CADGen

Code Generator for Semi-Algebraic Iteration Sets
Edition 1.0.1 for CADGen version 0.1
01 October 2009

Armin Größlinger

This manual describes CADGen, a code generator for semi-algebraic iteration sets.

Table of Contents

1 Introduction

CADGen is a code generator which generates loop code (nested for-loops) from a model description. It is similar to the well-known CLooG code generator [Bas04b], page 10. The main difference is that CADGen uses cylindrical algebraic decomposition (CAD) to generate loop code. This enables CADGen to generate code for semi-algebraic sets (i.e., iteration sets bounded by arbitrary polynomials in the variables and parameters) whereas CLooG generates loops for iteration sets defined by affine expressions (i.e., polyhedra), only.

To handle the non-linearities, CADGen needs to manipulate logical formulas, do quantifier elimination in the real numbers and perform algebraic number arithmetic. To this end, CADGen uses the Reduce computer algebra system (`http://reduce-algebra.com/`), the Redlog package for Reduce and QEPCAD (`http://www.usna.edu/Users/cs/qepcad/B/QEPCAD.html`), see Chapter 2 [Installing CADGen], page 2 for details how to obtain them.

2 Installing CADGen

CADGen is available at `http://www.infosun.fim.uni-passau.de/cl/loopo/`. It is part of HsLooPo, the Haskell modules for the LooPo loop parallelizer. CADGen can be built *without* LooPo (other parts of HsLooPo will not build without LooPo). (Therefor, the CADGen source distribution includes quite some code that is not actually used in CADGen.)

To build and use CADGen, you need:

- Reduce version 3.8 or later with Redlog package.
  You can download current binary distributions for your platform at `http://sourceforge.net/projects/reduce-algebra/files/reduce-algebra/` which include Redlog already. If Redlog is not included in your Reduce package, you can get it at `http://redlog.dolzmann.de/`.
- QEPCAD version 1.50 or later (earlier versions may not work).
  The source code of QEPCAD and its dependency Saclib can be downloaded from `http://www.usna.edu/Users/cs/qepcad/INSTALL/IQ.html`.
- The Glasgow Haskell Compilater (GHC), version 6.8 or later, Alex (a scanner generator for Haskell) and Happy (a parser generator for Haskell).
  Binary and source distributions are available at `http://www.haskell.org/ghc/` for GHC, `http://www.haskell.org/alex/` for Alex, `http://www.haskell.org/happy/` for Happy. Some Linux distributions (e.g., Ubuntu) provide packages for GHC, Alex and Happy.
- CADGen source, available at `http://www.infosun.fim.uni-passau.de/cl/loopo/`.

To compile HsLooPo after unpacking the sources, do

```
./configure --with-ghc=.../ghc
            --with-reduce=.../reduce
            --with-qepcad=.../qepcad
```

where `--with-ghc`, `--with-reduce` and `--with-qepcad` tell `configure` where to find the GHC, Reduce and QEPCAD binaries, respectively. (The paths to Reduce and QEPCAD can be supplied by command-line parameters to CADGen later overriding the configured paths.) An option can be omitted if the respective binary is in the search path. `configure` will warn that LooPo could not be found but this is ok, since CADGen can be built without LooPo. When `configure` completes successfully, issue

```
make programs
```

and after successful compilation, the CADGen binary can be found in

```
./programs/bin/cadgen
```

and should be ready to run.

A few example inputs for CADGen are included in the source code bundle in `programs/cadgen/examples/`. Some of them are semi-algebraic examples, others are CLooG test cases that CADGen is able to generate code for.

3 Input File Format

CADGen can parse CLooG input files (see [cloog-doc], page 10) or its own input format (as CLooG's input format can express affine bounds, only). CADGen always outputs code in C notation and ignores the language flag ('c' or 'f') at the beginning of the input file. If the input file starts with the string "`cadgen`" (after some whitespace), it is an input file in CADGen's own format (see below).

3.1 Input File Grammar

The grammer for CADGen's own input format loosely follows the structure of CLooG input files. The main difference is that domains and scattering relations are not expressed by (the coefficients of) affine expressions but quantifier-free formulas.

