histogramPsum

March 21, 2016

1 Thread based parallelism comparison using the "PSUM" example.

1.0.1 Abstract

The GraviT team has created a kernel called PSUM to explore thread based parallel strategies. We present a comparison of suggested parallel methods. The conclusions are derived from performance experiements with a single executable per implementation. This is to removed the possibility of cache reuse from a previous implementation run. Secondly, we ran the implemenation executable 100 times under a python script (subprocess) to alleviate any memory reuse from the previous interation with the intent of independent trials. The results suggest more attention to **OpenMp** implementations should be explored for the GraviT framework with regards to array manipulation.

Load in modules for data post processing.

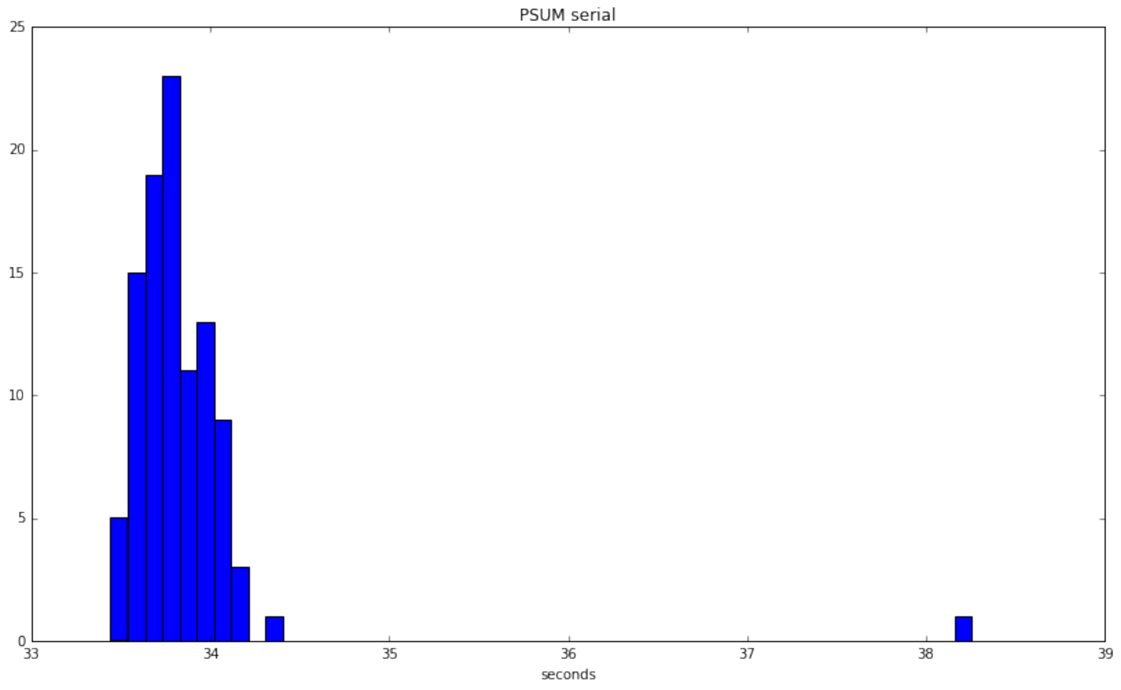
```
In [1]: %matplotlib inline
        import sys,os,getopt,argparse,math
        import numpy as np
        import matplotlib.pyplot as plt
        import mpld3
        mpld3.enable_notebook()
```

