0025	0.0006	0.26
5	0.0003	0.0020	0.0005	0.0068	0.0017	0.46
6	0.0023	0.0046	0.0015	0.0054	0.0010	0.27
7	0.0026	0.0039	0.0013	0.0059	0.0011	0.32
8	0.0011	0.0057	0.0011	0.0057	0.0020	0.55
9	0.0015	0.0041	0.0005	0.0056	0.0021	0.59
10	0.0018	0.0055	0.0012	0.0035	0.0023	0.65
12	0.0015	0.0054	0.0001	0.0029	0.0017	0.47
14	0.0013	0.0059	0.0015	0.0032	0.0022	0.60
16	0.0011	0.0057	0.0012	0.0031	0.0014	0.38
18	0.0005	0.0056	0.0012	0.0037	0.0016	0.44
20	0.0009	0.0069	0.0007	0.0045	0.0013	0.35
25	0.0014	0.0019	0.0012	0.0035	0.0023	0.65
30	0.0008	0.0025	0.0001	0.0029	0.0017	0.47
35	0.0014	0.0021	0.0015	0.0032	0.0022	0.60
40	0.0011	0.0015	0.0012	0.0031	0.0014	0.38
45	0.0007	0.0013	0.0012	0.0037	0.0016	0.44
50	0.0006	0.0010	0.0007	0.0045	0.0013	0.35

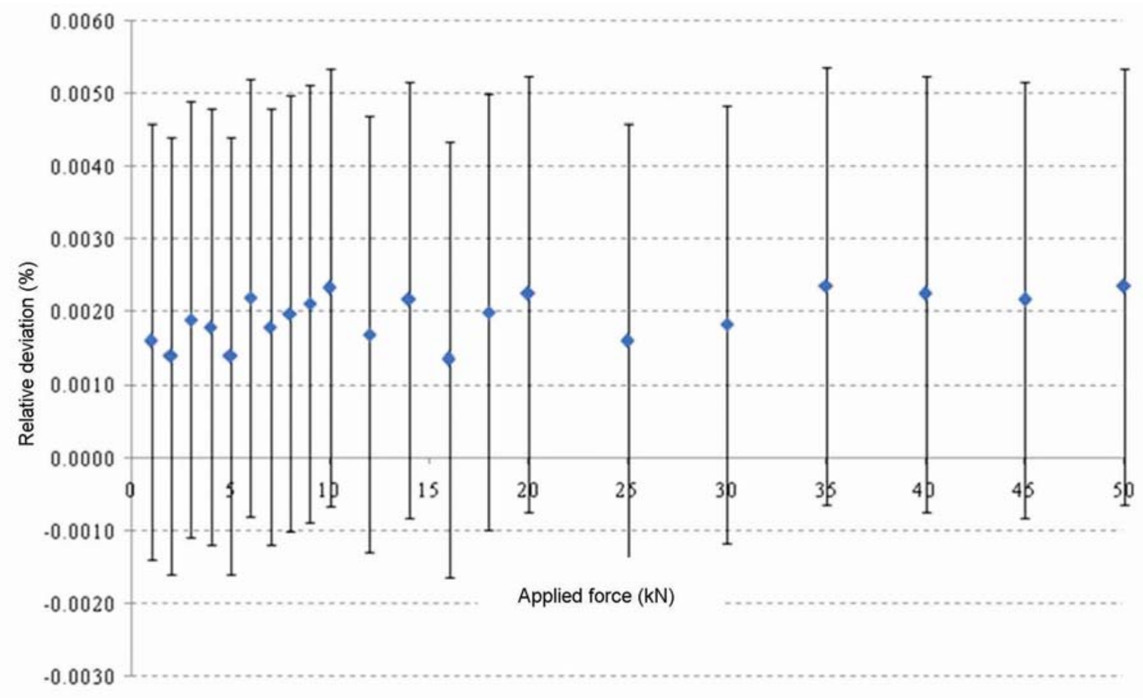

Figure 9. Normalized error (*En* value) for time interval 360 sec.

weight force machine have been computed. Using the average values obtained from 1 MN force standard machine and 50 kN dead weight force machine, the relative deviation and the normalized error (*En* value) have been computed (Figures 5–8). The 5 kN force transducer has been used for the range 1–5 kN, while the observations of 10 kN force transducer are used for the range 6–10 kN, 20 kN force transducer for 12–20 kN and 50 kN force transducer for 25–50 kN respectively, though they have been calibrated for their range according to standard procedures. The normalized error (*En* value; Figure 8) has been found within the permissible range, which indicates the conformity of the claimed uncertainty of force realized by 50 kN dead weight force machine. The conformity of *En* value also confirms the equivalence of force realization by both the force machines. The conformity also states the equivalence of the force realization by both force realizing machines.

The 1 MN force standard machine with uncertainty of force realized 0.002% ($k = 2$) for forces between 1 and 100 kN using dead weights and 0.009% ($k = 2$) for forces between 10 and 1000 kN using lever multiplication system, has been recently established by GTM, Germany and metrologically characterized by PTB, Germany, by means of intercomparison. Hence, an intercomparison has been carried out between 50 kN dead weight force machine and 1 MN force standard machine serving as primary standard force machines in the range 1–50 kN to affirm the metrological capabilities of the former. The study confirms that the normalized error (*En* value) computed is within the permissible limits and hence, the claimed uncertainty of 50 kN dead weight force machine has been justified.

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Cancer gene identification using graph centrality

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One of the most significant challenges of modern bioinformatics is in the development of computational tools to understand and treat diseases like cancer. So far, a variety of methods have been explored for identifying candidate cancer genes. Since protein interactions carry out most biological processes, we propose an algorithm for identifying cancer genes from graph centrality values of the human protein–protein interaction network. The precision and accuracy of the results obtained while applying the method on actual protein–protein interaction data assert that it can be used as an effective model to identify novel cancer proteins.

Keywords: Biological networks, cancer gene identification, graph centrality, network characteristics, protein–protein interaction.

PROTEIN–PROTEIN interactions (PPIs) are fundamental to virtually every cellular process[1]. They can inactive a protein, alter the kinetic properties of proteins, result in the formation of a new binding site or change the specificity of a protein for its substrate. The past few decades have marked many major milestones in understanding PPIs and thereby exploring more about these complex biological systems[2]. Protein complexes performing a specific biological function often contain highly connected protein modules[3]. Study about these protein modules plays a crucial role in understanding the pathophysiological properties of complex diseases like cancer.

Cancer is a disease caused by uncontrolled growth of abnormal cells in the body. There are over 200 types of cancers and it is estimated that about 9 million new cancer cases are diagnosed every year and over 4.5 million people die from the disease each year in the world. Early detection of cancer can greatly improve the odds of successful treatment and survival. It is an extremely complex genetic disease and almost 5–10% of human genes contribute to the genesis of cancer, but only 1% has been identified so far. As cancer is caused by uncontrolled growth of cells, a systematic examination of the proteins encoding cancer genes in the protein–protein network may help us to identify new candidate genes.

In this communication, we made an approach to identify cancer genes from PPIs. The algorithm focuses on

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