TOWARDS CROWDSOURCING SPATIAL MANUFACTURING TASKS FROM RURAL INDIA

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ABSTRACT

Many tasks involving production software that involve spatial reasoning can only produce "good" rather than optimum solutions. It is frequently possible for humans to improve on algorithmically generated solutions computed by CAD/CAM software. The thesis motivating this research is that large numbers of industrial optimisation tasks involving spatial reasoning (such as 2D part nesting) can be outsourced as human intelligence tasks to rural workers to provide a sustainable source of skilled employment. We hypothesis that 3D spatial reasoning ability is essential to solve spatial optimization tasks. In this paper we reported the 3D spatial manipulation ability of eighty rural workers in four rural business process outsourcing (BPO) centres in India. The assessments reveal that although the average spatial manipulation ability is less than the literature reported benchmark, there are talented workers identified in all the four rural centres, and the results identify priority activities required to enable the proposed approach.

Keywords: crowdsourcing, optimization task, rural worker.

1   INTRODUCTION

Material waste minimization in manufacturing has been an active area of research for many decades. It has been noted that in stamping sheet metal process, material costs can typically represent 75% or more of total costs (Rao 2004). Since high volumes of parts are produced by this manufacturing operation, even small inefficiencies in material utilization per part can lead to very large amounts of wasted material. However, since computers find it extraordinarily difficult to manipulate and reason about shapes, many operations management software applications that involve spatial reasoning can only produce "good" rather than optimum solutions. Our survey with laser job shops reveals that it is frequently possible for humans to improve on algorithmically generated solutions computed by commercial CAD/CAM software, and most of them in practise do not rely on the software. Motivated by the observed industrial practices and the research literature, in this research work we hypothesis that large numbers of industrial optimisation tasks involving spatial reasoning can be outsourced as 'human intelligence' tasks to rural workers to provide a sustainable source of skilled employment.

Crowdsourcing is the practice of obtaining needed services, ideas, or content by soliciting contributions from a large group of people, and especially from an online community, rather than from traditional employees or suppliers (Howe 2007). The success of crowdsourcing globally has been widely reported. It has been estimated that in the last decade, over 1 million workers have earned $1-2 billion via crowdsourced work allocation (Frei 2009). A survey of crowd workers on MTurk web platform reported that more than one-third of them are from India and are typically young and highly educated (Ross *et al.* 2010). In that survey, 92% of respondents have a PC and Internet connection in their homes and they are located widely in metro areas and smaller cities. In another survey, Theis *et al.* (2011) reported that the median Indian MTurk workers have an individual income of $2700 annually which is more than double the Indian average (Khanna *et al.* 2010) and an annual house-hold income of twice that amount.

Although crowdsourcing platforms source labour widely across developing countries, many authors have pointed that there is minimal evidence to show low-income workers have benefitted from the opportunities of crowdsourcing (Theis *et al.* 2011). Khanna *et al.* (2010) defined low-income worker as earning less than $1700 per year and only having a high school education. He reported that less than 3% of India-based MTurk workers fall into the demographic of low-income workers. The reasons cited for this low participation rate could be because crowdsourcing platforms are often too complex for low-income, low-literate staff (Pai and Davis 2012) and face usability barriers in accomplishing simple tasks. They need simplified user interfaces and task instructions with language localization (Khanna *et al.* 2010), and low cost access to computers (Theis *et al.* 2011).

This work is motivated by the belief that the geometric reasoning tasks associated with many industrial processes and engineering computations have the potential to provide sustained 'value proposition' for both buyers and sellers of the work. The belief is based on the observation that humans, regardless of their educational or social background, are adept at manipulating and reasoning about shapes, a task that computers find extraordinarily difficult to do. We postulate that spatial reasoning skills are required to solve geometrical CAD/CAM tasks. As a first step, this paper presents an assessment of the 3D spatial manipulation ability of eighty rural workers in India using a standardized test. The remaining sections of this paper present literature related to spatial reasoning work on crowdsourcing platforms, research questions and the methodology followed in assessing spatial manipulation ability, and an analysis of the results.