1.1 Serial executable.

```
In [2]: mavSerialList=[]
        with open('maverick_serial') as f:
            for line in f:
              mavSerialList.append(float(line.split()[1]))
        mavSerialArray=np.asarray(mavSerialList)
```

```
In [3]: fig = plt.figure(figsize=(14,8))
        ax = fig.add_subplot(111)
        ax.hist(mavSerialArray,50)
        plt.xlabel('seconds')
        plt.title('PSUM serial')
        plt.show()
        print 'PSUM serial average is' ,np.average(mavSerialArray)
        print 'PSUM serial standard deviation is',np.std(mavSerialArray)
```

```
/usr/local/lib/python2.7/site-packages/IPython/core/formatters.py:92: DeprecationWarning: DisplayFormat
  def _ipython_display_formatter_default(self):
/usr/local/lib/python2.7/site-packages/IPython/core/formatters.py:669: DeprecationWarning: PlainTextForm
  def _singleton_printers_default(self):
```



```
PSUM serial average is 33.84031
PSUM serial standard deviation is 0.481275507688
```

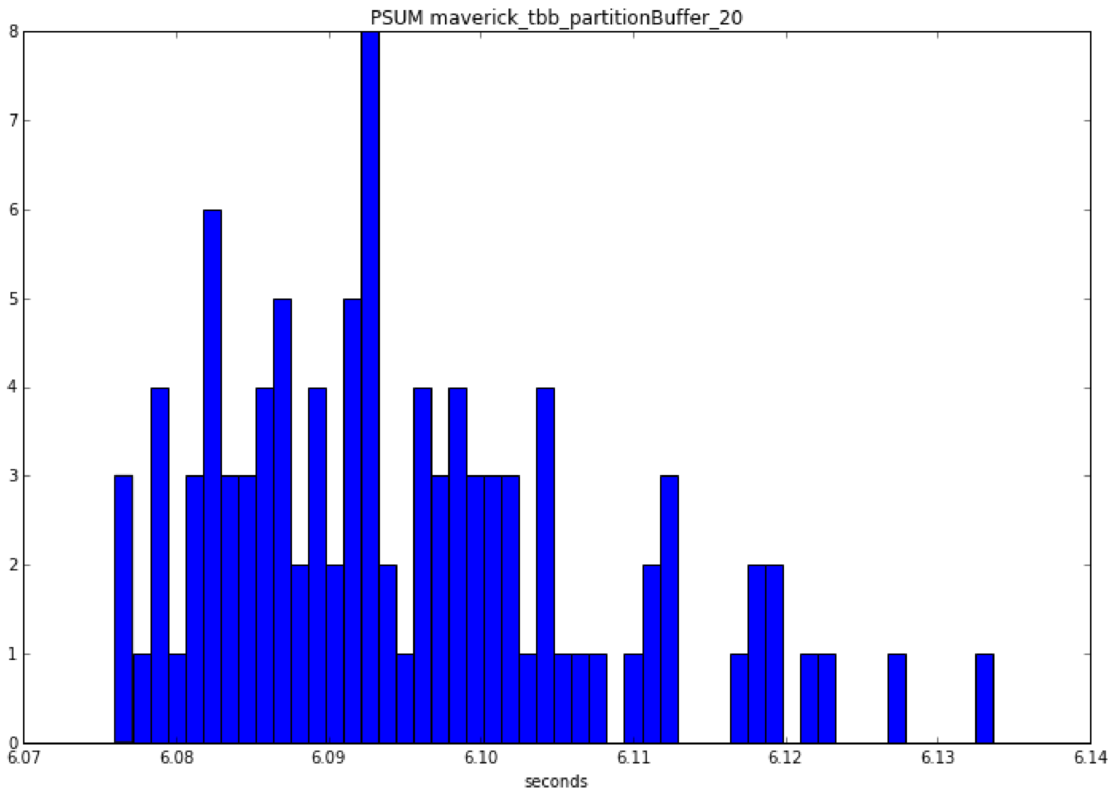
The above distribution for the serial implementation shows a noticable variance.

```
In [4]: #fastOpenMP1_data=np.array(filter(lambda x: x <= 42., dataArray))
```

