Spectral Technologies' Fast Disaggregaton In Time Technology For Quants

Nathaniel Rogalskyj

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1 Introduction

Time is a critical dimension in finance. Time value of money is one of the core principles and is the basis for the discounted cash flow in equities markets. Time value of money is also the basis of carrying cost in commodities markets.

Likewise, the high speed nature of financial markets requires one to be able react in real-time. Reaction in real time requires having benchmarks that are in continuous time. An individual cannot react in real time if the benchmarks one is using are at a monthly, quarterly or yearly frequency. However, much of the data that drives these markets come in aggregated form and at a lower frequency than that of the high frequency nature of the financial markets. Lower frequency data with its potential greater time for collection can often have higher quality. Furthermore, when modeling markets, it is often good to have a small, finite set of numbers that explain the market, even though these numbers may very well be aggregations or averages of more complicated continuous processes.

Due to the criticality of the time dimension of the financial market, an investment process will have two desirable properties: (a) use high quality lower frequency data or a simple set of lower frequency data in the investment process, (b) be able to relate this lower frequency data to a higher frequency time scale at which the financial markets trade. These two properties argue for the development of processes that allow for transform of lower frequency data to higher frequency, accurate data.

Spectral Technologies has developed this transform. The transform that has been developed is called Fast Disaggregation in Time Technology (FDTT). FDTT is derived using variational principles and energy minimization techniques. FDTT has been applied to improve the Discounted Cash Flow, a core formula in equities markets. Such improved Discounted Cash Flow has been endorsed by Christopher Jones, Oxford PhD, Jump Trading Researcher. Furthermore, FDTT has also been applied to EIA Natural Gas Market Data, and is in usage at major, global hedge fund for their commodities division. The techniques have drawn interest from researchers and exists in code bases at Capital One, NextEra Energy and DC Energy.

1.1 Executive Summary

The development of Fast Disaggregation in Time Technology (FDTT) is a key innovation that can be used in many trading/financial applications. Indeed it has attracted the interest of many industrial researchers and academic researchers.

1.2 Mathematical Setup

There is a time dimension $t \in [0, T]$. There are M functions that will be estimated. Notation is provided by, f_1, f_2, ..., f_M. There are then N integral constraints that are known ahead of time. Each constraint i, $1 \leq i \leq N$ has a known set of functions S_i that participate in it, where $j \in S_i$, then $1 \leq j \leq M$, over a known time period $t_{i,s} \leq t \leq t_{i,e}$, where $t_{i,s}$ is the start time of the interval and $t_{i,e}$ is the end time of the interval. The integral constraint is expressed as:

$$\int_{t_{i,s}}^{t_{i,e}} \sum_{k \in S_i} f_k(t) dt = C_i$$

1.3 Problem

Given M, N, S_i, and C_i where $1 \leq i \leq N$, estimate f_j, $1 \leq j \leq M$ for $[0, T]$

1.3.1 Problem Solution

There are many possible f_j that satisfy the above integral constraints. There are many ways of estimating the f_j. A goal can be to choose an optimal set of functions. Such a goal motivates finding a functional to optimize. In many areas of physics, the key functional to minimize is the energy functional. The chosen functional that is picked for Fast Disaggregation in Time Technology (FDTT) is the kinetic energy functional.

The functional can be described as:

$$L(t, f_1, ...f_M, f_1', ...f_M') = \sum_{j=1}^{M} f_j'^2 + \sum_{i=1}^{N} (\lambda_i (\sum_{s \in S_i} f_s - C_i) 1_{x_{s,i} \leq x \leq x_{e,i}})$$

This can be solved using the Euler-Lagrange equations.

1.4 Physical Interpretation

A mathematical setup states something mathematically; it has no physical meaning, unless what is specified mathematically can be mapped into a physical problem. The FDTT mathematical setup can be mapped into a physical problem setup and hence the mathematical solution can then be interpreted as the solution to the dual physical problem. The physical interpretation is that of a set of particles taking a minimal energy path where the average position of the particles is constrained.