In the grammar rules given here, terminal symbols are either given literally in single quotes or marked by a leading underscore (if a terminal cannot be given literally).

```
File            ::= Program
Program         ::= 'cadgen' Context Statements Scattering

Context         ::= Nb_parameters  Name_list Formula
Statements      ::= Nb_iterators   Name_list Nb_statements Domain_list
Scattering      ::= Nb_scatterdims Name_list Nb_relations  Scatter_list

Name_list       ::= _String   Name_list                  | (void)
Domain_list     ::= _Integer Formula ';'  Domain_list    | (void)
Scatter_list    ::=          Formula ';'  Scatter_list   | (void)

Formula         ::= '[' Formula ']'  |  Formula '/\' Formula  |
                    Formula '\/' Formula  |  AtomicFormula
AtomicFormula   ::= _Polynomial RelOp _Polynomial
RelOp           ::= '<' | '<=' | '=' | '>=' | '>' | '/='
Name_list       ::= _String Name_list  |  (void)

Nb_parameters   ::= _Integer
Nb_variables    ::= _Integer
Nb_statements   ::= _Integer
Nb_domains      ::= _Integer
Nb_relations    ::= _Integer
```

After the initial keyword "`cadgen`", the number of parameters, the names of the parameters and a formula in the parameters describing the assumptions on the parameters (e.g., `n >= 0 /\ m >= 1`) is given.

This is followed by the number of iterator variables (i.e., variables for describing the domains of the statements) and names for the iterator variables. Then, the number of statements follows and, for each statement, the number of dimensions for the domain and a formula describing the iteration domain.

Finally, the number of scattering dimensions, names for the scattering dimensions, the number of scatterings (which must match the number of statements) and the scatterings themselves (as formulas) are given. Scatterings may be relations, i.e., there is no requirement for them to be functions from the respective domain to the scattering dimensions.

A formula (`Formula`) is composed of atomic formulas joined by the logical junctors `/\` (meaning "and") and `\/` (meaning "or"); `/\` takes precedence over `\/`. Note that to group sub-formulas, square brackets (`[` and `]`) are used. An atomic formula (`AtomicFormula`) is a comparison between two polynomial expressions (`_Polynomial`) written with the operators `+`, `-`, `*`, `^` and parentheses (`(` and `)`) for grouping. The relational operators `<`, `<=`, `=`, `>=`, `>` have their usual meanings, `/=` means "not equal".

Since there is no logical negation operation defined for formulas, negations have to expressed by "pushing" them to the atomic formulas. For example, "not `(x >= 0 /\ y = 0)`" has to written as "`x < 0 \/ y /= 0`".

Single line comments are started with a hash mark `#`. They are allowed everywhere except before the introductory "`cadgen`" and inside formulas.

3.2 Notes for Using CADGen with CLooG Input Files

When CADGen is run on a CLooG input file, it translates the affine expressions into quantifier-free formulas with the same meaning. When no scattering functions are given, CADGen does not exploit the fact that there is no ordering among the statements. In fact, CADGen uses identity functions (of the common dimensionality of the domains) as scattering. This behaviour has been chosen to make the test cases included with CLooG without scattering more interesting test cases for CADGen.

4 Running CADGen

4.1 Command Syntax

The CADGen binary takes a file name containing the description of the iteration sets as input and, optionally, several parameters:

```
Usage: cadgen [OPTION...] file.cadgen | file.cloog
  -o OUTPUT  --output=OUTPUT                write output to OUTPUT
             --no-combine                   do not combine adjacent cells
             --testcode[=parameter values]  generate test code
             --reduce=REDUCE                path to Reduce executable
             --qepcad=QEPCAD                path to Qepcad executable
```

`-o` *OUTPUT*
`--output=`*OUTPUT*
: Write generated code to the given file instead of standard output.

`--no-combine`
: Do not combine neighbouring CAD cells which carry "compatible" code. This leads to (much) longer code which reflects directly the computed cylindrical decomposition.

`--testcode[=`*N*`]`
: Generate a compilable program that executes the loop iterations. If N is not given, the program will read the parameter values from the command line. If N is given, the parameters are set to the given value.

`--reduce=`*REDUCE*
`--qepcad=`*QEPCAD*
: Supply paths to the executable for Reduce or QEPCAD, respectively, overriding the compiled-in default.