1.1.1 Distriubtion plots generation

```
In [5]: testList=['serial','stdVec','openmp','openmp-2','tbb_rankBuffer','tbb_singleBuffer','tbb_partit
        threadCount=[1,2,4,8,10,12,14,16,18,19,20,25,30,35,40]
        dataListDict={}
        dataArrayDict={}
        for test in testList[1:]:
            for thread in threadCount:
                listPre='maverick_' + test + '_' + str(thread)
                dataFileName=listPre + '.txt'
                listName=listPre
                dataListDict[listName]=[]
                with open(dataFileName) as f:
                  for line in f:
                    #print line
                    if "tbb" in test:
                      dataListDict[listName].append(float(line.split()[4]))
                    else:
                      dataListDict[listName].append(float(line.split()[2]))
        for key in dataListDict:
            dataArrayDict[key]=np.asanyarray(dataListDict[key])
```

```
In [16]: fig = plt.figure(figsize=(12,8))
         ax = fig.add_subplot(111)
         dk='maverick_tbb_partitionBuffer_20'
         ax.hist(dataArrayDict[dk],50)
         plt.xlabel('seconds')
         plt.title('PSUM '+ dk)
         plt.show()
```



Users can change the above dk value to other distributions. Try 'OpenMp_1' and see an experiment that demonstrates NUMA effects.

1.2 Compare Implemenations.

We will create data structures for both the many single executable experiments and the single file PSUM.cpp and plot their respective comparisons.

```
In [19]: orgListDict={}
         orgArrayDict={}
         with open('maverick_psum.txt') as f:
             for line in f:
                 if 'non-parallel' in line:
                     orgListDict['non-parallel']=float(line.split()[1])
                 if 'std' in line:
                     orgListDict['stdVec_' + line.split()[1]]=float(line.split()[2])
                 if 'openmp' in line:
                     orgListDict['openMp_' + line.split()[1].strip(':')]=float(line.split()[2])
                 if 'tbb single' in line:
                     orgListDict['tbb_singleBuffer_' + line.split()[3].strip(':')]=float(line.split()[4
                 if 'tbb rank' in line:
                     orgListDict['tbb_rankBuffer_' + line.split()[3].strip(':')]=float(line.split()[4])
         for key in orgListDict:
             orgArrayDict[key]=np.asanyarray(orgListDict[key])
```

