Capstone Project:
Predicting the Stock Market

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Agenda

1. The extreme unpredictability of stock markets
2. A short intro to Hidden Markov Model
3. Part 1: HMM for Daily Market Regime Prediction
4. Part 2: HMM for Daily Price Return Prediction
5. Conclusion & Recommendations
6. Limitations & Caveats

Stock markets are extremely hard to predict due to “**Reflexivity**”

“In situations that have thinking participants, there is a two-way interaction between the participants’ thinking and the situation in which they participate.”

~ George Soros, billionaire hedge fund manager who nearly bankrupted the Bank of England

★MOST SUCCESSFUL

CHIMPANZEE ON WALL STREET

Raven, a six-year-old chimpanzee, became the 22nd most successful money manager in the USA after choosing her stocks by throwing darts at a list of 133 internet companies. The chimp created her own index, dubbed MonkeyDex, and in 1999 delivered a 213% gain – outperforming more than 6,000 professional brokers on Wall Street. "She quadrupled the performance of the Dow and doubled the performance of the Nasdaq composite," said Roland Perry, editor of the *Internet Stock Review*.


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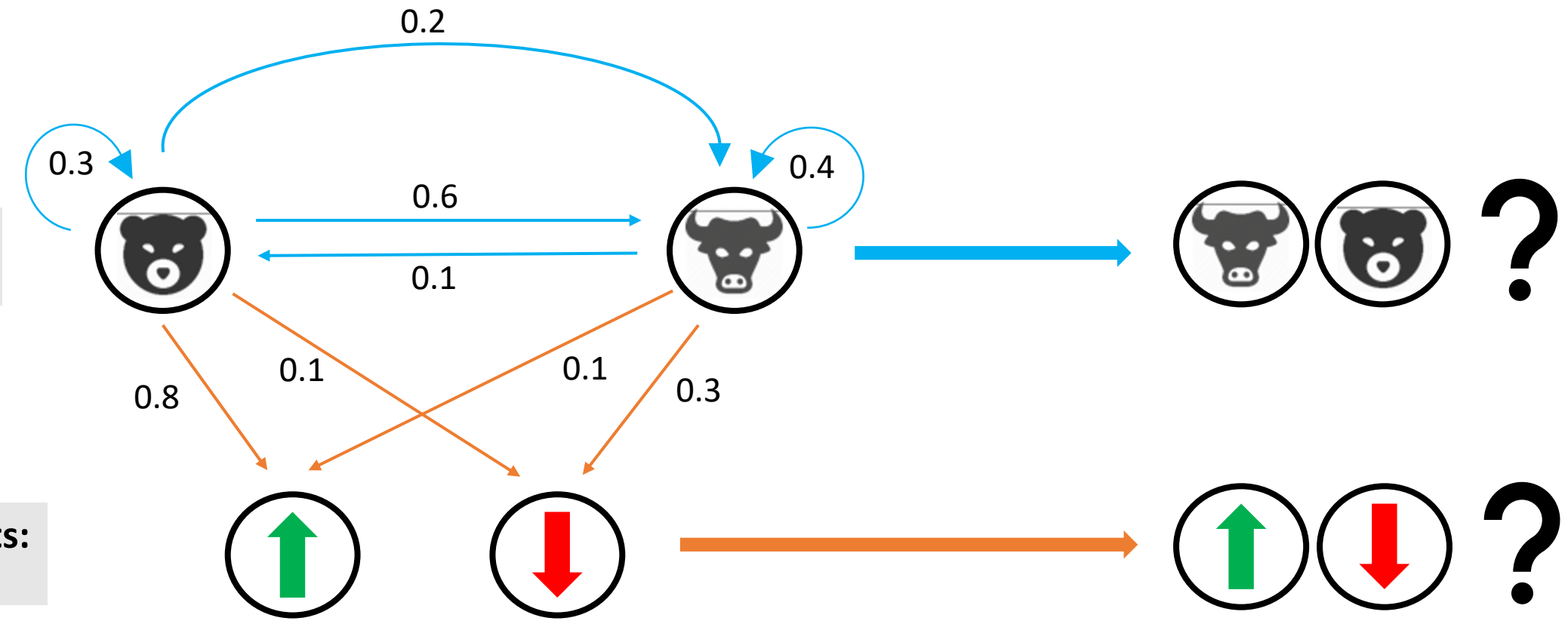
. . . 45 3/4. . . . 35 3/4 @ 6. . . . . 97 1/8. . . 100 3/4. . . . 64 1/8. . . . . 76. . . 4S. 14. 9
“It’s a bull market.”
Mr Partridge, from The Reminiscence of the Stock Operator

But what defines a Bull or Bear market?