4.2 Generated Code

The code generated by CADGen is written in C notation. The loop bounds may contain the following functions:

`ceild(a,b)`
: Ceiling of `a` divided by `b`.

`floord(a,b)`
: Floor of `a` divided by `b`.

`OneOf(a0,...)`
: Any one of the given values. This is used by CADGen to express that several different expressions (which evaluate to the same value) can be used as the loop bound.

`ceilRootOf(nbRoot,degree,a0,a1,a2,...,aN)`
`floorRootOf(nbRoot,degree,a0,a1,a2,...,aN)`
: Ceiling or floor of a certain root of the polynomial $\sum_{i=0}^{N} a_i z^i$ in z. Root number `nbRoot` (counting from "left" (lower values) if `nbRoot` is positive

and from "right" (higher values) if `nbRoot` is negative). For example, `floorRootOf(1,2,-a,0,1)` is the floor of the first (`nbRoot`=1) root of the polynomial $z^2 - a$, i.e., $\lfloor -\sqrt{a} \rfloor$ (for $a > 0$). `floorRootOf(-2,2,-a,0,1)` has the same meaning (second root counting from "right").

4.3 Example

Let us consider the following example input for two statements. Statement 1 has a two-dimensional iteration set: `x` is betwen 0 and `p*p` and `y` is between 0 and the (positive) square root of x. Statement 2 has a one-dimensional iteration set for `x` between 0 and `p`. The scattering for statement 1 is simply `x`, whereas for statement 2 the scattering is `p*x`.

```
cadgen

1  # number of parameters
p  # names for the parameters
# context (conditions on parameters)
p >= 1;

2   # number of variables
x y # names of variables

2   # number of domains
2   # dimensionality of domain (excluding scattering dimensions)
x >= 0 /\ x <= p*p /\ y >= 0 /\ y*y <= x;
1   # dimensionality of domain (excluding scattering dimensions)
x >= 0 /\ x <= p;

1 # number of scattering dimensions
c # name of the scattering dimensions
2 # number of scatterings (must match number of domains)
c =   x;  # first scattering
c = p*x;  # second scattering
```

The code generated by CADGen is shown below. The root expression `floorRootOf(2,2,-x,0,1)` denotes the second (positive) root of `x` (formally, the second root of $z^2 - x$ in z). Note that S2 is executed only every `p`-th iteration. The loop on x from `ceild(c,p)` to `floord(c,p)` performs one iteration if, and only if, `p` divides `c`.

Unfortunately, CADGen cannot combine the cases for `c`=0 and `c`>0, because for `c`=`x`=0, the upper bound for `y`, which is $\sqrt{x}$, is given by the *first and only* root of $z^2 - x$ in z, instead of the second root (which does not exist for `x`=0).

```
if (1 <= p) {
  for (c=0; c<=0; c++) {
    for (x=OneOf(0,c); x<=OneOf(0,c); x++) {
      for (y=OneOf(0,ceilRootOf(1,2,-x,0,1));
                   y<=OneOf(0,floorRootOf(1,2,-x,0,1)); y++) {
        S1(x,y);
      }
    }
    for (x=OneOf(0,ceild(c,p)); x<=OneOf(0,floord(c,p)); x++) {
       S2(x);
    }
  }
  for (c=0+1; c<=p*p; c++) {
    for (x=c; x<=c; x++) {
      for (y=0; y<=floorRootOf(2,2,-x,0,1); y++) {
        S1(x,y);
      }
    }
    for (x=ceild(c,p); x<=floord(c,p); x++) {
      S2(x);
    }
  }
}
```

5 Conclusions

CADGen is a proof-of-concept prototype at the moment. It can generate code for small examples only. Depending on the interest in code generation for semi-algebraic sets, CADGen may be improved in the future.

6 Version History

2009-10-01 Edition 1.0.1 of the manual.
Fixed some typos in the manual.

2009-09-30 Version 0.1 of CADGen, Edition 1.0 of the manual.
Initial public release.

6.1 Known Bugs

- Sometimes the terminal is messed up when CADGen exits (one has to run, e.g., `reset` to get a usable terminal back).