Let's create data lists for the original and distribution results

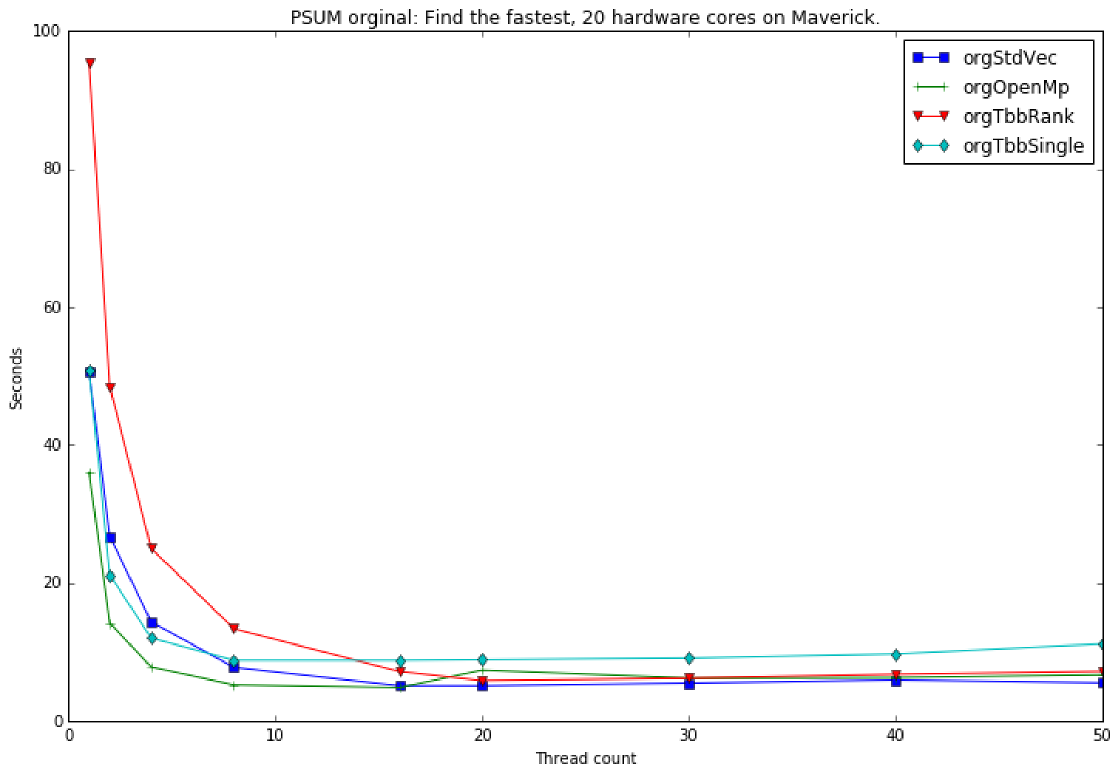
```
In [20]: orgStdVec=[]
         orgOpenMp=[]
         orgTbbRank=[]
         orgTbbSingle=[]
         for key in orgArrayDict:
             if 'stdVec' in key:
                 orgStdVec.append((np.average(orgArrayDict[key]),key.split("_")[-1]))
                 orgStdVec.sort(key=lambda tup: int(tup[1]))
             if 'openMp' in key:
                 orgOpenMp.append((np.average(orgArrayDict[key]),key.split("_")[-1]))
                 orgOpenMp.sort(key=lambda tup: int(tup[1]))
             if 'tbb_rankBuffer' in key:
                 orgTbbRank.append((np.average(orgArrayDict[key]),key.split("_")[-1]))
                 orgTbbRank.sort(key=lambda tup: int(tup[1]))
             if 'tbb_singleBuffer' in key:
                 orgTbbSingle.append((np.average(orgArrayDict[key]),key.split("_")[-1]))
                 orgTbbSingle.sort(key=lambda tup: int(tup[1]))
```

```
In [22]: stdVec=[]
         openMp=[]
         openMp2=[]
         tbbRank=[]
         tbbSingle=[]
         tbbPartition=[]
         for key in dataArrayDict:
             if 'stdVec' in key:
                 stdVec.append((np.average(dataArrayDict[key]),key.split("_")[-1]))
                 stdVec.sort(key=lambda tup: int(tup[1]))
             if key.split("_")[1]=='openmp':
                 openMp.append((np.average(dataArrayDict[key]),key.split("_")[-1]))
                 openMp.sort(key=lambda tup: int(tup[1]))
             if key.split("_")[1]=='openmp-2':
                 openMp2.append((np.average(dataArrayDict[key]),key.split("_")[-1]))
                 openMp2.sort(key=lambda tup: int(tup[1]))
             if 'tbb_rankBuffer' in key:
                 tbbRank.append((np.average(dataArrayDict[key]),key.split("_")[-1]))
                 tbbRank.sort(key=lambda tup: int(tup[1]))
             if 'tbb_singleBuffer' in key:
                 tbbSingle.append((np.average(dataArrayDict[key]),key.split("_")[-1]))
                 tbbSingle.sort(key=lambda tup: int(tup[1]))
             if 'tbb_partitionBuffer' in key:
                 tbbPartition.append((np.average(dataArrayDict[key]),key.split("_")[-1]))
                 tbbPartition.sort(key=lambda tup: int(tup[1]))
```

Plot the original single run timings.

