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SCIENCE OF COMPUTER PROGRAMMING

OPTIONAL SINGLE-PATH INFORMATION PROPAGATION IN GRADIENT-BASED ALGORITHMS

The article addresses the challenges of distributed computing in dynamic environments such as the Internet of Things (IoT) and wireless networks, where devices frequently change position and communication frequency.

Gradient computation (estimating distances or shortest paths to source nodes) is essential for self-organization, information dissemination, and distributed detection. However, existing gradient algorithms struggle to balance accuracy and responsiveness to environmental changes.

The BIS (Bounded Information Speed) gradient algorithm, an improvement over existing distributed gradient methods for estimating distances in dynamic networks such as IoT, ad-hoc wireless systems, and pervasive computing.

The core issue tackled is that traditional gradient algorithms (classic, CRF, and FLEX) fail to achieve an adequate trade-off between accuracy, reaction speed, and output smoothness. Specifically, they exhibit

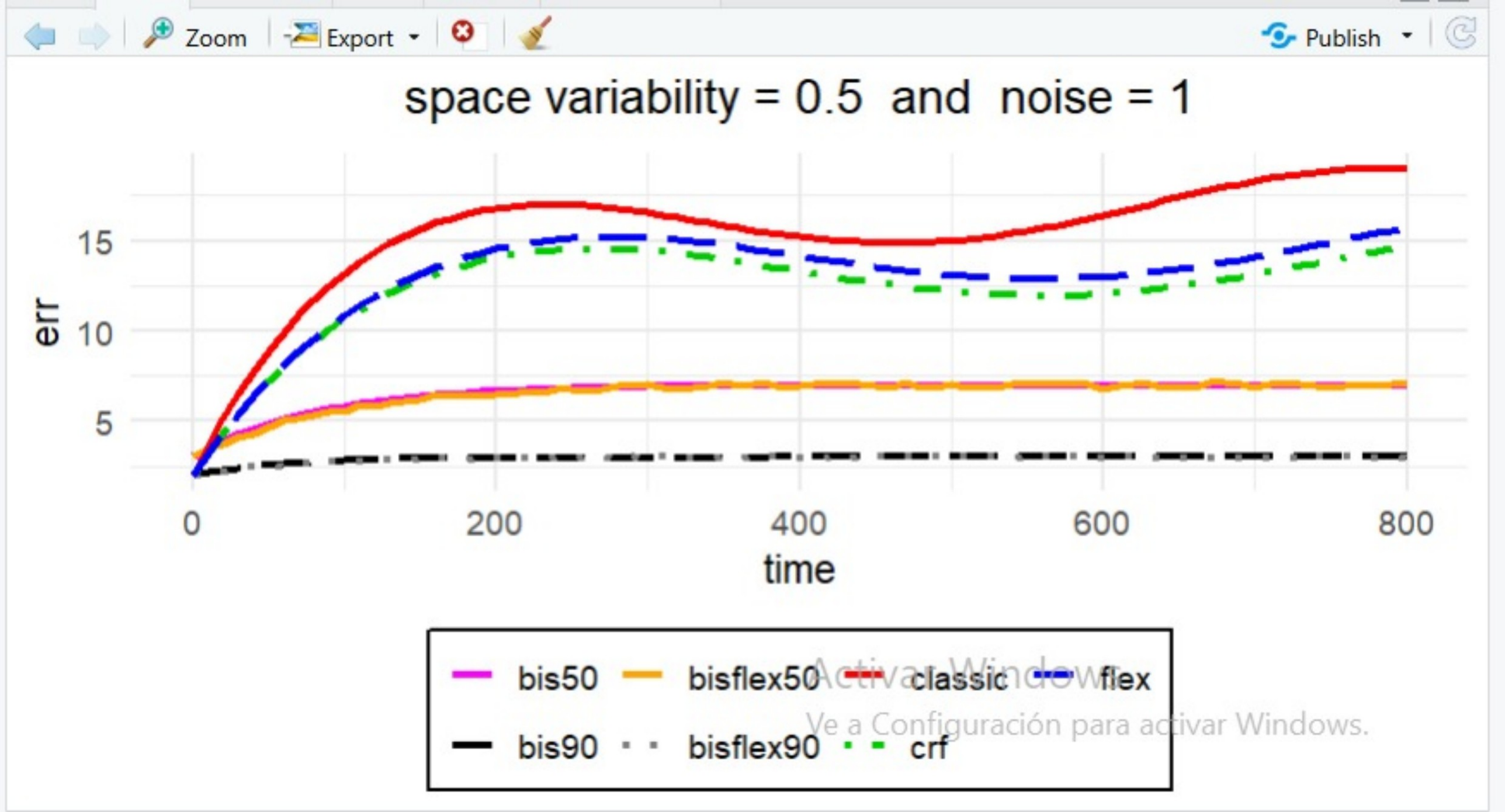
Systematic underestimation in mobile environments, slow recovery of increasing values when a source disappears (The "rising value" problem) and instability in the presence of noise or mobility

The BIS gradient introduces a lower bound on information speed (v) as a key parameter, using temporal information to control the propagation speed of updates. When v is set close to the average single-path communication speed, the algorithm achieves optimal reactivity

Theoretical analysis proves that BIS is optimal in reaction speed among single-path communication algorithms. The paper also provides formulas to estimate average communication speed based on network parameters such as communication range, computation period, and node mobility.

BIS was empirically tested against existing algorithms in three scenarios - isolation tests, channel communication, and data collection. Results showed that BIS achieved higher accuracy and faster recovery while maintaining stability with the BISflex filtering variant

In conclusion, the BIS gradient algorithm is a robust and efficient approach for dynamic environments, outperforming previous methods in both precision and adaptability. Future work will focus on multi-path communication, enhanced smoothing techniques, and adaptation to real-world mobility models.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- Al principio (tiempos < 100): todos los algoritmos incrementan su error mientras el campo de gradiente se forma
- entre $t = 200$ y $t = 300$, el sistema sufre una perturbación (ruido o cambio de red) → el error sube bruscamente
- Despues de $t = 400$ los gradientes BIS y BISFLEX se recuperan más rapido y estabilizan el error en niveles bajos

Esto demuestra que los gradientes BIS aplica una propagación controlada. evitan que la información "viaje" más rapido de lo que el sistema puede manejar y por tanto reducen las oscilaciones y el sobreajuste