Where is the knack in lifting of human-like objects: one should be careful before starting the actuation

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Lifting is one of the common hard tasks for nursing care and material handling. It is also one a demanded task for the humanoid robots. Except the industrial robots, lifting up a heavy object is challenging task for humanoid robots and only a few results are reported, e.g., (Ohmura and Kuniyoshi, 2007, Odashima et al., 2006). Especially, there is difficulty of maintaining the balance in human lifting due to flexible body and it can be regarded as a target of next challenge.

In this work, we experimentally studied human movement of lifting of human-like dummy and analysed features of experienced subjects to find the "knacks" of this skill, which is an essential information to achieve or improve the task (Kuniyoshi et al., 2004). Also, to make our results transferable to robots, we focus on the features that are commonly applicable for human and humanoid robots.

The human-like dummy (1.2 [m] high and weighs 25/30/35 [kg]) is hard to handle and we expect highly organised skillful movement can be observed, compared to lifting of hard object as is studied in biomechanics and ergonomics (Dieën et al., 1999, Burgess-Limerick, 2003).

So far we have studied skill of kneading, samba dancing (Yamamoto and Fujinami, 2004) and a dynamical way rising (Kuniyoshi et al., 2004) based on the concept of Global dynamics (Kuniyoshi and Nagakubo, 1997, Yamamoto and Kuniyoshi, 2002). In this concept, possible movement patterns form a web of envelopes, the region where the trajectory is predictable and the nodes, where decision making is needed, as the junction point of envelopes. See figure 1. The knack corresponds some of nodes in the path, which are important but often neglected by the inexperienced person.

Ten healthy male participated in the study (average age and SD are 23.8 and 1.87). Three of them have occupational experience and they are classified into group E (Experienced) and rest of the subjects are group G (General).

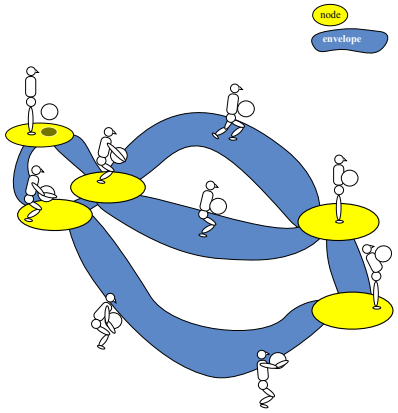

Figure 1: Schematic drawing of Global dynamics for lifting. The yellow circle and the blue region represent the node and envelope, respectively.

The human-like dummy is made of weights and a jumpsuit. Its height is 1.2 [m] and weight is 25/30/35 [kg] by changing the number of weighs. Each subject performed lifting for 15 times (5 trials for each weight). Their Performances are measured by VICON motion capture system (Vicon Motion Systems, UK) with 10 cameras and F-scan pressure distribution sensor (Nitta Corp., Japan/Tekscan Inc., USA). Temporal resolutions are 60 [Hz] for the both.

By visual and video playback observations, we classified lifting strategies for roughly two; stoop and squat. While this is common classification for lifting, we found variety in the leg poses. Three of subjects opened their leg fore and aft and lifted the body and dummy mainly single leg. Three subjects used open strategy, two used

"open-squat" and one used "open-stoop". Two of them belong to group E (Experienced) and one to group G (General).

Comparing the subjects' torso movements between group E and G, an obvious feature is that laying back is commonly seen in group G during holding phase. In figure 2, average attitudes of torso during the holding phase are shown. All subjects in group E and only one subject in group G have average value near $\pi/2$ (i.e., vertical). Possible reasons for laying back are balance and support of the dummy, using abdomen as a supporting surface. Also, arm's pulling force may be supported.

However, one do not have to pull the dummy by the arms when the arms are fully extended. The flection of the arms are likely to happen when a subject lift the dummy by the arms. We do not specify lifting height and arm lifting is not necessary.

We evaluated effective arm lifting height. While initial height differ by trial, arm lifting tendency is not obviously seen in all subjects in group E and three in group G. See figure 3. Then arm lifting tendency is thought as indication of premature skill.

As a preliminary result of CoP (Center of Pressure) analysis by pressure distribution sensor, while CoP remain near the center of the foot for one of the subject in group E (only subject who used close strategy), while those of the subjects in group G are variable and tend to be near the toe at the beginning of the lift (data not shown).

Therefore we conclude that laying back and arm lifting are seen as signs of immature skill of lifting. Taking these results into account, we suggest following three knacks.

- open the legs
- grasp the object, not to loosen the arms (i.e., full extension of the arms)
- when lifting, keep the body straight up

First two knacks are about preparation. In general, inexperienced person seems to concentrate about action itself (e.g., lifting) and take less care about preparation. Once use those knacks, above three features is expected to be realised.

In epigenetic robotics context, those results have importance for planning. Based on the idea of Global dynamics, to know branching point of envelope is essential for realising skillful movements. Especially, in heavy work, once path is selected, tuning or retry are hardly possible and to give rough design of behavior is believed to be a promising method. Within the envelope, behavior is predictable and learning is expected to be possible.

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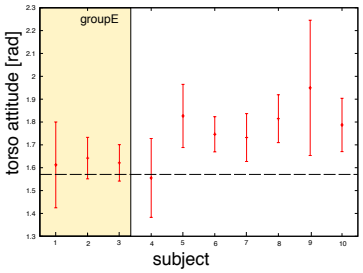

Figure 2: Errorbar plot of torso attitude during the holding phase. Group E and subject 4 do not lay back.

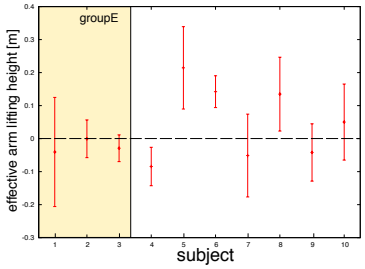

Figure 3: Errorbar plot of effective arm lifting height. Group E, subject 4, 7 and 9 show no arm lifting when average value is compared.

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