QuantumContact: A Python- and AI-Based Pipeline for Micro-Activity Analysis in a Double-Slit Experiment

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# Abstract

This paper presents QuantumContact, a Python- and AI-based pipeline designed to detect and quantify micro-fluctuations in light intensity recorded by multiple photodiode sensors in a double-slit experiment under different cognitive states of a human observer. A continuous laser, a double-slit grid and three sensors (S1–S3) generate high-resolution interference data, while a digital channel (S4) encodes two conditions: focused observation (ON) and relaxed, off-task viewing (OFF). CSV recordings are segmented into ON→OFF pairs following the QC-MicroFirst v1.4 protocol, and for each pair and sensor we compute micro-activity features such as mean, standard deviation, coefficient of variation and z-score–based spike counts. These features feed classical statistics and machine-learning models (Random Forests, SVMs and clustering) that test whether the observer state can be predicted from micro-activity patterns. The pipeline automatically produces plots, verdict tables and reproducible reports, providing a reusable computational framework for AI-assisted analysis of double-slit and related optical experiments.

**Keywords:** Double-slit experiment, Micro-activity analysis, Machine learning, Python pipeline, Photodiode sensors

# 1. Introduction

Double-slit experiments provide a canonical testbed for studying the interplay between interference, noise and measurement in optical systems. Beyond their foundational role in quantum theory, they generate rich data streams suitable for computational analysis, signal processing and the application of modern AI techniques. High-resolution intensity measurements acquired from photodiode sensors across the interference pattern enable the study of subtle micro-fluctuations that would be difficult to detect by visual inspection alone.  
  
In parallel, advances in Python-based scientific computing and open-source machine-learning libraries make it feasible for independent researchers to build complete analysis pipelines—from raw CSV files to statistical summaries and trained models—using reproducible, shareable code. However, publicly documented frameworks that combine double-slit experiments with systematic micro-activity analysis and AI methods remain scarce.  
  
This work introduces QuantumContact, a Python and AI pipeline designed to: (i) acquire and pre-process multi-sensor intensity data in a double-slit setup; (ii) extract micro-activity features at the level of ON→OFF intervals defined by an observer state channel; and (iii) apply supervised and unsupervised learning to explore whether micro-activity patterns encode information about the observer’s cognitive condition. The emphasis is methodological: the goal is to offer a reusable framework and protocol, QC-MicroFirst v1.4, that other groups can adapt to their own optical experiments.  
  
The remainder of this paper is organised as follows. Section 2 briefly reviews related work on computational analysis of double-slit data and observer-dependent effects. Section 3 describes the experimental setup, data acquisition, feature extraction and AI models. Section 4 sketches example results obtained with a pilot dataset. Section 5 discusses implications and limitations, and Section 6 concludes with directions for future work.

# 2. Related Work

Double-slit and multi-slit experiments have long been used to probe interference phenomena, decoherence and the limits of classical versus quantum descriptions. Many studies focus on theoretical modelling or on aggregate intensity distributions, while fewer works publish detailed pipelines for analysing micro-scale fluctuations in sensor readings over time.  
  
On the computational side, Python, NumPy, pandas and scikit-learn have become standard tools for signal processing and machine learning, enabling reproducible workflows for time-series analysis, anomaly detection and classification. In parallel, there is a growing body of literature exploring the potential influence of measurement context or observer-related variables on experimental outcomes, though such claims are often controversial and require careful methodological scrutiny.  
  
QuantumContact situates itself at the intersection of these lines of work. It does not claim definitive evidence for non-classical ‘observer effects’; instead, it provides an open, AI-ready framework for testing such hypotheses in a transparent and statistically grounded way, inviting independent replication and critique.

# 3. Methods

## 3.1 Experimental Setup

The QuantumContact apparatus is built around a classical double-slit configuration. A continuous-wave laser source illuminates a double-slit grid, producing an interference pattern on a screen where three photodiode sensors (S1, S2, S3) are positioned at fixed locations.  
  
S1 is placed in a region dominated by the particle-like (single-slit–like) component of the pattern and serves as a reference channel. S2 is positioned in a region of high interference sensitivity, offset from the central maximum to enhance responsiveness to small fluctuations. S3 is located near the central interference region and captures a comparatively stable intensity baseline.  
  
A fourth digital channel, S4, encodes the cognitive state of the human observer during each measurement interval. The experiment alternates between two conditions: S4 = 1 (ON) – the observer actively focuses attention on the interference region; and S4 = 0 (OFF) – the observer intentionally relaxes and looks away from the setup. Each measurement unit is defined as an ON→OFF pair (S4: 1→0), hereafter referred to as a pair interval.

## 3.2 Data Acquisition and QC-MicroFirst v1.4 Protocol

Intensity values from S1, S2 and S3, together with the S4 channel, are recorded and stored as comma-separated values (CSV) files. The acquisition system samples each sensor at a fixed rate, and each CSV file corresponds to a single experimental session comprising multiple ON→OFF pairs.  
  
All analyses follow the QC-MicroFirst v1.4 protocol, which specifies: segmentation of the continuous time series into pair intervals based on S4 transitions 1→0; a minimum number of samples per phase (ON and OFF) to include a pair in the analysis; quality checks to discard incomplete or corrupted intervals; and a priority focus on micro-activity metrics rather than only macro-level averages. The pipeline is implemented in Python and automatically logs processing steps, together with date- and time-stamped output folders for each session.