Hidden Markov Model

Hidden States:
2-state Market Regimes

Observable Inputs:
Price Changes



Emission Probabilities

Transition Probabilities

Part 1

Hidden Markov for Market Regime Prediction

Research Methodology

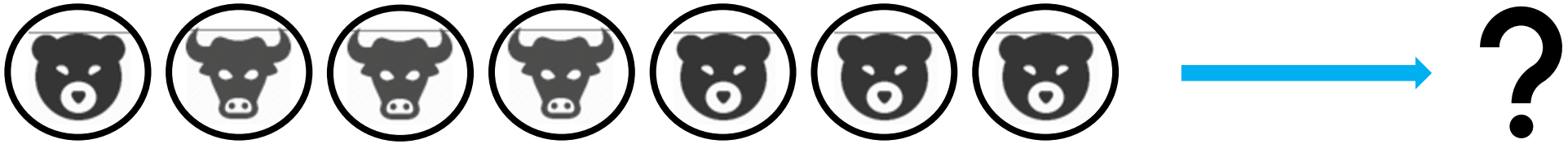
Asset	SPY ETF (underlying index: S&P500 Index)
Model Training Period	Since inception 1993-2009
Model Testing Period	2010-2023/1
Backtest Period	2018-2023/1
Model Evaluation Metric	Cumulative %Returns during Backtest Period

Backtesting Strategy:

- Daily trading strategy
- Long SPY when last regime=BULL; Short SPY when last regime=BEAR

Converting Price Observations into Technical Indicators

Hidden States:
Market Regimes



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Observable Inputs:
Technical Indicators

