# Optimal Control Based Analysis of Human Painting Motions

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**Abstract:** When looking at art works, people often report a sense of bodily empathy. An often-cited example is Michelangelo's $prisoners$, where contemplators in many cases claim to feel an activation of the muscles that appear to be activated within the person depicted by the sculpture itself. In 2007, David Freedberg and Vittorio Gallese predicted similar results to occur when the stimulus is chosen to be from art works that are characterized by the particular gestural traces of the artist, as in Fontana and Pollock. In recent years, there has been increasing evidence for this claim. Several studies found indications that $embodied\ simulation$ of $motor\ resonance$ does indeed play a role in the process of aesthetic experience. However, a quantitative analysis of the relation between an artist's motion, the resulting work of art and the aesthetic experience evoked in an observer has not been performed yet.

We present a framework in which we perform optimal control based motion analysis and motion generation to investigate this relation with a focus on the painting style known as "action painting". We recorded, reconstructed and analyzed the painting motion of an artist while creating action paintings and transferred that motion to a robotic arm.

To achieve this, we created dynamic rigid-body models of the human artist and the painting robot that allow the investigation of dynamic motion properties. These models were used in three kinds of optimal control problems. For motion reconstruction, we solved a least-squares fitting problem using the differential equations of the rigid multi body dynamics and joint limits as constraints to ensure physical plausibility. To detect underlying optimality criteria in the reconstructed motions, we formulated an inverse optimal control problem, comparing bilevel approaches using different upper-level solvers with a direct all-at-once approach. We found that motion described as similar to each other by the artist lead to similar objective functions whereas motion described as unalike result in differing objective functions. The criteria identified with this method are then used as cost functions in a motion generation optimal control formulation for the robotic system.

To investigate the perception of action paintings by human contemplators, we created a web-framework that includes several psychological tests. Collected data has been processed statistically and analyzed regarding the aforementioned psychological questions. Data shows that participants were able to discriminate between paintings generated by different cost functions. This supports the hypothesis that the perception of action paintings is influenced to a certain degree by an internal reconstruction of the painting motion.

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