Pencil-drawing physics

Laboratory: Institut de Physique de Nice (INPHYNI), Université Côte d'Azur et CNRS (UMR 7010)
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Thesis possibility after internship: YES Funding: Not secure.

Description

Pencil drawing is one of the most ancient forms of human expression. At its core, it consists of rubbing a brittle material against a rough surface to leave behind a permanent trace. Over centuries, it has served as a medium for art, as well as a simple and inexpensive exercise for children to develop coordination and precision. The final pattern produced depends on a wide variety of factors: the type of paper (e.g., Canson versus printer paper), the hardness of the pencil, the pressure applied, and the speed of the stroke. Artists intuitively exploit these variables to create specific textures and expressions, as illustrated in Fig. 1(a).

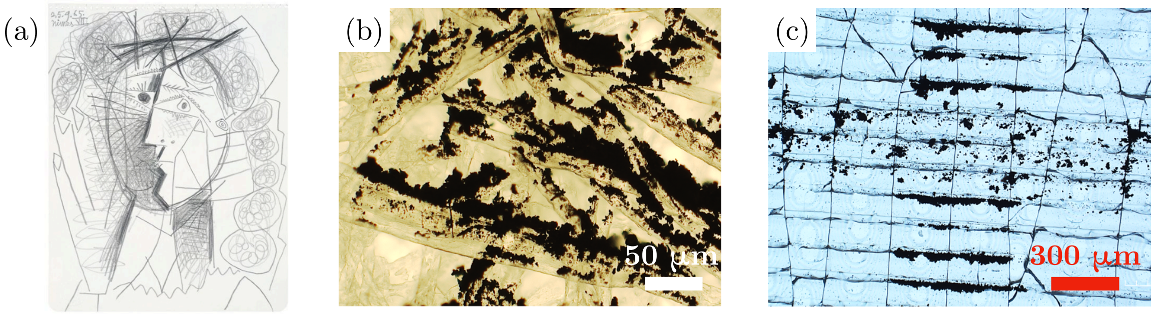

Figure 1: (a) Drawing *Tête de Femme* from Pablo Picasso (Weinstein gallery, San Francisco). Graphite pencil traces under the microscope over cellulose-base paper (b) and engraved glass (c).

At the microscopic level, a first surprise is that graphite does not cover the surface uniformly; instead, most of the area remains void. Tiny flakes are torn off by the cellulose fibers that make up the paper (Fig. 1(b)), making the writing process a complex interplay between the rough surface and the brittle pencil lead. Changing the substrate—using a smoother or rougher paper, or even a different material—drastically alters the size, shape, and density of the deposited debris (Fig. 1(c)).

These simple observations raise fundamental questions: **What controls the rate at which the pencil wears down? How does the interplay between surface roughness, applied load, and lead hardness determine the size and distribution of graphite debris, and thus the perceived shade of the drawing?** Addressing these questions requires linking the local contact mechanics and fracture of graphite—a problem at the crossroads of physics, tribology, materials science, and art.

To tackle these questions, we will design an automatic drawing machine inspired by 3D printing technology. Following a low-tech, DIY philosophy, it will rely on Arduino control and 3D-printed components for flexible, accessible experimentation. This setup will enable controlled drawing on various rough surfaces (papers, engraved glass, corroded glass, sanded plexiglass) while monitoring the wear and trace morphology. The resulting debris and patterns will be analyzed with optical and atomic force microscope. In parallel, we aim to develop a theoretical wear model linking microscopic fracture mechanics to macroscopic wear, inspired by the most recent wear theories (Persson et al., J. Chem. Phys. **162**, 074704 (2025)).

Candidate profile: Student (bachelor or master) in physics, mechanics or engineering. The project can take several directions depending on the candidate's interests—from experimentally-focused approaches to theoretical modeling or even art–science exploration. No specific prerequisites beside curiosity.
Funding for the internship: YES
Date: Starting from February 2026.
Collaborations: Lucie Domino and Aubin Archambault (IUSTI, Marseille) for the experimental side and Lucas Frérot (SU, Paris) for the theory.