7 References

[Bas04b] Cédric Bastoul, Code Generation in the Polyhedral Model Is Easier Than You Think, Proceedings of PACT'13 IEEE International Conference on Parallel Architecture and Compilation Techniques, pages 7–16, September 2004.

[CLooG-Doc]
http://www.bastoul.net/cloog/documentation.php or
http://www.cloog.org/

Appendix A GNU Free Documentation License

0. PREAMBLE

   The purpose of this License is to make a manual, textbook, or other functional and useful document *free* in the sense of freedom: to assure everyone the effective freedom to copy and redistribute it, with or without modifying it, either commercially or noncommercially. Secondarily, this License preserves for the author and publisher a way to get credit for their work, while not being considered responsible for modifications made by others.

   This License is a kind of "copyleft", which means that derivative works of the document must themselves be free in the same sense. It complements the GNU General Public License, which is a copyleft license designed for free software.

   We have designed this License in order to use it for manuals for free software, because free software needs free documentation: a free program should come with manuals providing the same freedoms that the software does. But this License is not limited to software manuals; it can be used for any textual work, regardless of subject matter or whether it is published as a printed book. We recommend this License principally for works whose purpose is instruction or reference.

1. APPLICABILITY AND DEFINITIONS

   This License applies to any manual or other work, in any medium, that contains a notice placed by the copyright holder saying it can be distributed under the terms of this License. Such a notice grants a world-wide, royalty-free license, unlimited in duration, to use that work under the conditions stated herein. The "Document", below, refers to any such manual or work. Any member of the public is a licensee, and is addressed as "you". You accept the license if you copy, modify or distribute the work in a way requiring permission under copyright law.

   A "Modified Version" of the Document means any work containing the Document or a portion of it, either copied verbatim, or with modifications and/or translated into another language.

   A "Secondary Section" is a named appendix or a front-matter section of the Document that deals exclusively with the relationship of the publishers or authors of the Document to the Document's overall subject (or to related matters) and contains nothing that could fall directly within that overall subject. (Thus, if the Document is in part a textbook of mathematics, a Secondary Section may not explain any mathematics.) The relationship could be a matter of historical connection with the subject or with related matters, or of legal, commercial, philosophical, ethical or political position regarding them.

   The "Invariant Sections" are certain Secondary Sections whose titles are designated, as being those of Invariant Sections, in the notice that says that the Document is released under this License. If a section does not fit the above definition of Secondary then it is not allowed to be designated as Invariant. The Document may contain zero Invariant Sections. If the Document does not identify any Invariant Sections then there are none.

The "Cover Texts" are certain short passages of text that are listed, as Front-Cover Texts or Back-Cover Texts, in the notice that says that the Document is released under this License. A Front-Cover Text may be at most 5 words, and a Back-Cover Text may be at most 25 words.

A "Transparent" copy of the Document means a machine-readable copy, represented in a format whose specification is available to the general public, that is suitable for revising the document straightforwardly with generic text editors or (for images composed of pixels) generic paint programs or (for drawings) some widely available drawing editor, and that is suitable for input to text formatters or for automatic translation to a variety of formats suitable for input to text formatters. A copy made in an otherwise Transparent file format whose markup, or absence of markup, has been arranged to thwart or discourage subsequent modification by readers is not Transparent. An image format is not Transparent if used for any substantial amount of text. A copy that is not "Transparent" is called "Opaque".

Examples of suitable formats for Transparent copies include plain ASCII without markup, Texinfo input format, LaTeX input format, SGML or XML using a publicly available DTD, and standard-conforming simple HTML, PostScript or PDF designed for human modification. Examples of transparent image formats include PNG, XCF and JPG. Opaque formats include proprietary formats that can be read and edited only by proprietary word processors, SGML or XML for which the DTD and/or processing tools are not generally available, and the machine-generated HTML, PostScript or PDF produced by some word processors for output purposes only.

The "Title Page" means, for a printed book, the title page itself, plus such following pages as are needed to hold, legibly, the material this License requires to appear in the title page. For works in formats which do not have any title page as such, "Title Page" means the text near the most prominent appearance of the work's title, preceding the beginning of the body of the text.

The "publisher" means any person or entity that distributes copies of the Document to the public.

