# Synthesizing Close Combat Using Sequential Monte Carlo

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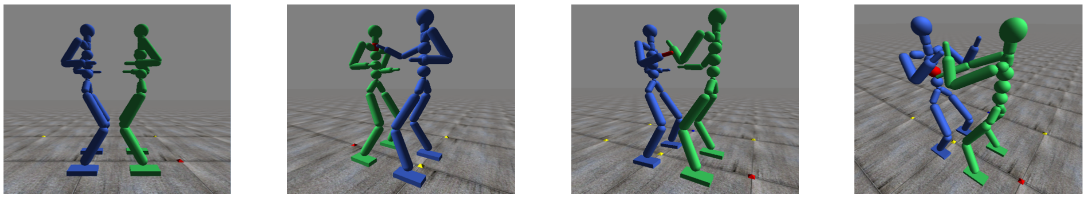

(a) (b) (c) (d)

**Figure 1:** *(a) The initial poses. (b) Pure attack: the blue avatar hits the green avatar's neck. (c) Pure defense: the green avatar blocks the previous attack from the blue avatar. (d) A typical two-character interaction: the blue avatar plans to hit its opponent's head and neck, but it fails, while the green avatar blocks the attack and hits its opponent's abdomen. In this case, the green avatar wins.*

## 1 Introduction

Synthesizing competitive interactions between two avatars in a physics-based simulation remains challenging. Most previous works rely on reusing motion capture data. They also need an offline preprocessing step to either build motion graphs or perform motion analysis. On the other hand, an online motion synthesis algorithm [Hämäläinen et al. 2014] can produce physically plausible motions including balance recovery and dodge projectiles without prior data. They use a kd-tree sequential Monte Carlo sampler to optimize the joint angle trajectories. We extend their approach and propose a new objective function to create two-character animations in a close-range combat. The principles of attack and defense are designed according to fundamental theory of Chinese martial arts. Instead of following a series of fixed Kung Fu forms, our method gives 3D avatars the freedom to explore diverse movements and through pruning can finally evolve an optimal way for fighting.

## 2 Objective Function

The proposed objective function is formulated as

$$f(x) = e^{-\sum_{j=1}^{N(x)} w_j \|b^j - g^j\|^2} + w_+ c(p^j, q_+^j) - w_- c(p^j, q_-^j)$$

, where $x$ defines a control strategy represented as joint angle trajectories and is used to run physics simulations to get a time series of positions for all the rigid bodies. The first term minimizes the distance between a specified body position $b$ and the target position $g$, while $N(x)$ is the number of simulated time steps and $j = 1$ denotes the current time step. $w_j, w_+, w_-$ are the weighting parameters, and $c$ is a function that detects collision between two body positions $\{p, q_+\}$ or $\{p, q_-\}$ for $j = [1, , N(x)]$.


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**Principle of Attack:** To hit the critical body regions of the opponent is the main goal of attack, and $b$ is set as one hand position of our side. Target position $g$ is defined as the opponent's head, neck, thorax and abdomen iteratively. Here $p$ is our moving hand, and $q_+$ mean opponent's critical parts while $q_-$ are opponent's arm parts.

**Principle of Defense:** The goal of defense is to block the opponent's blow in order to prevent injuries to critical regions, which means we need to track opponent's hand movement. We found that setting $b$ to be forearm of our side and $g$ to be opponent's hand can withstand the attack. $p$ is the opponent's hand that throws the punch, while $q_+$ are our arm parts and $q_-$ are our critical parts.

**Two-Character Interactions:** To synthesize fighting animation, we maintain individual samplers for each model. Both avatars use generated samples to run simulations simultaneously, yet they select the best sample as the final control strategy independently. The process imitates the real combat behavior where one can only guess opponent's movement and employ the optimal tactics. We use both attack and defense principles to evaluate the objective function for each hand of the character and choose the highest fitness value to determine the fight mode.

## 3 Future Work

So far we substitute both models' arm positions into our objective function, and other body parts such as legs should be considered to realize kick actions. Furthermore, we plan to measure impact force on character's body to evaluate the effectiveness of the strategy. We believe that the proposed system can combine more principles to learn higher level martial arts.

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## References

HÄMÄLÄINEN, P., ERIKSSON, S., TANSKANEN, E., KYRKI, V., AND LEHTINEN, J. 2014. Online motion synthesis using sequential monte carlo. *ACM Trans. Graph. 33*, 4 (July), 51:1–51:12.