T1M Returns

T3M Returns

Mass Index

ADX^

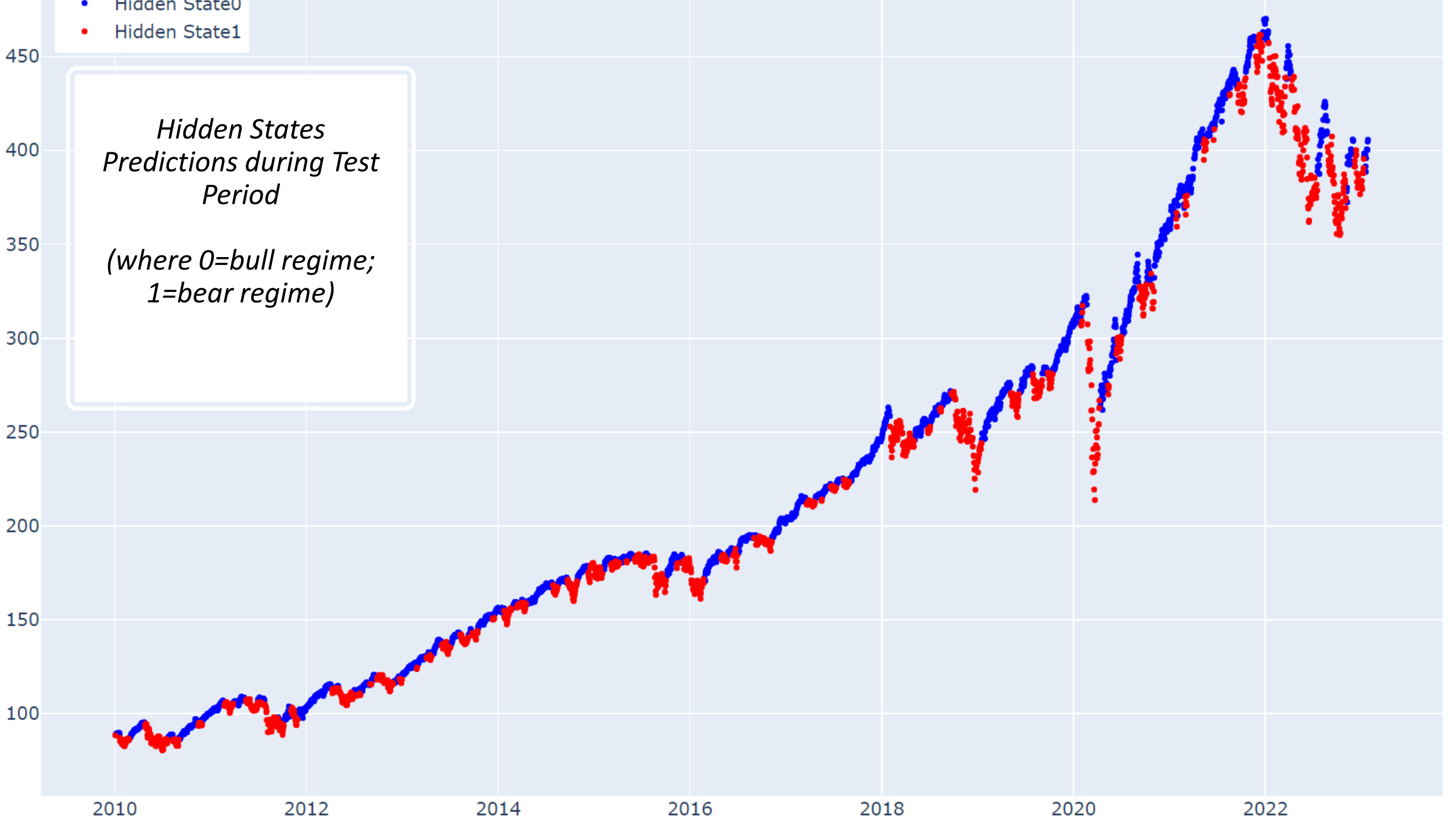
RSI*

Donchian Channel

Observable Output:
Prices

CLOSE

^ Average Directional Index
** Relative Strength Index*


Hidden State0
Hidden State1
Hidden States Predictions during Test Period
(where 0=bull regime; 1=bear regime)
450
400
350
300
250
200
150
100
2010
2012
2014
2016
2018
2020
2022

Strategy Backtest during 2018-2023/1

Start date	2018-01-02
End date	2023-01-27
Total months	60

	Backtest
Annual return	5.5%
Cumulative returns	31.1%
Annual volatility	19.1%
Sharpe ratio	0.38
Calmar ratio	0.19
Stability	0.36
Max drawdown	-28.6%
Omega ratio	1.07
Sortino ratio	0.55
Skew	NaN
Kurtosis	NaN
Tail ratio	1.02
Daily value at risk	-2.4%
Alpha	0.13
Beta	-0.39

Part 2

Hidden Markov for Daily Price Returns Prediction

Research Methodology

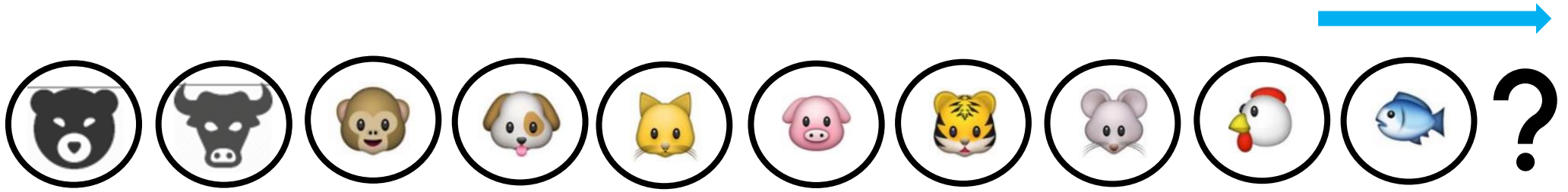
Asset	SPY ETF (underlying index: S&P500 Index)
Model Training Period	Since inception 1993-2009
Sampling Period for “Possible_Outcomes”	2010-2017
Model Testing Period	2018-2023/1
Backtest Period	2018-2023/1
Model Evaluation Metric	Cumulative %Returns during Backtest Period

Backtesting Strategy:

- Day trading strategy (to trade on the OPEN)
- If Predicted Close > Actual Open: Buy SPY at OPEN price and Sell at CLOSE
- If Predicted Close < Actual Open: Sell SPY at OPEN price and Buy at CLOSE

