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Efficiency and Efficacy Comparison between NSGA-II and Differential Evolution in Multi-Objective Portfolio Optimization

Comparative Analysis of NSGA-II and DE in Portfolio Optimization

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Contents

- **Context of the Study**
  - Importance in improving economic decision-making for players and traders in the agricultural commodities market.
  - Multi-objective, multi-period portfolio optimization.
  - Comparison of NSGA-II and Differential Evolution (DE) algorithms to enhance decision-making.
- **Justification and Demand**
  - Need for robust optimization algorithms to manage portfolio risks and returns in dynamic markets.
  - Importance of selecting appropriate algorithms based on market dynamics for effective portfolio management.
  - Enhanced financial optimization techniques for better decision-making.
  - Application of computational finance optimization to industrial engineering, especially in production planning and control.

Multi-Objective Portfolio Optim. Algos last findings and gaps

Algorithm	Key Findings
NSGA-II (Deb et al., 2002) [1]	Superior capabilities in portfolio management, especially in its optimized forms.
Iorio and Li (2004, 2006) [2]	DE variants improve convergence speed and solution distribution compared to NSGA-II.
Babu et al. (2005) [4]	Highlighted the importance of selecting algorithms based on optimization challenge and goals.
Zhang and Sanderson (2008) [5]	Demonstrated computational efficiency and effectiveness of DE variants like JADE2 in achieving optimal solutions.
Krink and Paterlini (2011) [6]	Highlighted the effectiveness of DE in portfolio optimizations, delivering satisfying results within a reasonable runtime.
Mishra et al. (2011) [1]	Emphasized the superior capability of NSGA-II-based methods compared to other standard methods.
Eftekharian et al. (2017) [2]	Introduced 2-Phase NSGA-II, significantly outperforming the standard NSGA-II in portfolio optimization.
Zhao et al. (2018) [3]	Proposed an improved NSGA-II integrated with differential evolution to enhance diversity and convergence in Pareto solutions.
Ardia et al. (2010) [4]	Noteworthy evolution, particularly in its variants; enhances convergence speed and solution distribution.
Jevne et al. (2012) [5]	Provided insights into aligning algorithm selection with portfolio needs based on comparative analysis and efficiency.
Zheng and Zheng (2021) [6]	Demonstrated the competitiveness of a parallel NSGA-II approach in optimizing portfolios through multi-objective optimization combined with multi-attribute decision making.
Awad et al. (2022) [7]	Confirmed the effectiveness of NSGA-II in handling two-objective optimization problems.

Table: Summary of Literature Review on NSGA-II and Differential Evolution (DE) in Portfolio Optimization

Proposed Methodology

The multi-objective optimization problem in portfolio optimization builds on Markowitz's mean-variance framework, incorporating return, risk, and diversification:

$$
\begin{aligned}
\underset{x}{\text{maximize}} \quad & E[R(x)]_t = \sum_{i=1}^{n} r_i x_i \\
\text{minimize} \quad & \sigma(x)_t = \sqrt{\sum_{i=1}^{n}\sum_{j=1}^{n} x_i x_j \sigma_{ij}} \\
\text{maximize} \quad & D(x)_t = -\sum_{i=1}^{n} x_i \ln(x_i) \\
\text{subject to} \quad & \sum_{i} x_i \leq 1, \; x_i \geq 0, \; i = 1, \ldots, n.
\end{aligned}
\tag{1}
$$

Subject to constraints:

- Budget constraint: Total allocation ≤ 1
- Allocation constraints: $0 \leq x_i \leq 1$

We employ NSGA-II and DEOptim to balance return, risk, and diversification.

Time Frames for Analysis:

1. **2019-01-01 to 2020-12-31:** Pre-pandemic market dynamics
2. **2021-01-01 to 2022-12-31:** Pandemic and aftermath
3. **2023-01-01 to 2023-12-31:** Current market trends

Performance Indicators:

- **Return**: Weighted sum of individual asset returns
- **Risk**: Std. dev. of portfolio returns
- **Sharpe Ratio**: Risk-adjusted return. It represents the additional return per unit of risk taken.
- **Diversification**: Shannon entropy measure (higher entropy values indicate a more diversified portfolio)

These indicators provide a comprehensive view of portfolio performance, encompassing return, risk, and diversification.

Data and Preparation

Portfolio Composition:

Asset	Ticker
Corn Futures	ZC=F
Wheat Futures	ZO=F
KC HRW Wheat Futures	KE=F
Rough Rice Futures	ZR=F
Feeder Cattle Futures	GF=F
SoyMeal Futures	ZS=F
Soybeans Futures	ZM=F
Soybean Oil Futures	ZL=F

Data Source:

- Daily data from Yahoo! Finance API (Jeffrey and Ulrich, 2023 [7])

Study Period:

- January 1, 2019 - December 5, 2023

Return Calculation:

