Experiments on Checkpointing Adjoint MPI Programs

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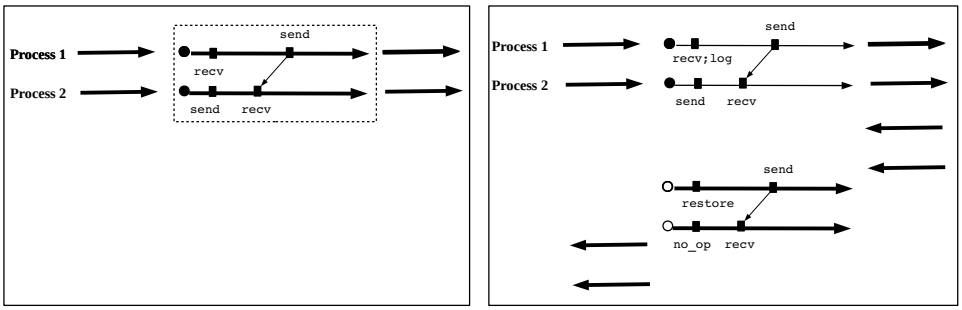
Checkpointing is a classical strategy to reduce the peak memory consumption of the adjoint. Checkpointing is vital for long run-time codes, which is the case of most MPI parallel applications. However, the presence of MPI communications seriously restricts application of checkpointing. In the most popular approach, a number of restrictions apply on the form of communications that occur in the checkpointed piece of code. In previous work, we proposed a general technique that lifts this restriction. This technique (called "receive-logging") is based on logging the values received, so that no duplicated communication is needed. However, the message logging makes it more costly than the popular approach. We proposed a refinement to our technique to duplicate communications whenever it is possible, so that the refined receive-logging now encompasses the popular approach. In this work we see checkpointing MPI parallel programs from a practical point of view. We discuss an important question about the choice of the checkpointed pieces. We validate our theorical results on a representative code in which we perform various choices of checkpointed pieces. We apply the refined receive-logging to these checkpointed pieces and we quantify the expenses in terms of memory and computation time for each resulting checkpointed adjoint.

Checkpointing is a classical technique to mitigate the overhead of adjoint Algorithmic Differentiation (AD). In the context of source transformation AD with the Store-All approach, checkpointing[1] reduces the peak memory consumption of the adjoint, at the cost of duplicate runs of selected pieces of the code. Checkpointing is vital for long run-time codes, which is the case for most MPI parallel applications. However, the presence of MPI communications seriously restricts application of checkpointing.
In most attempts to apply checkpointing to adjoint MPI codes (the "popular" approach), a number of restrictions apply on the form of communications that occur in the checkpointed piece of code. In particular, both ends of each communication must belong to the same checkpointed piece and the non blocking routines and their waits must be checkpointed together. If only one end is contained in the checkpointed piece of code, the resulting adjoint fails.
In previous work[2], we proposed a technique to apply checkpointing to adjoint MPI codes. This technique (called "refined receive-logging") is more general than the popular approach, i.e. it imposes less restrictions. The main idea of this technique (see figure 1) is to duplicate every communication whose ends belong to the checkpointed piece and to apply "receive-logging" to all the remaining communications, which are actually ends of communications whose other ends are outside the checkpointed piece (we call them "orphan communications"). Applying the receive-logging to one end of a communication means that:

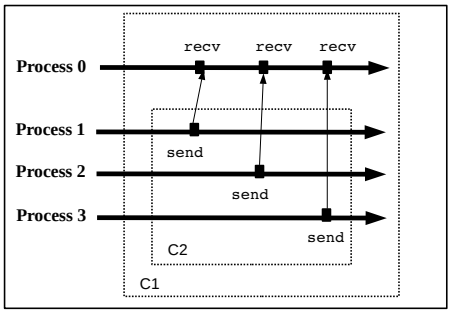
- During the first execution of the checkpointed piece, this end of communication is executed normally. However, if it is a receive operation, then it stores its received value into some location local to the process.
- During the duplicated execution of the checkpointed piece, this end of communication is not executed anymore. However, if it is a receive operation, then it reads the previously received value from where it has been stored during the first execution of the checkpointed piece.



In this work we study checkpointing of MPI programs from a practical point of view. Before actually experimenting the refined receive-logging on a representative example, we want to study the question of the choice of checkpointed pieces. More precisely, we want to ask: if we have the choice between two checkpointed pieces, both of them reducing in the same way the peak memory consumption, is it better to choose the one that does not contain any orphan communication, in which case the application of the refined receive-logging implies the application of the standard approach? Or is it better to choose the one that contains a blend of orphan and non-orphan communications? One may think that the first choice is better as it does not require any message logging. However, in practice, this may not be right. In fact, applying checkpointing on MPI parallel programs has not only the cost of logging orphan receives, but also the cost of snapshots. In general the memory cost of the refined receive-logging may be written as:

$$CheckpointingCost = \sum_{i=1}^{n}(SnapshotCostP_i) + \sum_{i=1}^{m}(OrphanReceiveCost_i)$$

where $SnapshotCostP_i$ is the snapshot cost at each process P_i, n is the number of processes involved in the checkpointed piece, $OrphanReceiveCost_i$ is the memory cost of one orphan receive and m is the number of orphan receives inside the checkpointed piece. We note here that when the checkpointed piece includes many communications, it contains consequently few orphan receieves and thus the cost of $\sum_{i=1}^{m}(orphanReceiveCost_i)$ is small. However, including many communications, means also that sometimes we have many processes involved in the checkpointed piece and thus the cost of $\sum_{i=1}^{n}(SnapshotCostP_i)$ is high. Consider the example of figure 2 with two alternative checkpointed pieces C1 and C2. Piece C1 contains only non-orphan communications and piece C2 contains only orphan communications, actually only sends. We apply the refined receive-logging to both alternatives.



The cost of checkpointing piece C1 is $\sum_{i=1}^{3}(SnapshotCostP_i)$ and the cost of checkpointing piece C2 is $\sum_{i=0}^{3}(SnapshotCostP_i)$. We observe that although piece C2 contains many orphan communications, the memory cost of checkpointing C2 is lower than that of checkpointing C1. This can be explained by the fact that these orphan communications are sends and then they do not require any message logging. However, if the orphan communications were receives operations, the result might have been different. Actually, in this case we would have to compare the snapshot cost of the process 0 with the message logging cost of the orphan receives.

We validate our theorical results on a representative code, with various choices of checkpointed pieces in which we apply the refined receive-logging. We quantify the cost in term of memory and computation time for every resulting checkpointed adjoint.

References

[1]Dauvergne, B. and Hascoët, L. The Data-Flow Equations of Checkpointing in reverse Automatic Differentiation. *International Conference on Computational Science, ICCS 2006, Reading, UK*, 2006.

[2]Taftaf, A and Hascoët, L. On The Correct Application Of AD Checkpointing To Adjoint MPI-Parallel programs *European Congress on Computational Methods in Applied Sciences and Engineering*, 2016