Automatic Lattice Translation between MAD-X and SAD

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Introduction

- Motivation of Development
  - MAD-X to SAD Translation
    - I want to use SAD for LHC simulation.
  - SAD to MAD-X Translation
    - Some MAD-X users request KEKB lattice written in MAD-X.
- How to Realize?
  - Develop lattice description in the other language
  - Develop general translator (My solution)
    - Write once, Apply any lattice
- What language to use for implementation?
  - SADScript language on SAD runtime environment
    - SADScript is one of functional language.
    - Turing complete (without tape length)

How to Translate?

- Parsing Input Lattice(Syntax Analysis)
  - Generate abstract syntax tree
    - MADX **sequence** parser is easily implemented on SADScript.
      - Support constant/element declaration and sequence directive.
    - SAD input can be directly parsed by SAD interpreter.
  - Transform into internal lattice description
    - List of beam line elements with geometry order:
      {name, location, length, type, type specific parameters...}

- Generate Target Description(Code Generation)
  - Key component of translator!
  - Element-to-element mapping for simple beam line element
  - Mapping to sequence of beam line elements for element emulation
  - Require knowledges of beam line element implementation about both source and target codes

Difference between SAD and MAD-X[1]

- Parameterization Strategy
  - Kn/SKn parameter
    - MAD-X use normalized field strength for thick element.
      - Integrated strength for thin element(multipole)
    - SAD use integrated normalized field strength for thick/thin element.
  - Solenoid strength
    - MAD-X use normalized field strength(ks)
    - SAD use magnetic flux density(BZ)
  - K0/SK0 semantics
    - MAD-X changes design orbit by K0/SK0.
    - SAD does not change design orbit by K0/SK0.
      - Closed orbit is changed by K0/SK0.
  - Alignment
    - MAD-X does not contain alignment information in sequence.
    - SAD contains horizontal/vertical offset of element.

Difference between SAD and MAD-X[2]

- Missing Parameter/Effect
  - SAD implements linear quadrupole fringe.
  - SAD implements vertical focusing on rectangle steering dipole (dipole corrector).
- Overlapped Solenoid
  - SAD supports overlap against drift, bend, quad and mult.
  - SAD supports solenoid tilt against beam line.
    - This feature is used by KEKB IR.
  - MAD-X does not support overlap.
    - MAD-XP supports overlap.
- Meta Information
  - MAD-X has meta information by element type
    - Monitor: hmonitor, vmonitor, monitor, instrument
    - Corrector: hkicker, vkicker, kicker
    - Bending Magnet: rbend, sbend

Difference between SAD and MAD-X[3]

- Marker Element
  - SAD mark can point to internal position of thick element.
- General-Purpose Element
  - MAD-X matrix element describes 2nd order map
    - $x^i \rightarrow v^i + m^i_j\, x^j + t^i_{jk}\, x^j\, x^k$
  - SAD map element describes arbitrary map by SADScript functions.
    - Turing complete!
    - Arbitrary computable beam line element MIGHT be implemented by map element.

Technical Summary

- Translation from MAD-X to SAD
  - Easy to implement.
    - Easy to make n-to-1 mapping.
      - Ex.) hkicker, vkicker, sbend, rbend → bend
    - Map function of element in twiss.F could be implemented by map element.
  - Meta information can not be kept.
- Translation from SAD to MAD-X
  - Difficult to implement, because of shortage of feature/parameter.
  - 1st order emulation is possible by using matrix element.
    - It means that all elements are translated into affine transformation.

Current Status of Implementation

- Round-trip translation support is impossible.
- MAD-X to SAD translation
  - LHCB1/2 lattice can be translated.
- SAD to MAD-X translation
  - KEKB arc cell can be translated.
    - MAD-XP can not be supported, because both matrix and quadrupole linear fringe are not supported.
  - KEKB LER wiggler section requires to replace bend with matrix, because of dipole kick(K0).
    - Without replacement, large closed-orbit and dispersion error are generated.
  - KEKB IR section requires to replace solenoid region with matrix, because of tilted solenoid overlap.
    - Without replacement, catastrophic closed-orbit and dispersion error are generated.

Summary

- To implement full spec. MAD-X to SAD translation is possible...
  - Need more coding and more test input!
  - I can't keep motivation...
    - LHCB1/2 translation is enough for my work.
- To improve SAD to MAD-X translation is impossible without MAD-X modification...
  - Need MAD-X hacker/maintainer to extend MAD-X.
    - I'm not MAD-X hacker.
    - Branching MAD-X source code base is bad idea.
  - MAD-XP is not enough, because PTC capability is limited by MAD-X syntax.
- Translation engine is distributed on SAD source archive.
  - Browse <Source Archives> link from http://acc-physics.kek.jp/SAD/SADrelease/
  - File Name: SAD-MADX-2008-09-17.tar.gz
  - No user's manul, Source code only!

Generalized Thesis of Translation

Compute the beam line element sequence which is equivalent to the given computable map f: $R^6 \rightarrow R^6$

- SAD can describe arbitrary map by map element.
- MAD-X can describe 2nd order map by matrix element.

- Point & Question
  - This is one of the reversed compiler!
    - Accelerator codes compile lattice description into map.
  - Can MAD-XP describe arbitrary map?
    - matrix element is not supported by PTC!
  - Can we write a general algorism without universal map?