

Chapter 12

DSP Acceleration for Dynamic Financial Models

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ABSTRACT

We present an extensive dynamic financial model that encompasses most models used today in finance and economics. We show that this model is a good match to the capabilities of DSP chips. Particularly, DSP is able to perform the high-speed Monte Carlo simulations that are required to solve many large-scale, intractable financial problems. By simulating a sufficiently large number of future scenarios, DSP chips can rapidly achieve a good approximation of the probable future joint probability distribution function of modeled variables. This probability distribution can be used for the valuation of financial derivatives, computing value at risk, studying macroeconomic policy decisions, and many other purposes. DSP enables such simulations to be faster, cooler, greener, and cheaper than ever before.

WHY DSP?

Digital Signal Processor Chips

The needs of finance and banking closely match the capabilities of DSP chips. Finance has been the bleeding edge all the way back to the beginnings of computers and mathematics. Financial assets are valuable so prices have been carefully recorded and studied throughout history. For centuries financial and economic databases were among the largest available for scientific study. Financial derivatives at large banks were US\$1140 trillion in 2007 with a correspondingly large daily

trading volume. Large percentages of the graduates of top universities take jobs in finance. Prior to the Internet most computer industry sales were for business and banking applications. The “B” in “IBM” stands for business. IBM introduced the industry standard 80-column punch card in 1928. Transactions, encrypted telecommunications, and the secure movement of funds have long been important uses of computers in finance.

Besides the mechanics of financial transactions, financial computing involves considerable “analytics” that we show below boils down to signal processing. Large databases of asset prices are studied by traders and analysts to find “signals” or “patterns” that might indicate when it is time to buy or sell a security, i.e. “buy low, sell high.”

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Large databases might be traversed many times during the testing of alternative models. Then the valuation of derivative assets requires numerically intense valuation methods such as Monte Carlo analysis, low discrepancy sequences, finite difference solutions of differential equations, finite element methods, and so on. The difficulty of typical computations is indicated by the fact that government regulators took months to complete those computations even though the results were needed as soon as possible to help stop the 2008 meltdown of the financial system (Bernanke, 2009). Ideally such calculations should be performed in real time by the bankers themselves. In 2009 42% of trading in 2009 occurred within milliseconds (Business Week, Dec. 2009). Whole conferences address further speedups (Wall Street & Technology, 2010). Firms fight to get the shortest fiber optic cables to the exchange. Shaving eight inches of fiber yields a one-nanosecond lead. Before buying or selling any asset bankers should know whether that trade would increase or decrease risk. Banks are still exposed to major risks due to inadequate computational power. DSP chips are a semiconductor technology that has the potential to achieve the needed speedup.

DSP Meets the Needs of Financial Models

The general umbrella financial model FGH presented below is a good match with DSP capabilities. Numerous DSP chip capabilities greatly help solving this time series model:

- DSP chips are designed for fast parallel multiply accumulate commands (MACs) that are needed for the extensive matrix multiplications in the FGH umbrella model presented below. The simplest example is the dot product $b \bullet x = b^T x = \sum b_i x_i$ where the sum is over N, the length of the

coefficient vector b and the lagged time series vector x_t .

- Hardware modulo addressing enables the circular buffers needed by time series models. For example, the expression $x_t = \sum_{i=1}^N b_i x_{t-i}$ is usually solved for period t then stepped up one period to solve for period $t+1$. The period $t+1$ calculation is a function of the exact same lag terms as the period t just calculated except the last term x_{t-N} is replaced by the term for x_t just calculated. It would be expensive to move all elements in vector x to new positions corresponding to lag. Instead all elements are left in place except one --- the new x_t term is plunked into the slot left by the departing x_{t-N} term. A pointer will record the changing location of the x_{t-N} term in vector x so that the location of all other terms can be located as offsets from the address of x_{t-N} . These circular buffers are hardware optimized in DSP chips to provide greater speed.
- Fixed-point arithmetic can be used as a speedup over floating-point. Most DSPs use fixed-point arithmetic because it is faster, cheaper, and simpler than floating-point. The additional range provided by floating-point is often not needed. Limited range is the case in finance and economics. Financial prices are always greater than a penny and usually less than a billion dollars --- a much smaller range than typical floating-point. But it is generally easier to implement algorithms in floating-point so financial applications often use floating-point. They would run faster if a little more work were done to get them onto fixed-point DSP.
- Saturation arithmetic lets overflows accumulate at the maximum values the register can hold. Similarly underflows cannot

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