Using Augmented Price Features

Hidden States:
10 states



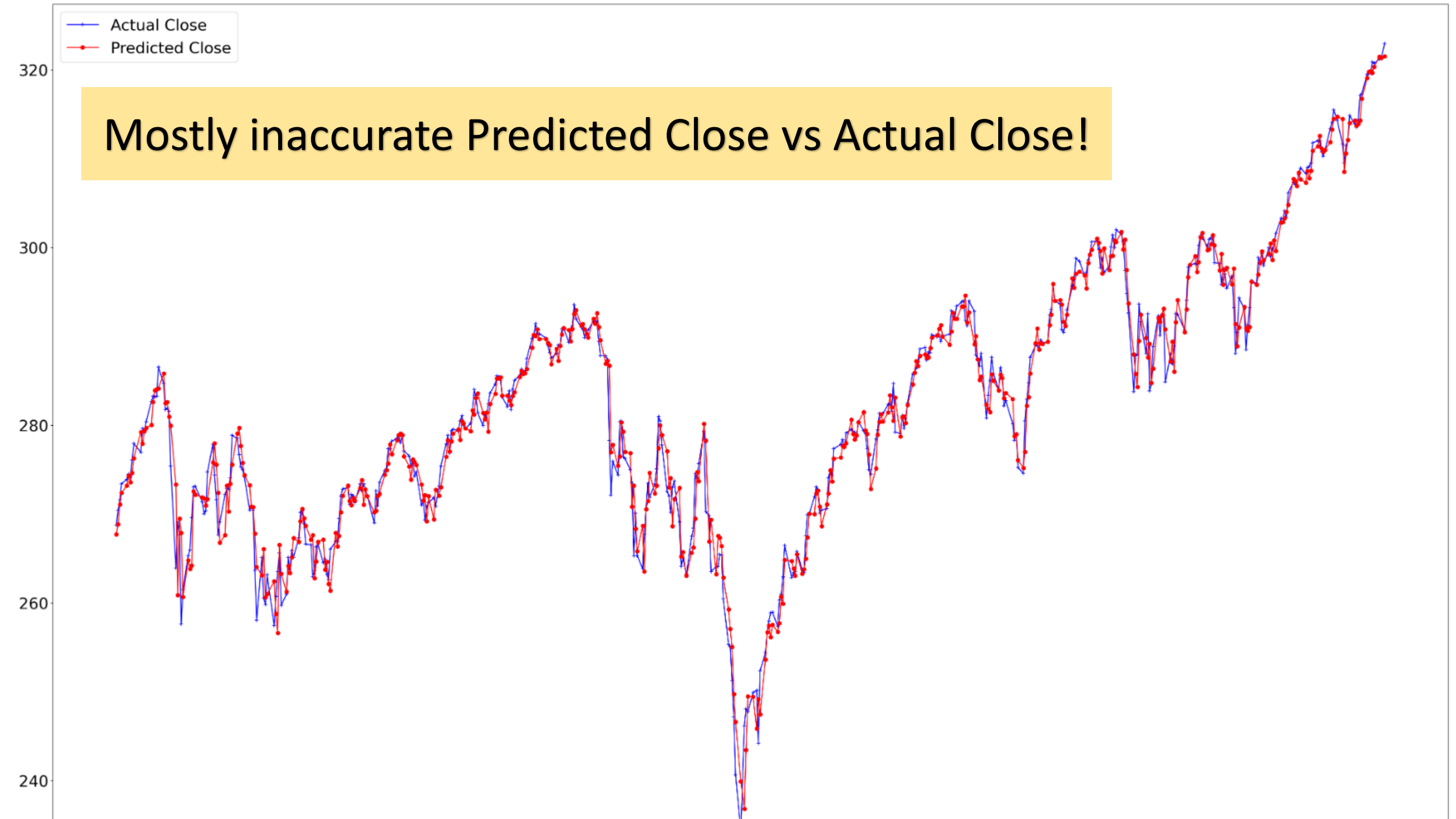
Observable Inputs:
Augmented Price Features

fracohp frachp fraclp

fracohp = (Close-Open)/Open
frachp = (High-Open)/Open
fraclp=(Open-Low)/Open

Observable Output:
Prices

OPEN HIGH LOW CLOSE


Actual Close
Predicted Close
320
300
280
260
240
Mostly inaccurate Predicted Close vs Actual Close!

Strategy Backtest during 2018-2023/1

Start date	2018-01-03
End date	2023-01-27
Total months	60

	Backtest
Annual return	0.8%
Cumulative returns	3.9%
Annual volatility	15.5%
Sharpe ratio	0.13
Calmar ratio	0.02
Stability	0.26
Max drawdown	-32.0%
Omega ratio	1.02
Sortino ratio	0.17
Skew	-0.27
Kurtosis	3.54
Tail ratio	0.95
Daily value at risk	-1.9%
Alpha	0.02
Beta	0.00

Conclusions & Recommendations

- Hidden Markov models proved to be reasonably capable of predicting current market regimes but underperformed considerably when trying to predict forward price returns.

- For the best alpha strategy, it is recommended to employ HMM models to predict current market regime just like Mr Partridge and not trade unnecessarily.

Limitations & Caveats

1. Trading Costs such as short-financing costs, trading commissions and liquidity costs have not been simulated in the backtesting.
2. Use of non-timeseries feature inputs may not be sufficient to capture underlying statistical patterns
3. Models such as the HMM-clustering of market regimes did not work as well for SPY ETF compared to other traditionally more volatile assets such as oil and gold. Even the choice of training window (static window, expanding window or walk-forward window) can result in vastly different backtesting profitability depending on the asset. **To obtain a statistically sound profitable trading strategy, one needs to not only select the right model but also the right training window and the right asset.**
4. Due to the inconsistencies of quantitative strategies, one needs to be especially clear about the characteristics of an asset that allowed the strategy to work and re-train the model if such characteristics changes in the future.