1.5 Comparison To Other Optimization Methods

Fast Disaggregation in Time Technology uses the approach of first optimizing and then discretizing versus the alternative approach of discretizing and optimizing. The alternative approach requires significantly more computation. Linear Programming uses significant computation, because it will discretize and then optimize, with the simplex method. Linear programming uses a series of linear solves, where FDTT uses only one linear solve that expresses the conditions for optimality. FDTT is much faster than linear programming. It has the flavor of solving the KKT conditions.

1.6 Computational Complexity

In this section, I will look to benchmark/compare the running time of linear optimization, interior point methods and Fast Disaggregation in Time Technology. Our technology is much faster than other optimization technology, since we directly solve the equations of optimality.

1.7 Algorithm Development

There are two major phases to the algorithm. First, calculate the matrix A that is setup in the solution. Second, find the $A = LU$ decomposition of the matrix which has a running time $O(N^3)$. And third, given a set of constraints C_i that form $C \in R^N$, I look to calculate the $LU = C$, which is further calculated as $\lambda = U^{-1}L^{-1}C$; this is can be calculated with forward-substitution which is $O(N^2)$.

1.8 Visualizations

In the following diagrams, I examine the uniform disaggregation, FDTT Disaggregation, and then the cumulative difference between the Uniform Disaggregation and the FDTT Disaggregation.

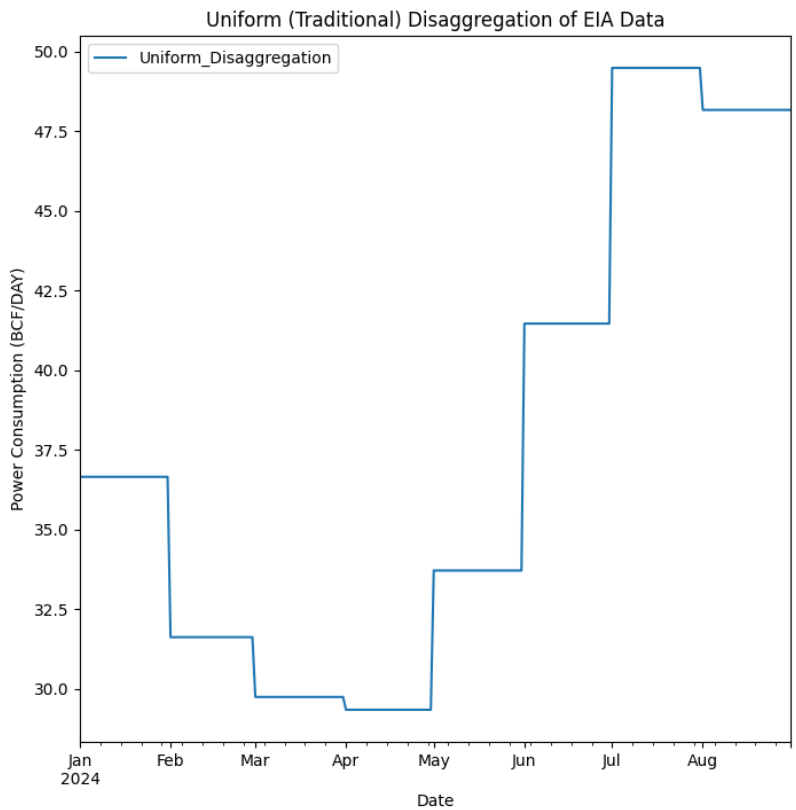

Figure 1: The traditional uniform disaggregation employed by a number of hedge funds applied to EIA US Aggregate Electric Power Consumption of Natural Gas

