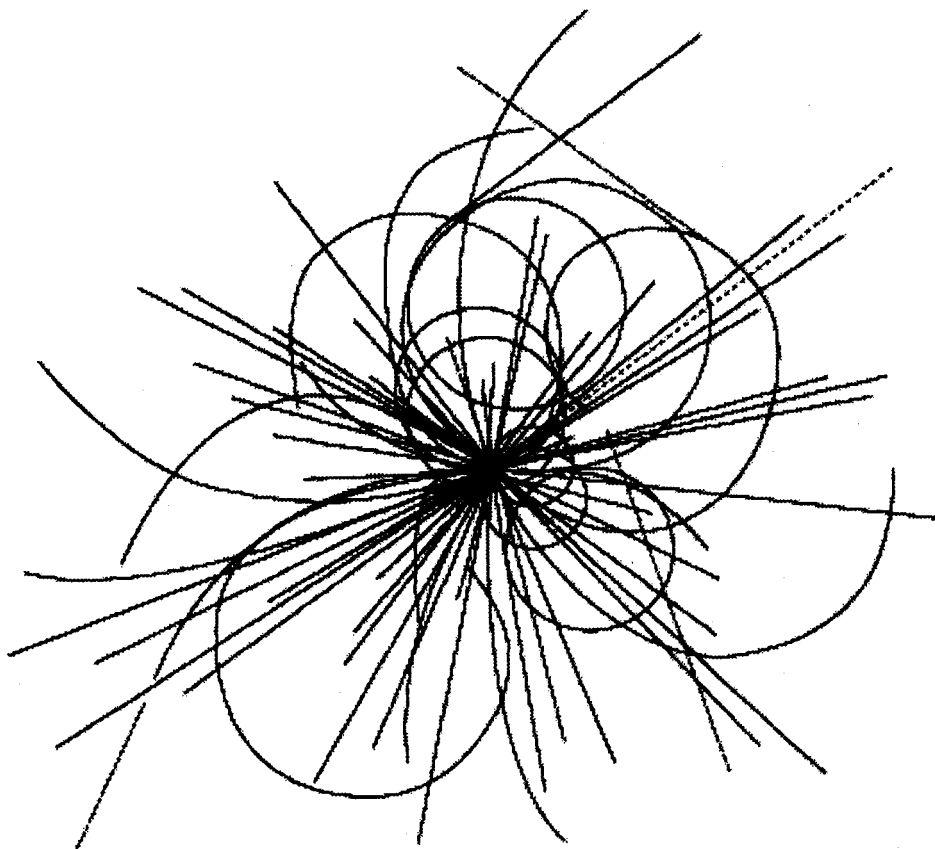


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Zlib and Related Programs for Beam Dynamics Studies



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Abstract

Zlib is a differential-algebraic and Lie-algebraic numerical library for subroutines that support beam dynamics studies. The source codes are written in Fortran. Hierarchical data structures are employed for speed optimization, particularly in vector computers (supercomputers). Dynamic memories are used for internal structural integer pointers and for required internal working memories. The use of Zlib is very much the same as the use of IMSL library except that a Zlib preparation subroutine should be called to set up the hierarchical structure before other Zlib subroutines can be called. There are currently about 200 subroutines in Zlib. Accompanying Zlib are some specialized programs such as one-turn-map extraction programs, nonlinear analysis programs, and symplectic one-turn-map tracking programs for practical use in beam dynamics studies.

Natural properties of accelerators, of being perturbative for nonlinear effects and of being periodic for storage rings, have made it very interesting in applying differential algebras and Lie algebras for the study of single-particle beam dynamics.^{1,2,3,4} However, such applications are very difficult or impossible without a systematic software that handles the algebras. Zlib is one among a few⁵ that provide subroutines for such algebras. Currently, what is most needed for Zlib is an updated manual although an old manual,⁶ which was written about three years ago, may still be somewhat useful.