- Natural logarithm of prices: $\ln(p_t) = \ln(p_t) - \ln(p_{t-1})$

Data and Preparation

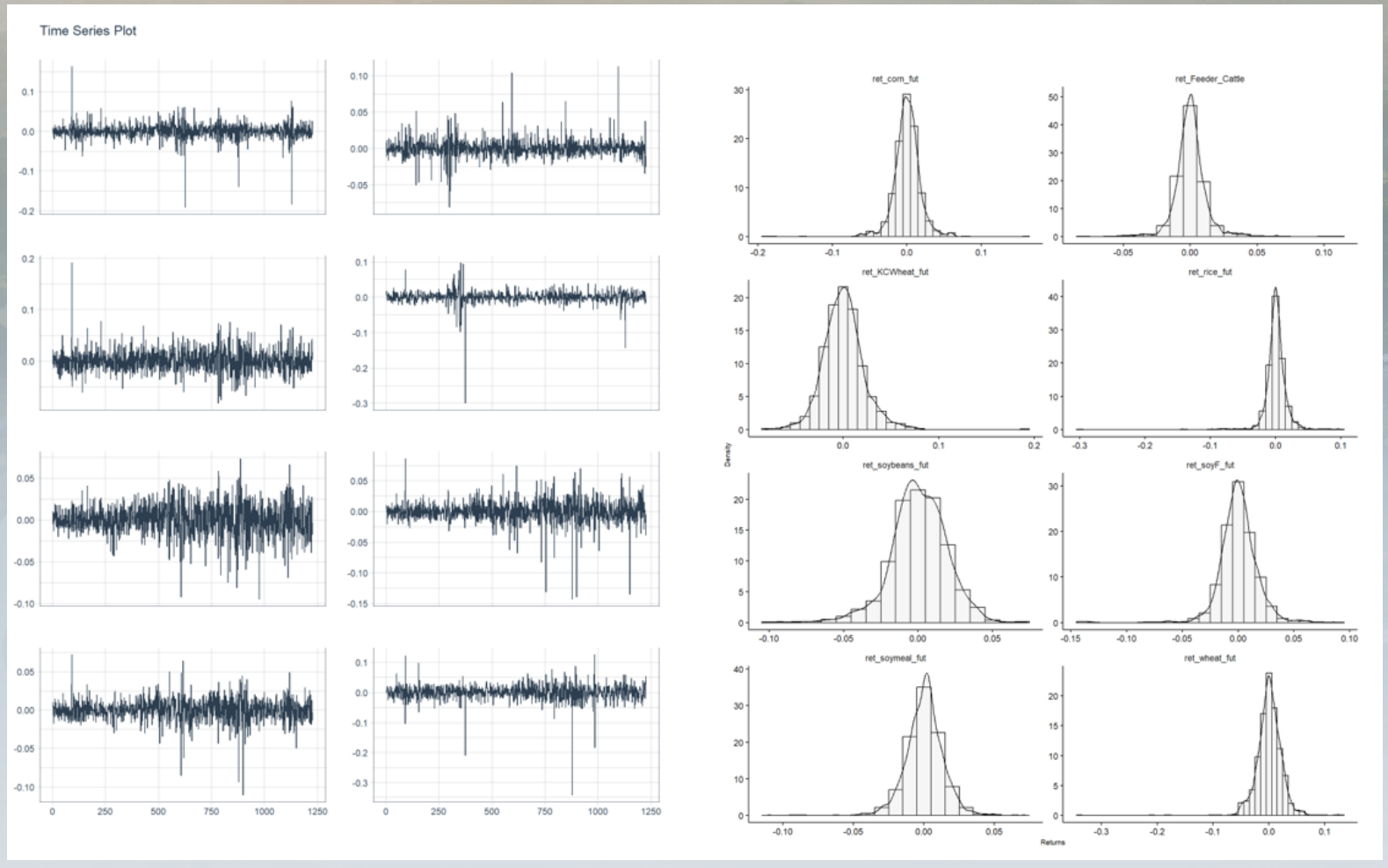

Figure: Commodities portfolio time series returns and their distributions

Results for Multiperiod Comparision

Our analysis contrasts the allocation strategies of NSGA-II and Differential Evolution across different periods, revealing their strategic adaptability to market conditions.

Time Period	Algo	ZC=F	ZO=F	KE=F	ZR=F	GF=F	ZS=F	ZM=F	ZL=F
Period 1	NSGA-II	1.83%	5.54%	2.66%	9.96%	27.99%	10.38%	24.93%	19.94%
Period 2	NSGA-II	4.83%	2.58%	4.83%	21.73%	28.08%	1.20%	7.01%	5.31%
Period 3	NSGA-II	3.66%	9.88%	3.24%	15.04%	28.79%	9.36%	9.00%	3.60%
Period 1	DEOptim	0.13%	0.05%	0.10%	99.47%	0.007%	0.09%	0.04%	0.08%
Period 2	DEOptim	0.00%	0.03%	0.06%	0.004%	0.04%	99.70%	0.007%	0.14%
Period 3	DEOptim	0.03%	0.20%	99.50%	0.02%	0.03%	0.02%	0.10%	0.06%

Table: Comparative Allocation of Weights in Different Time Periods

Algorithm	Period	Return	Risk	Sharpe	Diversification	Time (Seconds)
DifEvol	1	0.1190	0.3018	0.3904	0.8532	9.4518
DifEvol	2	0.0344	0.3933	0.0875	0.8532	9.4297
DifEvol	3	-0.3603	0.2825	-1.2753	0.8532	6.4744
NSGA-II	1	0.1183	0.1192	0.9928	1.7939	0.7025
NSGA-II	2	0.1488	0.1120	1.3292	1.6659	0.6507
NSGA-II	3	-0.0239	0.1270	-0.1884	1.8218	0.5115

Table: Performance Indicators of Differential Evolution and NSGA-II Algorithms

Final Considerations

Strategic Implications:

- Portfolio managers should consider both financial returns and broader implications on sustainability and market resilience.
- NSGA-II is more suitable for volatile markets due to its diversification and risk management capabilities.
- Differential Evolution is advantageous in stable conditions for maximizing returns.

Relevance to Industry 5.0:

- Integration of computational finance with sustainable economic models.
- Importance of adaptability and strategic selection in algorithmic choices.

Future Research Directions:

- Integrate dynamic programming and explore GARCH models with Markov regime shifts.
- Use hypervolume metrics to identify optimal multi-objective algorithms.
- Apply analysis to other asset classes and market conditions.

Thank You
Q & A

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Acts 8:31... Many thanks to all! ☺

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