A section "Entitled XYZ" means a named subunit of the Document whose title either is precisely XYZ or contains XYZ in parentheses following text that translates XYZ in another language. (Here XYZ stands for a specific section name mentioned below, such as "Acknowledgements", "Dedications", "Endorsements", or "History".) To "Preserve the Title" of such a section when you modify the Document means that it remains a section "Entitled XYZ" according to this definition.

The Document may include Warranty Disclaimers next to the notice which states that this License applies to the Document. These Warranty Disclaimers are considered to be included by reference in this License, but only as regards disclaiming warranties: any other implication that these Warranty Disclaimers may have is void and has no effect on the meaning of this License.

2. VERBATIM COPYING

You may copy and distribute the Document in any medium, either commercially or noncommercially, provided that this License, the copyright notices, and the license notice saying this License applies to the Document are reproduced in all copies, and that you add no other conditions whatsoever to those of this License. You may not use technical measures to obstruct or control the reading or further copying of the copies you make or distribute. However, you may accept compensation in exchange for copies. If you distribute a large enough number of copies you must also follow the conditions in section 3.

You may also lend copies, under the same conditions stated above, and you may publicly display copies.

3. COPYING IN QUANTITY

If you publish printed copies (or copies in media that commonly have printed covers) of the Document, numbering more than 100, and the Document's license notice requires Cover Texts, you must enclose the copies in covers that carry, clearly and legibly, all these Cover Texts: Front-Cover Texts on the front cover, and Back-Cover Texts on the back cover. Both covers must also clearly and legibly identify you as the publisher of these copies. The front cover must present the full title with all words of the title equally prominent and visible. You may add other material on the covers in addition. Copying with changes limited to the covers, as long as they preserve the title of the Document and satisfy these conditions, can be treated as verbatim copying in other respects.

If the required texts for either cover are too voluminous to fit legibly, you should put the first ones listed (as many as fit reasonably) on the actual cover, and continue the rest onto adjacent pages.

If you publish or distribute Opaque copies of the Document numbering more than 100, you must either include a machine-readable Transparent copy along with each Opaque copy, or state in or with each Opaque copy a computer-network location from which the general network-using public has access to download using public-standard network protocols a complete Transparent copy of the Document, free of added material. If you use the latter option, you must take reasonably prudent steps, when you begin distribution of Opaque copies in quantity, to ensure that this Transparent copy will remain thus accessible at the stated location until at least one year after the last time you distribute an Opaque copy (directly or through your agents or retailers) of that edition to the public.

It is requested, but not required, that you contact the authors of the Document well before redistributing any large number of copies, to give them a chance to provide you with an updated version of the Document.

4. MODIFICATIONS

You may copy and distribute a Modified Version of the Document under the conditions of sections 2 and 3 above, provided that you release the Modified Version under precisely this License, with the Modified Version filling the role of the Document, thus licensing distribution and modification of the Modified Version to whoever possesses a copy of it. In addition, you must do these things in the Modified Version:

A. Use in the Title Page (and on the covers, if any) a title distinct from that of the Document, and from those of previous versions (which should, if there were any, be listed in the History section of the Document). You may use the same title as a previous version if the original publisher of that version gives permission.

B. List on the Title Page, as authors, one or more persons or entities responsible for authorship of the modifications in the Modified Version, together with at least five of the principal authors of the Document (all of its principal authors, if it has fewer than five), unless they release you from this requirement.
C. State on the Title page the name of the publisher of the Modified Version, as the publisher.
D. Preserve all the copyright notices of the Document.
E. Add an appropriate copyright notice for your modifications adjacent to the other copyright notices.
F. Include, immediately after the copyright notices, a license notice giving the public permission to use the Modified Version under the terms of this License, in the form shown in the Addendum below.
G. Preserve in that license notice the full lists of Invariant Sections and required Cover Texts given in the Document's license notice.
H. Include an unaltered copy of this License.
I. Preserve the section Entitled "History", Preserve its Title, and add to it an item stating at least the title, year, new authors, and publisher of the Modified Version as given on the Title Page. If there is no section Entitled "History" in the Document, create one stating the title, year, authors, and publisher of the Document as given on its Title Page, then add an item describing the Modified Version as stated in the previous sentence.
J. Preserve the network location, if any, given in the Document for public access to a Transparent copy of the Document, and likewise the network locations given in the Document for previous versions it was based on. These may be placed in the "History" section. You may omit a network location for a work that was published at least four years before the Document itself, or if the original publisher of the version it refers to gives permission.
K. For any section Entitled "Acknowledgements" or "Dedications", Preserve the Title of the section, and preserve in the section all the substance and tone of each of the contributor acknowledgements and/or dedications given therein.
L. Preserve all the Invariant Sections of the Document, unaltered in their text and in their titles. Section numbers or the equivalent are not considered part of the section titles.
M. Delete any section Entitled "Endorsements". Such a section may not be included in the Modified Version.
N. Do not retitle any existing section to be Entitled "Endorsements" or to conflict in title with any Invariant Section.
O. Preserve any Warranty Disclaimers.