Accompanying Zlib are some programs for beam dynamics studies. Programs that use Zlib subroutines are Zmap: a map extraction program,⁷ Zimaptrk: a symplectic implicit one-turn-map tracking program,⁸ and some small specialized programs for nonlinear mapping analyses and post-tracking analyses. Implementation of Zlib subroutines in the program Teapot⁹ is currently undergoing. Also, Zlib is used in the program SSCTRK for one-turn map extraction.¹⁰

Shown in the next page is a chart that shows how Zlib and its related programs are used. First a lattice design program, Synch¹¹ (not shown in the chart),

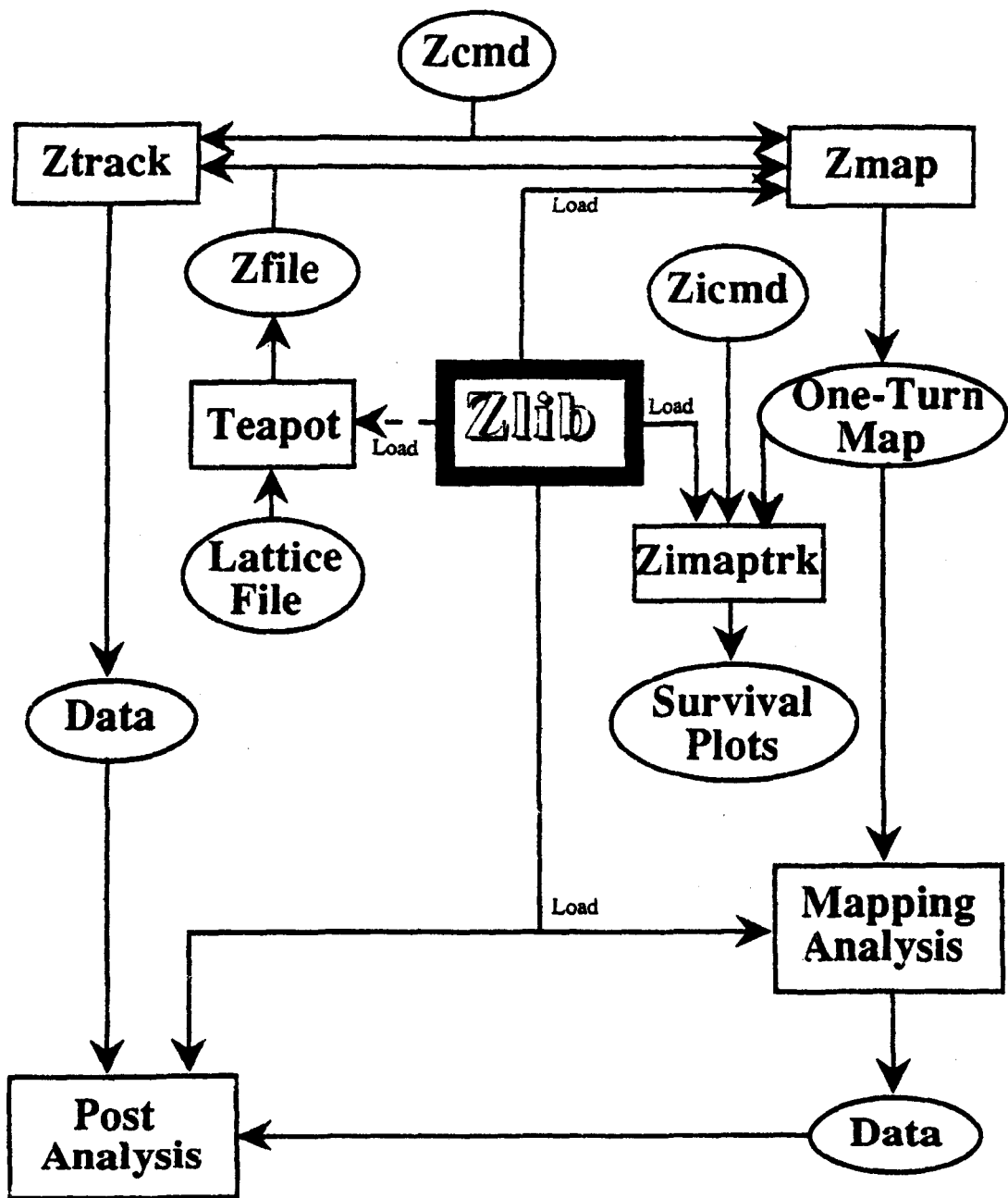
*Operated by the Universities Research Association, Inc., for the U.S. Department of Energy under Contract No. DE-AC35-89ER40486.