2   RELATED LITERATURE

Literature observed that reaching low-income workers in metro areas and smaller cities itself is a challenge and currently, rural villages (where there are no, or limited, access to computers and Internet) are consequently excluded from the Internet economy. However there are few approaches proposed and implemented to reach untapped human resources in rural areas. For example Samasource is a successful non-profit organization which aims to connect women and youth living in poverty to dignified work via the Internet (Samasource, 2013). They work with in-country partners to identify, recruit and train poor women and youth to perform work for their clients. Similarly commercial companies such as RuralShores, Anudip Foundation, Desicrew and Sourcepilani have also recognized the potential of rural workers and have many centres that recruit and train workers across rural India. Elsewhere since mobile penetration predominates more than computer accessibility, various crowdsourcing applications via mobile networks have been proposed. Txteagle distributes text-based tasks via SMS for low-income workers to perform on mobile phones in Kenya (Eagle 2009). However, it has been reported that typing is faster on a personal computer than mobile (Antin and Shaw 2012). So these platforms provide only low value low skills enrichment tasks such as text and image based data entry to these workers. In order to undertake high value industrial tasks such as 2D packing or 3D feature recognition, rural workers must possess spatial reasoning ability.

Spatial ability is defined as the ability to generate, retain, retrieve, and transform well-structured visual images (Lohman 1995). Within these processes, spatial factor could be separated into two parts: an ability involving sensing and retention of geometric forms and a facility in the mental manipulation of spatial relationship (Smith 1964). For both of these spatial abilities, humans perform much better than algorithmic solutions. However in crowdsourcing of micro-tasks, the spatial ability of crowd workers is mostly assessed as an ability involving sensing and retention of geometric forms. For example, image tagging and labelling tasks are common applications. Crowdsourcing tools such as MTurk are popular for annotation of large scale image data sets. Image annotations using bounding boxes or coarse outlines of objects are commonly used for simpler interfaces. However even though the volume of MTurk business related to image recognition and retrieval is high (because of the limitation of algorithmic solutions), these kinds of tasks provide low value to the workers in terms of earnings and skills enhancement.

Compared to spatial recognition tasks, spatial manipulation tasks are more challenging and provide opportunities for skill developments that generate high value for the outcomes produced. However tasks related to spatial manipulation are not currently widely explored on commercial crowdsourcing platforms. Spatial manipulation skills play a vital role in various optimization tasks found in manufacturing processes. In such tasks it is not uncommon for even small improvements in

the quality of the results to increase efficiency and hence the profits of many different industrial sectors (e.g. sheet steel fabricators, automated manufacture, clothing etc.). These tasks bring "real" high value problems to the crowd sourcing sectors because algorithmic geometric modelling technologies still produce less than optimal solutions for many industrial applications such as packaging and nesting problems. Indeed observed industrial practice is for human production engineers to manually improve the algorithmic solution created by CAM software based on their intuitive visualization of the spatial problem. The global market for CAD/CAM systems is estimated to be around $26.3 billion in 2010 (CIMdata 2011).

Even though the potential of crowd workers has been established (Corney *et al.* 2010), the number of commercial CAD/CAM tasks posted on MTurk related to spatial manipulation is very small. The possible reasons could be due to difficulties in framing micro-tasks related to these tasks, assumption of extensive training requirement before implementing the real-time work, crowdsourcing platforms are not versatile enough to build and test skills related to spatial manipulation, and integration issues with industrial work practices. However the major issue is one of data security related to the need for confidentiality when working with industrial data in a public domain.

Given the above requirements, the aim of our research is to investigate the feasibility of a crowdsourcing platform that overcome the confidentiality issue, by using rural workers in secure BPO environments to do spatial manipulation tasks and so increase skilled employment opportunities and contribute to the broadening of the populations' skills base. The spatial manipulation tasks provide a significant economic contribution, a long term source of high value tasks via a form of "distributable" work that does not demand professional levels of numerical or linguistic skills.

3   RESEARCH QUESTIONS AND METHODOLOGY

To understand and establish baseline capability of rural BPO workers for spatial manipulation the following research questions are framed:
1. What is the demographic (age, level of education) of rural BPO workers in India?
2. What is the 3D spatial manipulation ability of rural BPO workers in India?
3. Does gender / educational level influences spatial manipulation ability?

To reach rural workers we have chosen rural BPO centres because presently more than 100 such units are estimated operating around India, most of them less than three years old (Wharton 2010). From our observational visit we found that rural BPO centres have better infrastructure in terms of availability of electricity, reliable internet services and trained work force compared to the surrounding environment in which these rural BPO centres are located. The merits of using BPO centres are earnings stability and fulltime employment for the rural workers. As a first step to establish our hypothesis, we assessed spatial manipulation ability of rural BPO workers through a standardized test.

