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Design method for multi-user workstations utilizing anthropometry and preference data

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ABSTRACT

Past efforts have been made to design single-user workstations to accommodate users' anthropometric and preference distributions. However, there is a lack of methods for designing workstations for *group* interaction. This paper introduces a method for sizing workstations to allow for a personal work area for each user and a shared space for adjacent users. We first create a virtual population with the same anthropometric and preference distributions as an intended demographic of college-aged students. Members of the virtual population are randomly paired to test if their extended reaches overlap but their normal reaches do not. This process is repeated in a Monte Carlo simulation to estimate the total percentage of groups in the population that will be accommodated for a workstation size. We apply our method to two test cases: in the first, we size polygonal workstations for two populations and, in the second, we dimension circular workstations for different group sizes.

1. Introduction

The co-location of team members has been shown to increase teamwork quality and an effectively-designed workstation improves a team's productivity (Hoegl and Proserpio, 2004). Methods that utilize anthropometric data to size workstations have been developed for *individual* accommodation (Das and Grady, 1983a; Das and Sengupta, 1996; Pheasant, 1987; Sengupta and Das, 1997) However, methods are lacking for sizing workstations with respect to *group* accommodation and interaction.

Previous studies have considered anthropometric quantities in the design of single-user workstations (Das and Grady, 1983a; Pheasant, 1987; Das and Sengupta, 1996; Sengupta and Das, 1997). The arm length and stature of female populations have been used to determine the optimal placement and sizing of cashier stations (Das and Sengupta, 1996) and nurse stations (Pheasant, 1987). Additionally, manikin-based approaches have been used to simulate user behavior at single-user workstations (Sengupta and Das, 1997). Digital human models have been employed to design and visualize workstations and other products tailored to targeted population segments (HFES 300 Committee et al., 2004; Jung et al., 2009). Despite these numerous methods for sizing workstations, they all considered only the physical dimensions of a user to determine how far they can comfortably reach and did not account for the user's preference.

Wang highlighted user interaction with objects on a planar, static workspace and provided the fundamental research for “inner boundaries” (Wang, 1999). The inner boundary better defined the space needed by a seated user. It has been demonstrated that a user's reaching behavior is affected by an object's distance and weight (Choi and Mark, 2004). These two ideas are synthesized in the investigation of comfortable tabletop reach zones by Toney and Thomas (Toney and Thomas, 2006). No application of these findings has been used in conjunction with an anthropometric model to drive workstation design, although it has been cited as an idea for further investigation (Toney and Thomas, 2006).

Designing a workstation for a group is more complicated than for an individual: consideration must be given to both a user's personal space and the shared space between users (Scott et al., 2003; Sulaiman Kharrufa and Olivier, 2010; Tang, 1991). For example, each user needs space for their personal laptop and notebook, but also needs to be able to share reference manuals or rapid prototypes with other group members. Scott observed that “territories” — personal, group, and storage — arise naturally in a collaborative workspace setting (Scott, 2003; Scott et al., 2004). It is suggested that these emergent territories be used as guidelines in workstation design (Sulaiman Kharrufa and Olivier, 2010). These

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aforementioned studies observed subjects working in a collaborative environment and make broad suggestions about design considerations. However, they do not offer a systematic way to design such workstations.

Personal space at the workstation falls within each user's *normal-reach zone* (NRZ). Also known as the "normal working area," the NRZ is generally defined as the area which can be comfortably reached while a seated user keeps their back upright. This size and shape of the zone has been modeled using anthropometric data and geometry (Das and Grady, 1983a,b; Pheasant and Haslegrave, 2005; Squires, 1956). The shared space on the workstation falls within a user's *extended-reach zone* (ERZ): the farthest a user can reach when their arm is fully extended and pivoting about the shoulder. Several studies have defined and modeled ERZs (Faulkner and Day, 1970; Sengupta and Das, 2000; Toney and Thomas, 2007). Empirically-based studies produced ranges of reach zone sizes based on a subject's stature percentile (Faulkner and Day, 1970; Sengupta and Das, 2000). However, the data is not available to correlate a subject's actual stature or other anthropometric data directly to their ERZ.