generates a linear lattice file which is then translated into a standard Mad¹² lattice file. After adding nonlinear error descriptions (for systematic and random multipole errors and random misalignment), the Mad lattice file serves as input to the program Teapot to generate Zfile, an element-by-element machine file. Accompanied with a command file, Zcmd, Zfile then serves as an input file of Ztrack for vectorized (and parallelized) element-by-element multi-particle tracking or as an input file for Zmap to extract one-turn maps. The one-turn maps are then analyzed by specialized mapping analysis programs or serve as an input of Zimaptrk for fast long-term tracking to obtain survival plots¹³ for dynamic aperture studies. Occasionally post tracking data are analyzed with the aid of the information provided by the one-turn maps.

Since the start of its development in 1988, Zlib has made some contributions to practical studies, particularly on long-term stability studies. The development of Zmap made it possible for the extraction of one-turn high-order "order-by-order symplectic" Taylor maps for the SSC. Indeed, such maps were used to demonstrate, for the first time, that one-turn maps can be extracted for large static circular accelerators, and that these maps contain sufficient information for long-term stability studies.^{14,15} Shown in Figure 1 is a survival plot for the SSC which shows that trackings up to a million turns with Ztrack (element-by-element tracking) and with the corresponding 11th-order Taylor-map tracking give the same dynamic aperture prediction. Straightforward conversion (without explicitly using a generating function) of "order-by-order symplectic" Taylor maps into exactly symplectic implicit Taylor maps has concluded that one should be encouraged to use one-turn maps for long-term stability studies for large circular accelerators such as the SSC or the SSC High-Energy Booster (HEB).⁸ For the same SSC nonlinear lattice as used for Figure 1, trackings with the corresponding 4th-order and 7th-order symplectic implicit Taylor maps show the same dynamic aperture as one can refer to the survival plots shown in Figure 1 of Reference 8. Indeed, all trackings with the corresponding symplectic implicit Taylor maps with an order equal to or larger than 4 show very much the same dynamic aperture.

Shown in Appendix A is a small program that shows how the author used Zlib to test a Zlib subroutine for Lie transformation (Dragt-Finn factorization)¹⁶ of "order-by-order symplectic" Taylor maps three years ago. For simplicity, only a fixed order "no" was used in this example program although different orders, equal to or lower than the maximum order "no" set up by the statement "call zpprep(nv,no,nm,0)", can be flexibly used in subroutine calls as provided by the subroutine parameters.

The author wishes to thank Robert Ryne and the program committee members for their invitation of his participation in this computational accelerator physics conference.



