# Delta-Stepping Synchronous Parallel Model

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## Abstract

Many synchronous parallel algorithms like PageRank require a large number of iteration steps. The overheads of global synchronizations on general-purpose clusters take substantial proportion of the execution time for lightweight computations. We propose a variant of Bulk Synchronous Parallel (BSP), Delta-Stepping Synchronous Parallel (DSP), with fewer iteration steps. It achieves faster convergence process by exploiting full advantage of data locality.

## Introduction

Many step-wise parallel algorithms can be intuitively expressed as BSP pattern [3]. This type of parallel pattern is described as in Figure 1.

![BSP Pattern](image1.png)

Figure 1: The BSP pattern

As is shown in Figure 1, varying degrees of interdependence exist among these processors \( P_1, P_2, \ldots, P_n \). When the dependence between \( P_i \) and \( P_j \) (\( j \neq i \)) is subtle, the orientation of the convergence of \( P_i \) will be mainly decided by the data residing in itself. So we conjecture that increasing local computing steps in each step will spread local convergence, sequentially advance the global convergence. The idea is sketched in Figure 2.

By further formalization and derivation, we prove that, if the algorithm converges with two local computations, then it converges with any number of local computations. For the convex optimization problems and local-optimal insensitive problems, the convergence is sufficient.

![DSP Pattern](image2.png)

Figure 2: The DSP pattern

## Case Study

To demonstrate the applicability and performance, we apply the model on several algorithms: Max Value Propagation (MVP), Jacobi Iterative Method (JIM) [1], Single Source Shortest Path (SSSP) and PageRank (PR).

As is shown in Figure 3, the figure shows that DSP reduces the numbers of iterations and communication of MVP, JIM, SSSP and PR significantly. Figure 4 show that DSP reduces the execution time and the number of iterations of SSSP and PageRank dramatically.

## Conclusion

DSP is a variant of BSP. It utilizes inaccurate global data when performs multiple computation steps in each step. These advanced computation steps further exploit the locality of data, and accelerate the convergence.

## References