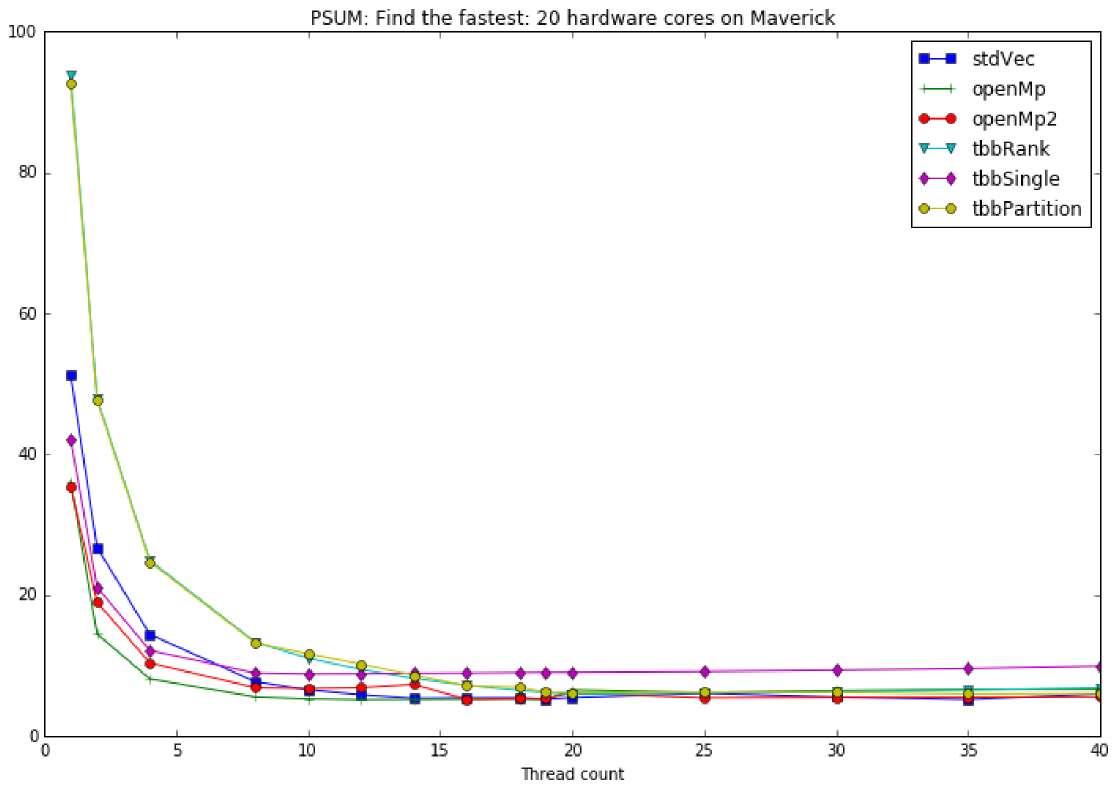
```
In [10]: fig = plt.figure(figsize=(12,8))
         ax = fig.add_subplot(111)
```

```
        dk='Find the fastest'
        ax.plot([x[1] for x in orgStdVec],[x[0] for x in orgStdVec],'s-',label='orgStdVec')
        ax.plot([x[1] for x in orgOpenMp],[x[0] for x in orgOpenMp],'+-',label='orgOpenMp')
        ax.plot([x[1] for x in orgTbbRank],[x[0] for x in orgTbbRank],'v-',label='orgTbbRank')
        ax.plot([x[1] for x in orgTbbSingle],[x[0] for x in orgTbbSingle],'d-',label='orgTbbSingle')
        plt.xlabel('Thread count')
        plt.ylabel('Seconds')
        plt.title('PSUM orginal: '+ dk + ', 20 hardware cores on Maverick.')
        plt.legend()
        plt.show()
```