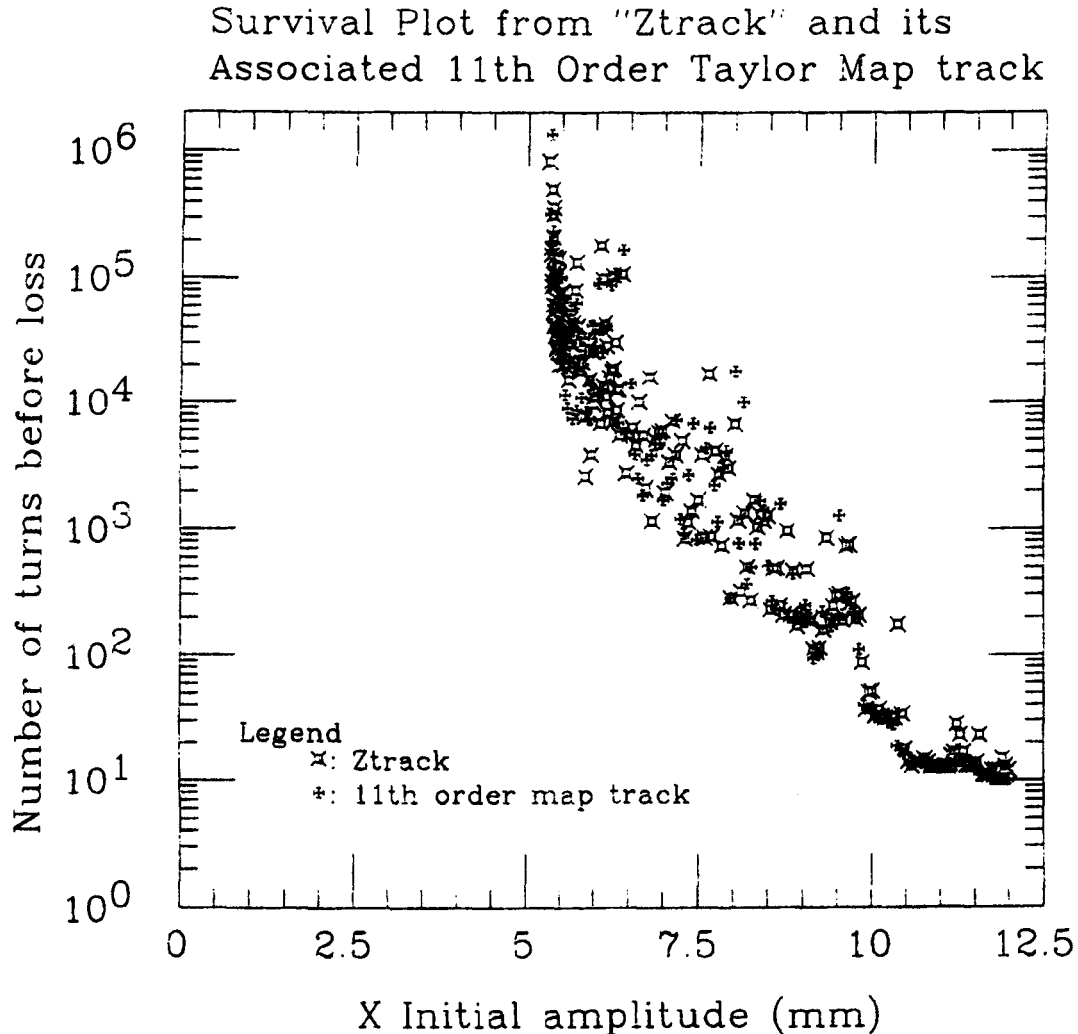


Figure 1. Million-turn survival plots for a 2-TeV injection lattice of the SSC, comparing the data from an 11th-order Taylor-map (extracted with "Zmap") tracking with the data from its associated "Ztrack" element-by-element tracking. The two sets of data match quite well, showing that: (a) round-off errors (64-bit precision) for long-term tracking in the SSC is of no concern since "Ztrack" element-by-element tracking is accomplished at an accuracy of 11 digits in one turn, while the 11th-order Taylor-map tracking is less accurate by 3 to 4 digits (7 to 8 digits of accuracy) in one turn for the selected region of interest, due to truncation of higher orders, and still generate the same result; and (b) Increasing the order of the Taylor map by one or two would allow reliable fast tracking up to 10 million turns for the SSC (the required proton-coasting time of the SSC injection lattice) since increasing one order higher in the Taylor map will enhance nearly 10 times as much accuracy (about one more digit accuracy) in one turn tracking. (Courtesy of Y. Yan et al., SSCL-301)

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