Advances in time-independent Hamiltonian simulation algorithms

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Problems & Ideas

- Problem: time-independent Hamiltonian simulation asks how to implement U(t) = exp(-iHt) efficiently for large quantum systems.
- Classical simulation becomes expensive as Hilbert space dimension grows, especially for chemistry, materials, and many-body dynamics.
- Idea: organize existing algorithms into two routes, product formulas and post-Trotter methods, under a common error-cost framework.

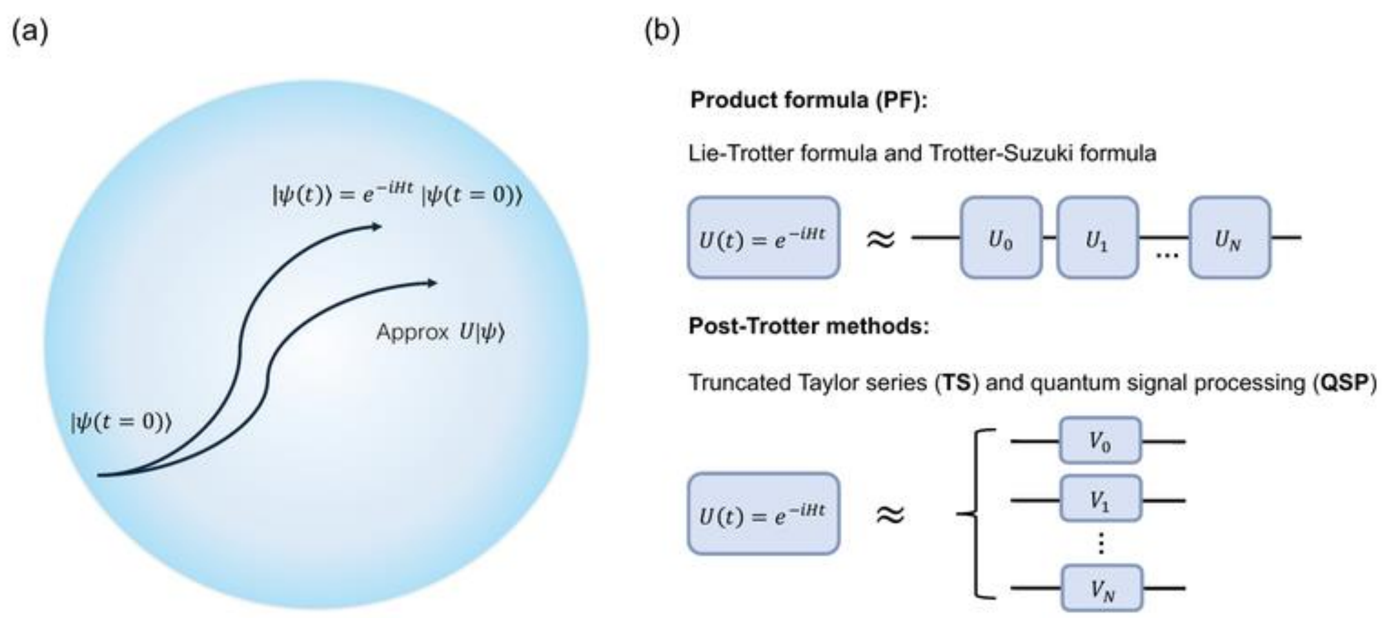

Figure 1 provides the full conceptual overview used in the review, connecting exact evolution with product-formula and post-Trotter simulation routes.

Main Contributions

- The review compares product formulas, truncated Taylor + LCU, QSP, qubitization, and QSVT within one roadmap.
- It relates operator-norm, channel, and observable error viewpoints to practical algorithm choice across simulation regimes.
- It highlights resource trade-offs and no-fast-forwarding lower bounds for realistic quantum-simulation settings.

Representative formulas by method

PF	$U_{\mathrm{PF}}(t) \approx \left(\prod_{\ell=1}^{L} e^{-iH_\ell t/r} \right)^r$
BCCKS / LCU	$\widetilde{U}_K(t) = \sum_{k=0}^{K} \frac{(-it)^k}{k!} H^k \approx \sum_j \alpha_j U_j$
QSP / QSVT	$U_{\vec{\phi}} = \left(\begin{array}{c\|c} P_d(H/\alpha) & * \\ \hline * & * \end{array} \right) \quad P_d(x) \approx e^{-i\alpha t x}$

The formula panel separates the core constructions behind PF, BCCKS/LCU, and QSP/QSVT, rather than collapsing all post-Trotter methods into one expression.