Temporally Sampled Gaussian Bridges for Visualizing Financial Time Series Uncertainty

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***Abstract*—We propose to visualize uncertainty in certain financial time-series by generating ensemble predictions in-browser for web users and by sequentially displaying these predictions in time. In particular, the ensemble predictions to be generated by end-user hardware may be drawn from the same distribution that would typically be used by financial firms for quantitative analysis, risk analysis, or derivative products, such as the pricing of options contracts.**

1. Motivation

Monte Carle methods, which involve repeatedly sampling from a modelled probability distribution to represent possible outcomes of an uncertain system, are used in a wide variety of applications. In particular, such methods are frequently used to assess risk and therefore underpin much of the modern financial world. Despite this fact, such "ensemble" methods of quantifying uncertainty are often poorly represented to the end-users of financial products, with consequences for communicating systemic risk [1], [2].

1.1. Related Work

While some visualizations expose the ensemble nature of predictions, a perennial challenge is the sheer volume of data available that must be filtered to provide meaningful representations to the user; a partial solution is to allow a knowledgeable user to interactively explore a static dataset of ensemble predictions [3].

Unfortunately, effective communication of uncertainty in quantitative finance must often be simple enough to widely disseminate (*e.g.*, by a central bank to the general public), yet prevailing standards for representing such risk are nacient [1]. Existing solutions, such as generalizations of boxplots to ensembles [4] or "heatmap" methods [5], [6] may readily communicate specific moments or features of a distribution, but obscure the underlying ensemble data and information about temporospacial correlations.

A latent assumption of existing representations of ensemble data is that the process by which such samples are generated is computationally expensive, and prior work in representing ensemble data has frequently been framed as domain-agnostic. Given advances in computing hardware and the ability to rapidly sample from many of the distributions used to model uncertainty in, *e.g.*, interest rates or stock prices [7], [8], [9], we recognize that visualizations need not rely soley on precomputed ensembles, but that sample forecasts or imputations may be generated on-the-fly by end-users, *e.g.*, in a web browser, and sequentially displayed in time.

2. Proposed Research

We seek to directly represent the underlying model of uncertainty in financial time series data by animating imputed regions, repeatedly updating uncertain data points by drawing them from the underlying numerical ensembles typically used to approximate statistical measures of risk. This method is readily combined with more traditional static representations of uncertainty or with other methods such as "heatmap" or "plume" representations [5], [6], [3].

The expected difficulty of this work is constrained to implementation details, since many of the major challenges have been worked out by existing research or software. To breifly detail the proposed pipeline, we provide pseudocode in Algorithm 1.

Algorithm 1 Pseudocode for proposal

```
// {unix timestamp: value }
load('time_series.csv');

parameters = fit(time_series);

function generate_sample() {
    x = random();
    y = model_predict(x, parameters);
    display.draw(y, fade=True);
}

// on each screen re-paint
requestAnimationFrame(generate_sample);
```

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