Plot the distribution average results.

```
In [23]: fig = plt.figure(figsize=(12,8))
        ax = fig.add_subplot(111)
        dk='Find the fastest'
        ax.plot([x[1] for x in stdVec],[x[0] for x in stdVec],'s-',label='stdVec')
        ax.plot([x[1] for x in openMp],[x[0] for x in openMp],'+-',label='openMp')
        ax.plot([x[1] for x in openMp2],[x[0] for x in openMp2],'o-',label='openMp2')
        ax.plot([x[1] for x in tbbRank],[x[0] for x in tbbRank],'v-',label='tbbRank')
        ax.plot([x[1] for x in tbbSingle],[x[0] for x in tbbSingle],'d-',label='tbbSingle')
        ax.plot([x[1] for x in tbbPartition],[x[0] for x in tbbPartition],'8-',label='tbbPartition')
        plt.xlabel('Thread count')
        plt.title('PSUM: '+ dk + ': 20 hardware cores on Maverick')
        plt.legend()
        plt.show()
```

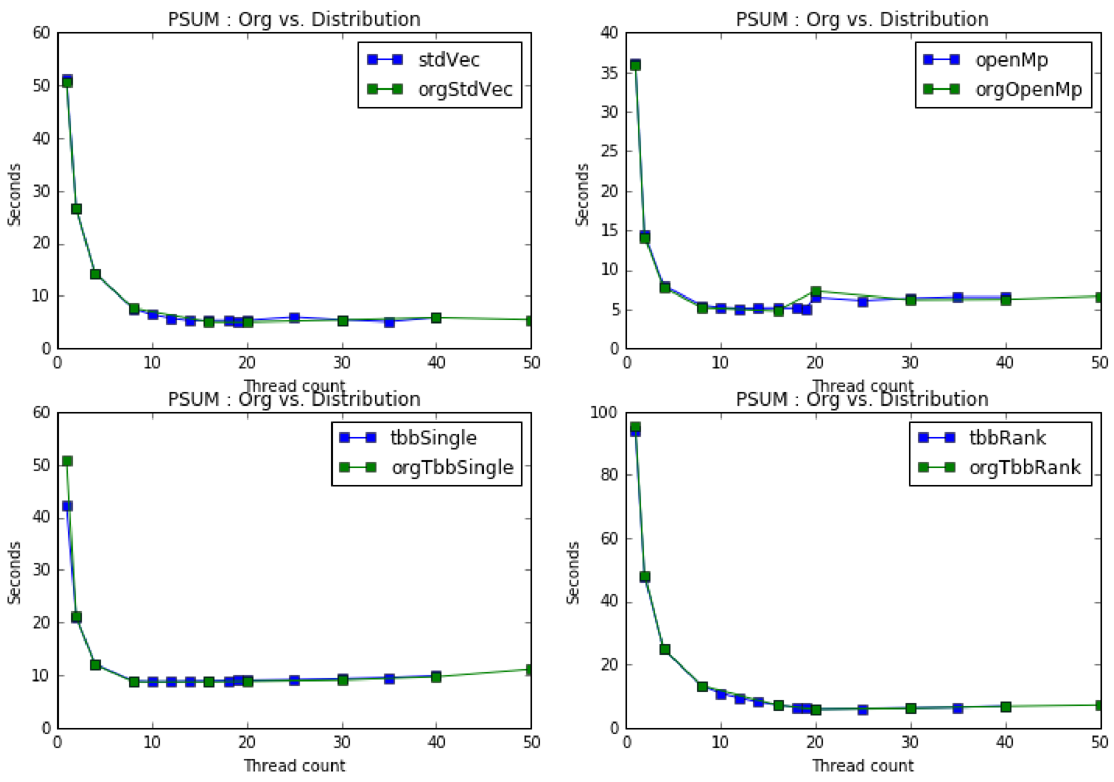


We can see that OpenMP starting with [12:19] threads is the fastest in general. We see “TBB” seems to do better at over subscription but not vs. a lower thread count.