If the Modified Version includes new front-matter sections or appendices that qualify as Secondary Sections and contain no material copied from the Document, you may at your option designate some or all of these sections as invariant. To do this, add their titles to the list of Invariant Sections in the Modified Version's license notice. These titles must be distinct from any other section titles.

You may add a section Entitled "Endorsements", provided it contains nothing but endorsements of your Modified Version by various parties—for example, statements of peer review or that the text has been approved by an organization as the authoritative definition of a standard.

You may add a passage of up to five words as a Front-Cover Text, and a passage of up to 25 words as a Back-Cover Text, to the end of the list of Cover Texts in the Modified Version. Only one passage of Front-Cover Text and one of Back-Cover Text may be added by (or through arrangements made by) any one entity. If the Document already includes a cover text for the same cover, previously added by you or by arrangement made by the same entity you are acting on behalf of, you may not add another; but you may replace the old one, on explicit permission from the previous publisher that added the old one.

The author(s) and publisher(s) of the Document do not by this License give permission to use their names for publicity for or to assert or imply endorsement of any Modified Version.

5. COMBINING DOCUMENTS

   You may combine the Document with other documents released under this License, under the terms defined in section 4 above for modified versions, provided that you include in the combination all of the Invariant Sections of all of the original documents, unmodified, and list them all as Invariant Sections of your combined work in its license notice, and that you preserve all their Warranty Disclaimers.

   The combined work need only contain one copy of this License, and multiple identical Invariant Sections may be replaced with a single copy. If there are multiple Invariant Sections with the same name but different contents, make the title of each such section unique by adding at the end of it, in parentheses, the name of the original author or publisher of that section if known, or else a unique number. Make the same adjustment to the section titles in the list of Invariant Sections in the license notice of the combined work.

   In the combination, you must combine any sections Entitled "History" in the various original documents, forming one section Entitled "History"; likewise combine any sections Entitled "Acknowledgements", and any sections Entitled "Dedications". You must delete all sections Entitled "Endorsements."

6. COLLECTIONS OF DOCUMENTS

   You may make a collection consisting of the Document and other documents released under this License, and replace the individual copies of this License in the various documents with a single copy that is included in the collection, provided that you follow the rules of this License for verbatim copying of each of the documents in all other respects.

   You may extract a single document from such a collection, and distribute it individually under this License, provided you insert a copy of this License into the extracted document, and follow this License in all other respects regarding verbatim copying of that document.

7. AGGREGATION WITH INDEPENDENT WORKS

   A compilation of the Document or its derivatives with other separate and independent documents or works, in or on a volume of a storage or distribution medium, is called an "aggregate" if the copyright resulting from the compilation is not used to limit the legal rights of the compilation's users beyond what the individual works permit. When the Document is included in an aggregate, this License does not apply to the other works in the aggregate which are not themselves derivative works of the Document.

   If the Cover Text requirement of section 3 is applicable to these copies of the Document, then if the Document is less than one half of the entire aggregate, the Document's Cover Texts may be placed on covers that bracket the Document within the aggregate, or the electronic equivalent of covers if the Document is in electronic form. Otherwise they must appear on printed covers that bracket the whole aggregate.

8. TRANSLATION

   Translation is considered a kind of modification, so you may distribute translations of the Document under the terms of section 4. Replacing Invariant Sections with translations requires special permission from their copyright holders, but you may include translations of some or all Invariant Sections in addition to the original versions of these Invariant Sections. You may include a translation of this License, and all the license notices in the Document, and any Warranty Disclaimers, provided that you also include the original English version of this License and the original versions of those notices and disclaimers. In case of a disagreement between the translation and the original version of this License or a notice or disclaimer, the original version will prevail.