We selected four rural BPO centres (identified as C1, C2, C3 and C4) located in different states of India. Two centres were chosen from South and North India respectively. Researchers agreed to anonymity for close commercial operations and so the exact locations of these centres are not presented. We aimed to get a wider demographic coverage of rural workers in these centres. Since these tests were conducted in real-time business environment, the choice of rural workers to participate in this test was controlled by the BPO centre. Twenty rural workers participated in each rural BPO centre. Overall, this paper reports the analysed results of eighty rural BPO workers. All the participated workers filled a questionnaire providing personal information.

To assess the spatial manipulation ability we used a version of the Mental Rotations Test redrawn by Peters et al. (1995). This is a three-dimensional mental rotation test. Each worker was given the paper-based 24-item Mental Rotation Test set, and 3 minutes were given for each subset of 12 items, separated by 4 minutes. The version of the test was the one illustrated in Figure 1. The subject is presented with four images of objects, two of which will be the same as the target object (shown on the left) but rotated in some way. The worker should identify two images that show rotated versions of the target object. Subjects had to identify both of the correct alternatives, and a score of "1" was given only if both choices were correct. The maximum test score is 24.
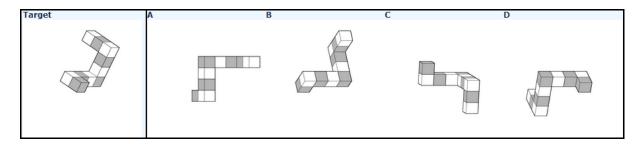
Figure 1: A sample question from spatial manipulation rotation test.

4   RESULTS

The results are presented subsequently in the numerical order in which the research questions are presented in the previous section.

4.1   Rural Workers Demographic

Table 1 details the demographics of rural workers who were participated in the test conducted across four rural BPO centres in India. Most of the rural workers who participated in the test were young (77.5% are less than 23 years old) and educated (70% had a graduate degree). This shows that on the average rural workers are much younger than MTurk workers in India (average age 27 years, Ross *et al.* 2010) but very similar to MTurk workers educational level (80% of respondents have completed a Bachelor's degree or higher, Ross *et al.* 2010). Only in one of the rural BPO centres was the spread of the age range limited to between 20-23 years and almost all of the workers possessed a college graduated degree. Nearly half (45%) of the participated workers are novices who have less than 12 months experience at the centre. Not surprisingly workers had greater experience in those rural BPOs that had been in operation a number of years. This observation supports the frequent assertion pointing the benefit of high worker retention rate in rural BPO centres.

Table 1: Demographic of workers in rural BPO centres.

		C1	C2	C3	C4
Age range		20-23	16-29	20-31	18-30
		Less than or equal to 20 years: 15 Between 21-23 years: 47 Between 24-27 years: 15 Between 28-31 years: 3			
Level of Education	High school finishers	1	9	7	7
	College graduates	19	11	13	13
Total work experience range (months)		1-36	3-65	2-62	5-24
BPO work experience (months)		1-36	3-65	2-54	5-24

4.2   3D spatial manipulation capability

Table 2 details the results of spatial rotation test across all the four rural BPO centres. The One-Way ANOVA analysis between centres identified that there is no statistical significant difference on the mean "both-correct" answers score ($F(3,76)=0.562$, $p=0.642$). The analyses of unanswered questions identified that rural BPO centres C1 and C3 had a better average of unanswered questions (3.7 and 5.1 respectively) than centres C2 and C4. This significant result suggests that training must be designed to not only improve appreciation of 3D shapes, but also in the appropriate response when unsure of the answer. Comparing these rural BPO results for the "both-correct" answers score with the Part-C test (greater difficulty test) of the Peters et al. (1995) study (involving undergraduate students at the University of Guelph, USA) suggests that the rural workers mental rotation skill is less than undergraduate American students. But the mean percentage variation between these results is minimal for female (13.2%) than male (36.4%). Figure 2 shows that there are exceptional workers possessing good spatial rotation ability. These results have justified the need for a program of selection and

training among the workforces and suggest that with minimal training the rural workers could do the spatial rotation task on par with urban population.