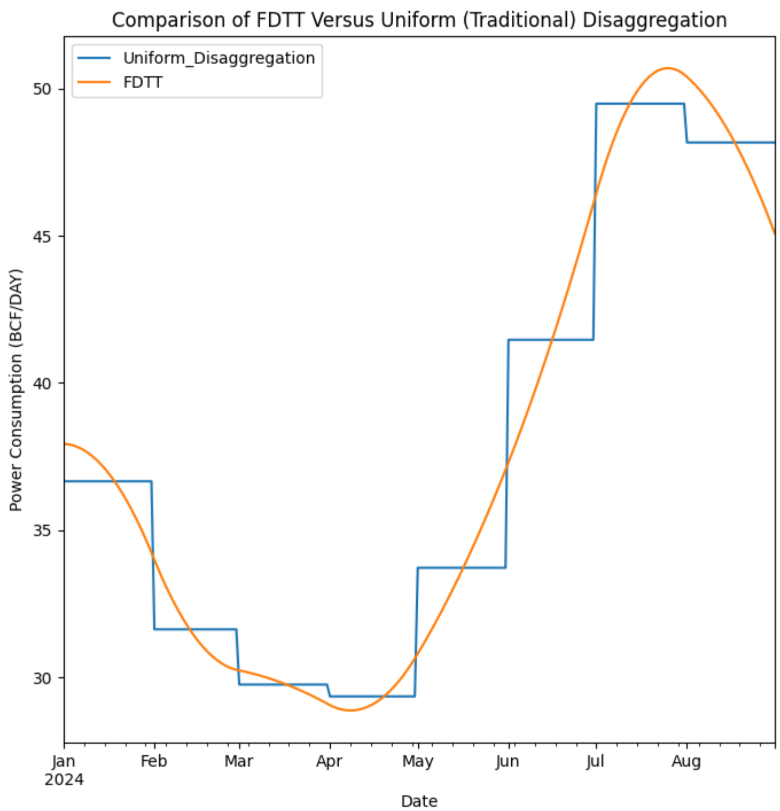

Figure 2: The traditional uniform disaggregation employed by a number of hedge funds applied to EIA US Aggregate Electric Power Consumption of Natural Gas compared to the FDTT Disaggregation of EIA US Aggregate Electric Power Consumption of Natural Gas.

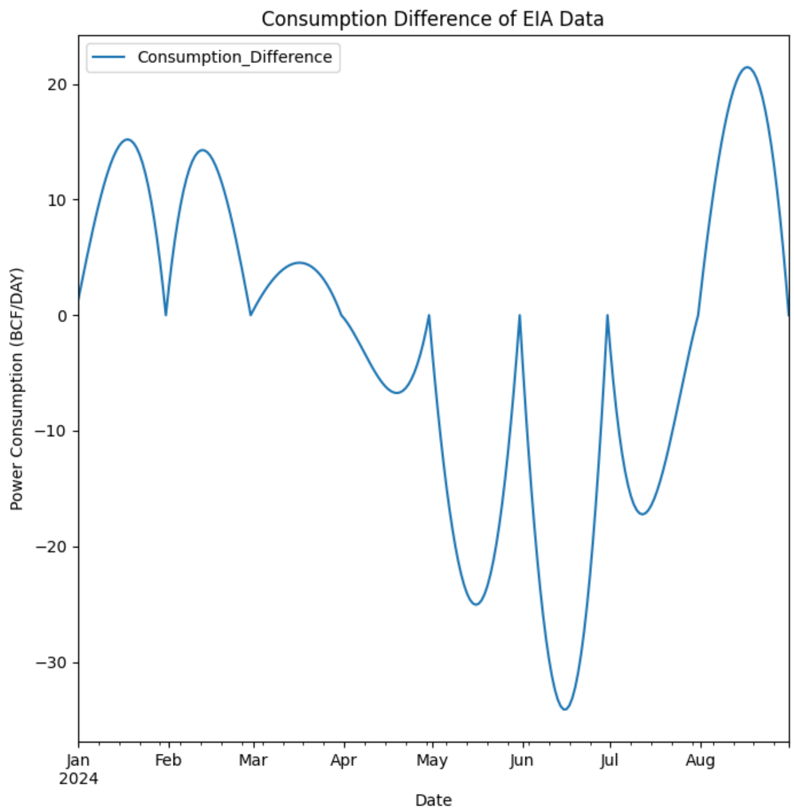

Figure 3: The cumulative sum of the difference between the FDTT Disaggregation and the Uniform Disaggregation. Positive values indicates that FDTT (and hence reality) has estimated higher consumption than the uniform disaggregation. Negative Values indicates that Uniform Disaggregation has estimated less consumption than FDTT Disaggregation.