## 3.3 Preprocessing and Interval Segmentation

Raw CSV files are processed using pandas and NumPy. For each session, the S4 channel is inspected to detect transitions from 1 to 0, which delimit ON and OFF phases. For each 1→0 transition, samples with S4 = 1 define the ON phase, and subsequent samples with S4 = 0 define the OFF phase, subject to the minimum-length criterion. For each pair interval and each sensor (S1, S2, S3), data segments for ON and OFF phases are extracted. Intervals failing quality criteria (e.g., insufficient samples, missing values) are excluded. The outcome is a structured table where each row corresponds to a (pair\_id, sensor) combination with associated ON and OFF segments.

## 3.4 Feature Extraction and Micro-Activity Metrics

For every (pair\_id, sensor) entry, the following features are computed for both phases: mean intensity, standard deviation, coefficient of variation (CV) and spike count (number of samples whose z-score exceeds a fixed threshold). From these, several micro-activity differentials are derived, such as ΔCV, Δμ, Δσ and Δspikes. An operational label micro-alteration vs. micro-stability can be defined using a user-defined threshold on |ΔCV|, within the QC-MicroFirst protocol. These features serve as input for both statistical analysis and AI models.

## 3.5 AI Models and Learning Tasks

To explore whether micro-activity patterns encode information about the observer state, two main AI tasks are defined. In the first task, the S4 state is treated as ground truth and classifiers such as Random Forests and Support Vector Machines are trained to predict ON vs. OFF from sensor features. Data are split into training and test sets using stratified partitioning, and performance is evaluated via accuracy, precision, recall, F1-score and ROC-AUC.  
  
In the second supervised task, the operational definition of micro-alteration is used as the label, indicating micro-stability or micro-alteration. The same feature vectors are used as input, allowing us to quantify how often micro-alterations occur under S4 = 1 versus S4 = 0 and which features dominate the decision boundary.  
  
Additionally, unsupervised clustering methods such as k-means and DBSCAN are applied to the feature space to discover latent micro-activity regimes. For each cluster, the distribution of S4 states is examined to assess whether certain clusters are enriched in ON or OFF intervals.

## 3.6 Statistical Analysis and Visualisation

Classical statistical summaries are computed for each sensor and condition: distributions of ΔCV, Δμ and Δσ; the percentage of intervals labelled as micro-alteration vs. micro-stability; and per-session as well as aggregate statistics. The pipeline generates visual panels such as bar plots of ΔCV per pair and sensor, histograms and boxplots comparing S4 = 1 and S4 = 0, and colour-coded verdict tables summarising whether pre-registered hypotheses are supported, partially supported or not supported. All figures and tables are exported to a PDF report together with the underlying CSV metrics.

## 3.7 Implementation and Reproducibility

The pipeline is implemented in Python, using pandas, NumPy, scikit-learn and matplotlib. Each run creates a dedicated output directory containing processed metrics, trained model artefacts (when applicable), plots, summary tables and the final PDF report. The code and example datasets are structured so that other researchers can reproduce the analyses or adapt the framework to different sensor placements and experimental protocols.

# 4. Results (Pipeline Demonstration)

In its current stage, QuantumContact is applied to pilot datasets consisting of multiple experimental sessions with several ON→OFF pairs each. For every session, the pipeline successfully segments intervals, computes micro-activity metrics and generates the corresponding visual panels and verdict tables. Supervised models trained to predict S4 from sensor features provide an estimate of how much information about the observer state is present in the micro-activity patterns. Unsupervised clustering reveals whether distinct micro-activity regimes emerge naturally and how they relate to sensors and conditions. The exact numerical results depend on the final dataset and protocol parameters and are therefore reported in detail in the full version of the paper.

# 5. Discussion

The QuantumContact framework demonstrates that a complete, AI-ready pipeline for double-slit micro-activity analysis can be implemented using only open-source Python tools. By formalising the QC-MicroFirst v1.4 protocol and publishing both code and data structures, the approach aims to shift discussions about observer-dependent effects from anecdotal claims to reproducible, quantitative analyses.  
  
At the same time, the framework highlights important limitations: small sample sizes, sensitivity to hardware noise, and the possibility that observed patterns may be fully explainable by classical sources of variability. QuantumContact is therefore best viewed as a methodological platform for hypothesis testing, not as proof of any specific non-classical effect.

# 6. Conclusion

This paper has presented QuantumContact, a Python- and AI-based pipeline for analysing micro-activity in double-slit experiments under different observer states. The framework covers the full path from raw sensor data to micro-activity metrics, machine-learning models and automated reports, and is intended to be reusable and extensible. Future work will expand the dataset, refine hardware configuration, incorporate EEG-based features and release the full toolkit and documentation to the research community.

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# Authors Short Biography



Juan Sebastián Baena Cock is an independent multidisciplinary researcher and experimentalist, leading the QuantumContact 👉 JSBC Labs research team. His work focuses on quantum physics, cognitive neuroscience and information verification technologies.  
  
His current research explores the potential detection of non-conventional interactions through quantum interference patterns, building on the classic double-slit experiment. In parallel, he develops practical tools for combating misinformation, including AI-based verification applications.  
  
Across these projects, he aims to bridge advanced scientific concepts with accessible and replicable methodologies, maintaining a rigorous yet exploratory approach. He is also passionate about science communication and interdisciplinary thinking, often producing content that connects scientific findings with broader societal insights.  
  
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