Table 2: Spatial rotation ability score of rural workers across rural BPO centres.

Max score: 24	C1	C2	C3	C4	Overall	Peters *et al.* 1995
"Both-answers" correct score - Mean (SD)	5.1 (2.6)	4.5 (2)	5.2 (2.3)	4.6 (2.2)	Male: 4.9 (2.6) Female: 4.6 (1.6)	Male: 7.7 (3.7) Female: 5.3 (2.5)
Number of questions unanswered	3.7	0.5	5.1	0.3	2.4	

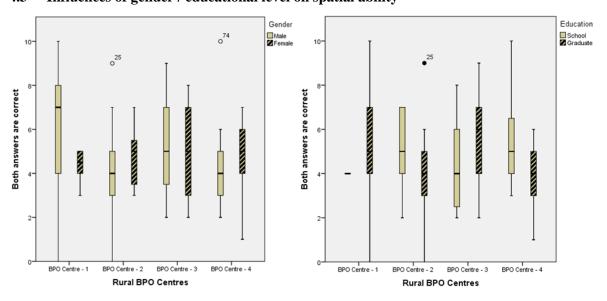## 4.3   Influences of gender / educational level on spatial ability

Figure 2: Box plots for "both-answers" correct score between gender and education level

Figure 2 shows the box plot for "both-answers" correct score between genders across four rural BPO centers. Even though the gender ratio in all the four rural BPO centers is evenly split, the test was undertaken predominately by males (65%). Most of the literature reports that males perform better than females in this kind of spatial rotation test (Voyer and Sullivan 2003). In our study there is no statistically significant difference identified between male and female rural workers for "both-answers" correct score (t(78)=0.56, p=0.577). The irregular sample size could have influenced these results which was an uncontrollable variable in our study. Except BPO center C1, the middle 50 percentile female population is better than male. More tests need to be conducted in these centers to interpret differences due to gender variation. As discussed in the demographic subsection the rural workers are predominately college graduates (70%; 56 workers) rather than high school finishers (24 workers). Figure 2 illustrates the difference for "both-answers" correct scores between education level across four BPO centers. There is no statistical significance identified between high school finishers and college graduates who are rural workers (t(78) = 0.518, p=0.606). In contradiction to expectation, the mean of "both-answers" correct scores of high school finishers (M:5, SD:2.1) are better than college graduate workers (M:4.7, SD: 2.3). The poor performance of college graduated could be due to lack of motivation and enthusiasm to perform better in the test. To change this situation, we have planned to conduct future tests that incorporate performance based incentives for the workers.

5   DISCUSSION AND FUTURE WORK

Presently underemployment, rather than unemployment, is a key issue in rural areas. The demographic of rural BPO workers suggests that the literacy rate is high and almost equivalent to urban population. Currently low skill work such as data entry is mostly prevalent tasks in rural BPO centers providing low value for their work. Consequently there is a need to bring high value and high

margin tasks to these centers. In this context the integration rural BPOs with industrial working practices could bring high value geometrical reasoning tasks to workers living in rural areas. With the growing number of rural centers, this can be done even though the penetration of personal computing and communication infrastructure is poor in many areas. From the assessment results we conclude that the spatial manipulation ability of young and mostly educated work force in rural areas in India is less than reported literature results in challenging spatial rotation test. Although the level of performance is below a level that would be commercially useful the study has established a base level against which future training and results from industrial tasks can be compared.

To motivate and perform better in this assessment we plan to reassess the rural BPO workers incorporating performance based monetary benefits. Also the effects of providing training in spatial manipulation will be investigated as these might bring significant improvement in their skills. Peer-to-peer engagement for collaborative solving could be an effective way to enhance their understanding and solving spatial problem. Another approach could be to adopt successful crowdsourcing strategies such as getting worker to verify the responses of other worker, or deriving results by the aggregation of results. To employ crowdsourcing validation and aggregation methods guessing must be discouraged by careful design of a bonus system. Lastly the results appear to support the belief that this is a form of employment is potentially accessible to a wide number of people regardless of educational attainments. The observation of the variation in spatial manipulation performance and exceptional workers possessing good spatial rotation ability justified the need for a program of selection and training among the workforces and suggest that with minimal training the rural workers could do the spatial rotation task on par with urban population.

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