Lets compare the distribution values to the single run.

```
In [12]: fig = plt.figure(figsize=(12,8))
         ax = fig.add_subplot(221)
         dk='Org vs. Distribution'
         ax.plot([x[1] for x in stdVec],[x[0] for x in stdVec],'s-',label='stdVec')
         ax.plot([x[1] for x in orgStdVec],[x[0] for x in orgStdVec],'s-',label='orgStdVec')
         plt.xlabel('Thread count')
         plt.ylabel ('Seconds')
         plt.title('PSUM : '+ dk)
         plt.legend()
         ax = fig.add_subplot(222)
         ax.plot([x[1] for x in openMp],[x[0] for x in openMp],'s-',label='openMp')
         ax.plot([x[1] for x in orgOpenMp],[x[0] for x in orgOpenMp],'s-',label='orgOpenMp')
         plt.xlabel('Thread count')
         plt.ylabel ('Seconds')
         plt.title('PSUM : '+ dk)
         plt.legend()
         ax = fig.add_subplot(223)
         ax.plot([x[1] for x in tbbSingle],[x[0] for x in tbbSingle],'s-',label='tbbSingle')
         ax.plot([x[1] for x in orgTbbSingle],[x[0] for x in orgTbbSingle],'s-',label='orgTbbSingle')
         plt.xlabel('Thread count')
         plt.ylabel ('Seconds')
         plt.title('PSUM : '+ dk)
         plt.legend()
```

```
ax = fig.add_subplot(224)
ax.plot([x[1] for x in tbbRank],[x[0] for x in tbbRank],'s-',label='tbbRank')
ax.plot([x[1] for x in orgTbbRank],[x[0] for x in orgTbbRank],'s-',label='orgTbbRank')
plt.xlabel('Thread count')
plt.ylabel ('Seconds')
plt.title('PSUM : '+ dk)
plt.legend()
plt.show()
```



```
In [13]: def twoSampZ(X1, X2, mudiff, sd1, sd2, n1, n2):
             from numpy import sqrt, abs, round
             from scipy.stats import norm
             pooledSE = sqrt(sd1**2/n1 + sd2**2/n2)
             z = ((X1 - X2) - mudiff)/pooledSE
             pval = 2*(1 - norm.cdf(abs(z)))
             return round(z, 3), round(pval, 4)
```

```
In [14]: print "Distribution average of OpenMP 20 threads is ", np.average(dataArrayDict['maverick_openm
         print "Distribution standard deviation of OPenMP 20 threads is ", np.std(dataArrayDict['maveri
         print "Single run OpenMP 20 timing is ", orgArrayDict['openMp_20']
```

```
Distribution average of OpenMP 20 threads is  6.48086
Distribution standard deviation of OPenMP 20 threads is  1.43573378065
Single run OpenMP 20 timing is  7.30815
```

```
In [15]: ompAvg=np.average(dataArrayDict['maverick_openmp_16'])
         ompStd=np.std(dataArrayDict['maverick_openmp_16'])
```

```
tbbRankAvg=np.average(dataArrayDict['maverick_tbb_rankBuffer_16'])
tbbRankStd=np.std(dataArrayDict['maverick_tbb_rankBuffer_16'])
ompSize=len(dataArrayDict['maverick_openmp_16'])
tbbRankSize=len(dataArrayDict['maverick_tbb_rankBuffer_16'])
z,p=twoSampZ(ompAvg,tbbRankAvg,0,ompStd,tbbRankStd,ompSize,tbbRankSize)
print "Omp w/ 16 threads minus tbb rank w/ 16 threads is ", ompAvg-tbbRankAvg
print "Z score with hypothesis that tbb and omp have the same mean is ", z
```

```
Omp w/ 16 threads minus tbb rank w/ 16 threads is  -2.0017638
Z score with hypothesis that tbb and omp have the same mean is  -79.312
```

2 Conclusion

The distribution plot shows that the OpenMp imlemenation is faster in most thread counts than all the other implementations. The suggestion of using OpenMp for this "psum" operation should be amplified by the ease of OpenMp coding. Implementing OpenMp tasks to handle the MPI computation/communication overlap should be explored. ## ToDO It is important to understand why OpenMp is better than Tbb in certain cases. This will be the next section.

```
In [ ]:
```