The Tight Game: Implicit Force Intervention in Inter-personal Physical Interactions on Playing Tug of War

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Figure 1: 1) A tug of war between two players. 2) An external mediator is controlling the game without the players noticing. 3) The players were totally engaged in the game since they believed it was a tight game.

ABSTRACT

Physical assistance can alleviate individual differences of abilities between players to create well-balanced inter-personal physical games. However, 'explicit' intervention can ruin the players' sense of agency, and cause a loss of engagements in both the player and audience. We propose an implicit physical intervention system "The Tight Game" for 'Tug of War' a one-dimensional physical game. Our system includes four force sensors connected to the rope and two hidden high torque motors, which provide realtime physical assistance. We designed the implicit physical assistance by leveraging human recognition of the external forces during physical actions. In The Tight Game, a pair of players engage in a tug of war, and believe that they are participating in a well balanced, tight game. In reality, however, an external system or person mediates the game, performing physical interventions without the players noticing.

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1 INTRODUCTION

Tight games, especially in sports, excite both players and audiences. On the other hand, predictable games that result from a huge differences in physical abilities between players are typically boring. This research investigates how technology can be used to (artificially) create dramatic, close games and empirically survey how both players enjoy the fixed games.

Realtime physically assistance technologies can provide us augmented experience with physical motions [Kasahara et al. 2019; Maekawa et al. 2020]. While physical assistance can narrow the skill gap between players, however, the obvious 'explicit' interventions removes the sense of being in control—the sense of agency—from the players. Without the sense of agency, players are discouraged from engaging in the game, since they noticed that the game is fixed by something (one) out of their control. Applying previous knowledge, we endeavoured to artificially create a close game in a physical game (sport) involving multiple human players, carefully managing players' sense of agencies.

We propose an implicit physical intervention system called *The Tight Game* for the 'tug of war', a one-dimensional physical game. Our system includes four force sensors in the rope and two hidden high torque motors that provide realtime physical assistance. We designed the implicit assistance by leveraging human recognition of external forces during physical actions. In a game, a pair of

Figure 2: 1) The players pull at the rope using handles. 2) Two force sensors on the handle measure forces at both the front and rear ends, which detects how each player is applying force. 3) A BLDC motor pulls at the rope from behind each player.

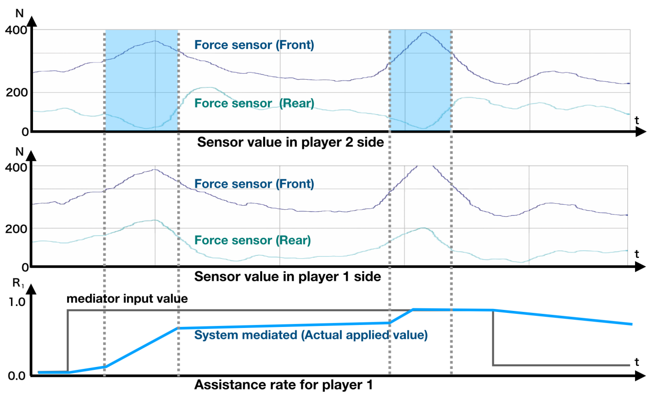

Figure 3: The system detects players' impulse pulling from the force sensors. Only when the player who will be assisted (Player1) gives a big pull, the assistance rate updates quickly.

players pull at the rope and believe that they participating in a tight game. In reality, however, an external systems or person mediates the game, performing physical interventions without the players noticing.

2 THE TIGHT GAME SYSTEM

A unit of our system consists of 1) two pairs of force sensors on the handle (Fig. 2-2) connected with the rope, and 2) a high torque motor (Fig. 2-3) at the end of the rope. We adopted a large-diameter brushless DC (BLDC) motor with a low reduction ratio. This motor was chosen for its backdrivability and high torque output. The sensors and motors are all connected to a main computer which controls the torque outputs according to the force sensor signals.

In our system, the two motor units are hidden from the players such that they unaware of the presence of the physical assistance. In addition to the hardware units, the system also has a remote user interface (Fig. 1-2) that can be provided to a mediator. The user interface allows the mediator to to control and intervene in the game without the players noticing.

3 IMPLICIT FORCE ASSISTANCE DESIGN

To perform unnoticeable interventions, we designed the realtime force assistance by leveraging forces fitting to humans' recognition. Each motor output force Fm_i are described as;

$$Fm_i = R_i f(Fs_1 + Fs_2) + Fc(i = 1, 2)$$

Here, $f(Fs_1 + Fs_2)$ is a non-linear assistive force which is dependent on the pulling (front) force sensor values (Fs_i) of both players. This provides a less noticeable force assistance to the players, because the processing keeps force assistance in the range of force by humans based on the Weber–Fechner law in the output force and the perceived force in muscle activity (e.g., [Takemura et al. 2013]). Fc is a constant force applied to prevent slack in the rope.

With this reactive force assistance, the system or/and the mediator can control the balance of the force assistance between two players by changing R_1 and R_2 (Here, $R_1 + R_2 = 1.0$). From our preliminary experiment, we found that naive (sudden) control of the assistance rate resulted in players noticing the existence of external force, since the weight of the rope changed asynchronously with the players' actions. Therefore, we only triggered changes in the assistance rate when the players were actively pulling on the rope. As depicted in Fig 3, the system detects the players' pulling as a the difference within a pair of force sensor values. Changes in the assistance rates (R_1 and R_2) are made gradually to match the mediator's input. When the player who is to be assisted gives a big pull, the assistance rate will quickly update to match the mediator's input.

4 CONCLUSIONS

We demonstrated implicit force intervention in the game of tug of war as an example of inter-personal physical interaction. Our design of the force assistance allows the system or another user to control the status of the game without the players noticing. With our implicit physical intervention, we also demonstrated a method for balancing individual physical differences between players without compromising the players' sense of agency and engagement in sports activities.

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