   If a section in the Document is Entitled "Acknowledgements", "Dedications", or "History", the requirement (section 4) to Preserve its Title (section 1) will typically require changing the actual title.

9. TERMINATION

   You may not copy, modify, sublicense, or distribute the Document except as expressly provided under this License. Any attempt otherwise to copy, modify, sublicense, or distribute it is void, and will automatically terminate your rights under this License.

   However, if you cease all violation of this License, then your license from a particular copyright holder is reinstated (a) provisionally, unless and until the copyright holder explicitly and finally terminates your license, and (b) permanently, if the copyright holder fails to notify you of the violation by some reasonable means prior to 60 days after the cessation.

   Moreover, your license from a particular copyright holder is reinstated permanently if the copyright holder notifies you of the violation by some reasonable means, this is the first time you have received notice of violation of this License (for any work) from that copyright holder, and you cure the violation prior to 30 days after your receipt of the notice.

   Termination of your rights under this section does not terminate the licenses of parties who have received copies or rights from you under this License. If your rights have been terminated and not permanently reinstated, receipt of a copy of some or all of the same material does not give you any rights to use it.

10. FUTURE REVISIONS OF THIS LICENSE

    The Free Software Foundation may publish new, revised versions of the GNU Free Documentation License from time to time. Such new versions will be similar in spirit to the present version, but may differ in detail to address new problems or concerns. See http://www.gnu.org/copyleft/.

    Each version of the License is given a distinguishing version number. If the Document specifies that a particular numbered version of this License "or any later version" applies to it, you have the option of following the terms and conditions either of that specified version or of any later version that has been published (not as a draft) by the Free Software Foundation. If the Document does not specify a version number of this License, you may choose any version ever published (not as a draft) by the Free Software Foundation. If the Document specifies that a proxy can decide which future versions of this License can be used, that proxy's public statement of acceptance of a version permanently authorizes you to choose that version for the Document.

11. RELICENSING

    "Massive Multiauthor Collaboration Site" (or "MMC Site") means any World Wide Web server that publishes copyrightable works and also provides prominent facilities for anybody to edit those works. A public wiki that anybody can edit is an example of such a server. A "Massive Multiauthor Collaboration" (or "MMC") contained in the site means any set of copyrightable works thus published on the MMC site.

    "CC-BY-SA" means the Creative Commons Attribution-Share Alike 3.0 license published by Creative Commons Corporation, a not-for-profit corporation with a principal place of business in San Francisco, California, as well as future copyleft versions of that license published by that same organization.

    "Incorporate" means to publish or republish a Document, in whole or in part, as part of another Document.

    An MMC is "eligible for relicensing" if it is licensed under this License, and if all works that were first published under this License somewhere other than this MMC, and subsequently incorporated in whole or in part into the MMC, (1) had no cover texts or invariant sections, and (2) were thus incorporated prior to November 1, 2008.

    The operator of an MMC Site may republish an MMC contained in the site under CC-BY-SA on the same site at any time before August 1, 2009, provided the MMC is eligible for relicensing.

ADDENDUM: How to use this License for your documents

To use this License in a document you have written, include a copy of the License in the document and put the following copyright and license notices just after the title page:

```
Copyright (C)  year  your name.
Permission is granted to copy, distribute and/or modify this document
under the terms of the GNU Free Documentation License, Version 1.3
or any later version published by the Free Software Foundation;
with no Invariant Sections, no Front-Cover Texts, and no Back-Cover
Texts.  A copy of the license is included in the section entitled ``GNU
Free Documentation License''.
```

If you have Invariant Sections, Front-Cover Texts and Back-Cover Texts, replace the "with...Texts." line with this:

```
with the Invariant Sections being list their titles, with
the Front-Cover Texts being list, and with the Back-Cover Texts
being list.
```

If you have Invariant Sections without Cover Texts, or some other combination of the three, merge those two alternatives to suit the situation.

If your document contains nontrivial examples of program code, we recommend releasing these examples in parallel under your choice of free software license, such as the GNU General Public License, to permit their use in free software.