# ISyE8900 Project Proposal

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## Introduction

In this project, we implement a nonparametric approach for modeling curves in the FICC market using various manifold learning methods. The main focus will be the following three original curves and two spread curves derived from the former: US Treasury Zero (Forward) Rate Curve, 3-month US LIBOR Zero (Forward) Rate Curve, 3-month SOFR Zero (Forward) Rate Curve; Swap Spread (LIBOR - Treasury), Basis Spread (LIBOR - SOFR). If time permits, will explore more interesting term structures in the FX markets.

## Literature Review

While term structure modeling has been well developed in past decades in the Treasury markets, advances in modeling the swap term structure or the spread term structure are comparatively small. Besides, for the purposes of managing risk or hedging derivatives, it is very common to see structural changes in local term structure areas, we would like to explore more advanced statistical approaches in the time series forecasting step to produce an adaptive term structure forecasting framework. Diebold and Li (2006) use the AR family models to obtain encouraging results for long-horizon ex-ante forecasts by reformulating the Nelson and Siegel (1987) model. Duffee (2002) argues the random walk model is superior to the previous affine term structure models. Apart from these general parametric models, economists have also tried add some exogenous macroeconomic variables (e.g. real activity, inflation, and fed funds rate) to improve the predicting power, such as Ang and Piazzesi (2003) and Diebold, Rudebusch and Aruoba (2006). Though a large part of term structure model specification has been deployed, a uniform conclusion with regard to the factor selection has not been achieved yet.

As the booming of model machine learning techniques, some elementary dimension reduction techniques like PCA have been applied in the fixed income market, such as Steeley (1990) and Litterman and Scheinkman (1991). Practitioners usually interpret the principle components as level, slope, and curvature effects. To link the factors with more understandable economic instances in the financial markets, Duffie and Singleton (1997) propose a multi-factor model for IRS that accommodates counterparty default risk and liquidity differences between the Treasury and Swap markets. By extending this work, Liu, Longstaff and Mandell (2006) estimate a five factor model to analyze swap spreads.

To the best of our current knowledge, there is no work that aimed to forecast the spread term structure using non-linear dimension reduction (manifold learning). We believe the heterogeneity of temporal evolution will be better captured by manifold learning compared with the PCA method. For the time series forecasting, we would like to extend the AR family model into two directions: (1) find a GARCH family model (e.g. E-GARCH) which could yield a feasible if not optimal model specification to capture the volatility pattern of the low dimensional representations; (2) find a state space model (e.g. Kalman filter) which could produce as much adaptability as possible.

## Problem formulation and Application

Fetching or build curves:

From the FEDNY website, we get the functional parameters of the Nelson-Siegel-Svensson structural models for Treasury instantaneous forward rates. Then, by simple bond math, we could construct the zero rate curves for any maturities by plugging the maturity index into the zero rate expression.

The data format should be daily data with continuous maturity spectrum from 1m to 30y (360 dimensions). To make it consistent with the following two swap curves, we re-sample it to get a weekly dataset with discrete maturity spectrum from 3m to 30y (120 dimensions).

For the LIBOR and SOFR curves, we directly download them from Bloomberg terminal by manually changing “As of Date” variable. If time permits, we will replicate the whole curve bootstrapping pipeline to get these curves using market instruments prices (deposits, futures/forwards, swaps).

Dimension deduction:

Start from baseline classical methods (PCA), then move to advanced methods according to the survey presentation published by Dr. Huo in 2004: semi-classical methods (MDS), manifold searching methods (LLE).

Time series forecasting for each univariate low dimensional coordinate:

Start from AR family models, then move to GARCH family models, finally add Kalman filter or more general state space models to refine and finalize the adapative forecasting engine.

Performance evaluation:

According to the work by Oliver Blaskowitz, we define a statistical measure and an economic measure to evaluate the forecasting performance. For the statistical measure, we focus on the changes of particular swap rates or linear combination of swap rates. The henrikkson-merton (hm) statistics is the conditional probability of correctly forecasting a positive or negative value of first-order difference given a positive or negative realization at the future. A successfully forecasting scheme should deliver hm-statistics in excess of unity. For the economic measure, we backtest three curve trading strategies based on the model forecasting. The level trading signal will be 0.33*2yr + 0.33*5yt + 0.33*10yr, the slope trading signal will be -0.5*2yr + 0.5*10yr, the curvature trading signal will be 0.25*2yr – 0.5*5yt + 0.25*10yr. By holding the corresponding swap portfolio for one-period suggested by the trading signal, we will get three cumulative PnL plot for each given model specification.

**Results**

**Discussion**

**References**

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