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Why Parallel in Time (PinT) methods are different for Parabolic and Hyperbolic Problems

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Space-time parallel methods, also known more recently under the name PinT methods, have received a lot of attention over the past two decades, driven by the parallel hardware architectures that have now millions of cores, and acceleration often saturates when one parallelizes in space only. Research focus has therefore shifted to trying to parallelize also the time direction. However, for parallelization, time is very different from space, because evolution problems satisfy a causality principle: the future is dependent on the past, and not the other way round. It is therefore not clear a priori if useful numerical work can be done simultaneously in the near and far future.

I will first show in my presentation why intuitively there is a fundamental difference when one parallelizes hyperbolic or parabolic problems in space-time, and which key properties need to be taken into account to be successful. I will then give examples of PinT methods which use the physical properties of the evolution problem to their advantage to parallelize in space-time. For hyperbolic problems, effective PinT methods are Domain Decomposition methods of Waveform Relaxation type, culminating in Unmapped Tent Pitching methods. Very powerfull techniques are also the ParaDiag methods, and direct time parallel methods like ParaExp. Several of these methods can also be very effectively used for parabolic problems, but for such problems there are also very successful multilevel methods, like Parareal, and the currently best ones are space-time multigrid methods. These multilevel methods struggle however when applied to hyperbolic problems.

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