Chapter 6

Summary and Conclusions

6.1 Introduction

Many of the existing period search methods were studied in detail and four popular methods were compiled for automated period search of variable stars. The theory of Lomb-Scargle periodogram and cubic spline interpolation using B-splines, were studied in detail. In brief,

- **$LSP/GLSP$** - The derivation is consolidated in two different ways.
- **$SigSpec$** - Method is re-coded in FORTRAN.
- **$PDM$** - Automated the method.
- **$MCS$** - The theory modified with unevenly spaced knots, coded in FORTRAN.

The developed automated method applied on the following two databases.

- **$ASAS$** - Re-analysed the database.
- **$CRTS$** - Re-analysed the database.

Our strategy was to use the above specified first three methods on the data for the initial period search and the results are compared with the published periods. Those results, which are different from the published periods are subjected to the $MCS$ interpolation method, including the harmonics of the newly detected period. The period corresponding to the minimum least square error is taken as the newly detected best period. In order to confirm this, we have visually examined all these light curves. We have applied this strategy to two databases $ASAS$ and $CRTS$, which are available to the public.
It has been found that, in the case of ASAS database, we have detected nearly 5% better periods than the published periods. In the case of CRTS database, we have detected 44 entirely different periods and many decimal place improved periods. This is due to the fact that, CRTS uses latest classification method and also only one type of variable star data (i.e. RRab type) is used. The results obtained to us show that, the period search methods are to be improved to get 100% exact periods of variable stars, when the data is subjected to automation. This is the need of time, since large scale variability surveys are producing lot of time series data and many of these data is available to the public. The computers are getting more powerful, storage media is becoming cheaper and long lasting, Internet becoming faster, the data analysis on astro-time-series becomes a prospectus research area in the near future.

The knowledge wise required skills for this kind of data analysis research are as follows. Some domain knowledge about the variability, variable stars, astro-time-series, light curves are required. The statistical knowledge about various statistics used to assess the quality of the data as well as the obtained results are required. The numerical methods and programming in few languages are also needed. The bash or any other scripting language should be known, which will help the automation of methods, by which lot of time can be saved. Finally the interpretation of the results require some experience with the shape and other properties of the characteristic light curve of variable stars.

6.2 Summary : Comparison of 3 methods and improvement by MCS interpolation method

It has been found that the automated methods are required, for analysing thousands of light curves. Also our analysis on two databases shows that some of the published periods are not correct. This is because, usually one method is used for period confirmation. But we have used two methods in sequence, one for detection and another for period confirmation. This kind of implementation takes little more time than a single method, but some good results obtained shows that, such strategies can be used for re-analysing the published results. The table below shows the results of the 3 popular period search methods applied on ASAS a2perlc data, which contain 384 time series data files. The table (6.2) shows that, the modified cubic spline (MCS) interpolation method improved the period detection rate nearly by 5 – 6% during automation.
6.3 Future prospectus

In view of above results, we can point some interesting problems that can be addressed in the future.

- Improve the method, so that full automation along with maximum success rate is obtained.

- Apply the automated methods of period detection to other available databases.

- Extract other features from the light curve.

- Extension into other time series for short term and long term periodicity predictions.

- Error analysis on the obtained periods.

- Classify the variable stars using supervised/unsupervised classification methods, Gaussian mixture model and Random forest automated classification methods, using minimum parameters.

<table>
<thead>
<tr>
<th>Method</th>
<th>Success rate</th>
<th>+MCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLSP</td>
<td>81%</td>
<td>88%</td>
</tr>
<tr>
<td>SigSpec</td>
<td>85%</td>
<td>91%</td>
</tr>
<tr>
<td>PDM</td>
<td>79%</td>
<td>84%</td>
</tr>
</tbody>
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Table 6.1: The sequential application of MCS improves the detection by 5 – 6%