In this paper, we create a methodology for sizing workstations for effective group use. Specifically, we find the group accommodation as a function of the workstation's dimensions. This methodology considers the target users' anthropometric information with the goal that any two adjacently-seated members from the population have non-overlapping NRZs *and* a shared region created by the members' overlapping ERZs. For simplicity, we define the NRZ by the arc swept out by a user's wrist-wall length (WWL): the distance between the wall and the right wrist when standing with the back against the wall and the outstretched right arm parallel to the floor. For this paper, we define the ERZ as the 2D curve made of the farthest points a user can comfortably reach while: (1) their arm is fully extended, (2) they are bending at the waist and back, and (3) they are remaining seated. For the case studies in Sec. 3, we gathered preference data to determine ERZ as detailed in Sec. 2.2.

In a first test case of the methodology, we use two example populations to design three polygonal workstation configurations. The three configurations are: a four-seated workstation where users sit at the midpoint of each side (referred to as side-seated four-user workstation (SFU) and shown in Fig. 1A), a four-seated workstation where users sit at the corners (referred to as corner-seated four-user workstation (CFU) and shown in Fig. 1B) and a three-seated workstation where users sit at the vertices (referred to as equilateral triangular three-user workstation (TTU) and shown in Fig. 1C). These three designs represent possible table layouts for an office or a library.

In a second test case, we apply the methodology to size circular workstations. We find the group accommodation as a function of workstation diameter for groups of three to six members. We use the results to find the dimensions that are optimal to accommodate multiple group sizes.

2. Methods

The design method calculates the accommodation for groups in three steps. We (1) create a virtual population (Nadadur and

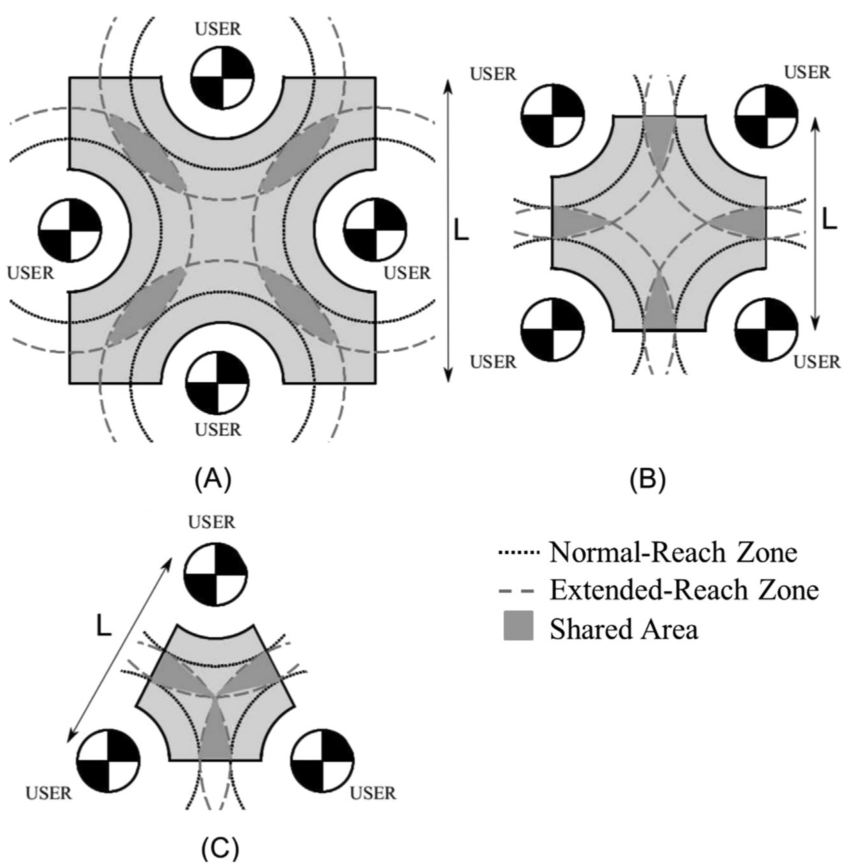

Fig. 1. Schematics of the three polygonal workstation configurations. *L* denotes the side length of the workstation. Note that the schematics are not to scale. The local work area is bounded by the dotted line and represents the normal-reach zone. This zone is the area that lies within the user's WWL – no bending at the waist or back is needed to reach objects within this area. The dashed line is the boundary of the *extended-reach zone*, where an individual can comfortably reach by extending their upper body and bending at the waist and back. It is assumed that users face the center of the workstation while seated. (A) Side-seated four-user workstation (SFU). (B) Corner-seated four-user workstation (CFU). (C) Equilateral triangular three-user workstation (TTU).