Isovariant mappings of degree 1 and the Gap Hypothesis

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Abstract Unpublished results of S. Straus and W. Browder state that two notions of homotopy equivalence for manifolds with smooth group actions — isovariant and equivariant — often coincide under a condition called the Gap Hypothesis; the proofs use deep results in geometric topology. This paper analyzes the difference between the two types of maps from a homotopy theoretic viewpoint more generally for degree one maps if the manifolds satisfy the Gap Hypothesis, and it gives a more homotopy theoretic proof of the Straus-Browder result.

AMS Classification 55P91, 57S17; 55R91, 55S15, 55S91

Keywords Blakers-Massey Theorem, deleted cyclic reduced product, diagram category, diagram cohomology, equivariant mapping, Gap Hypothesis, group action, homotopy equivalence, isovariant mapping, normally straightened mapping

In order to motivate and explain our results more thoroughly, we shall begin with various pieces of background material. Readers who would rather focus on the main results and their proofs may go directly to Section 2.

1 Background

The `latex` document class file `gtart.cls` is intended for formatting articles for submission to *Geometry & Topology* and *Algebraic & Geometric Topology*. You are welcome to adapt it for any other purpose, but if you do adapt the file, then *please change its name*. If you use a modified version for formatting an article submitted to *Geometry & Topology* or *Algebraic & Geometric Topology*, then please submit the modified file as well.

To use `gtart.cls` collect a copy of the file [2] from the `gt/info/macros` subdirectory; install it on your system where `tex` can find it (eg in your working directory) and start your file with the line:

`\documentclass{gtart}`

Then type your file using standard `latex` structure. If you wish to use `amslatex` commands, add the following line:

`\usepackage{amsmath,amssymb}`

and then type your file exactly as if you were using `amsart` style.

If you are using `gtart.cls` to format an article for *Geometry & Topology* or *Algebraic & Geometric Topology* then:

> *Do not use any commands which alter page height or width or line-spacing or the headline or footline* eg `\texheight`, `\textwidth` or `\baselinestretch` or `\pagestyle`.

In use `gtart.cls` is virtually transparent and all the usual commands from `latex` article class and `amsart` class, respectively, are available. However there are differences in the layout of the title material for *Geometry & Topology* and *Algebraic & Geometric Topology* articles over the standard layout in `latex`; the commands are much the same, but you may need to adjust them to get a reasonnable layout. One point to note is that, with `gtart.cls`, the command `\maketitle` must come after the abstract, keywords and AMS classification numbers. For details here see section 2 below.

`gtart.cls` uses the `amsthm` package to set theorem style. If you are not already familiar with the facilities provided by this package then read section 3. The package allows you to use theorem-like environments in a very flexible way.

Important note `gtart.cls` can only be used with `latex2e`. If you are still using the original `latex` (now known as `latex2.09`) then you are strongly advised to upgrade your installation; `latex2e` is a much improved format.[1]

The base style for `gtart.cls` is `latex` 11pt article style and essential use is made of the `amsthm` package (part of the `amslatex` distribution). This package needs one other package from the `amslatex` distribution, namely `amsgen`. Thus in order to use `gtart.cls` you need `latex2e` and the two files `amsthm.sty` and `amsgen.sty`. You will probably find that these two files are already installed as part of the `latex2e` installation that you are using. If not, copies of both files can be collected from the `gt/info/macros` subdirectory [1].

[1] If you cannot upgrade, then use the template `gtlatex.old` [4], which contains basic instructions on formatting articles for *Geometry & Topology* and *Algebraic & Geometric Topology* using `latex2.09`.

Using gtart.cls to reformat existing articles

gtart.cls is also intended to act as a "drop-in" replacement for both latex {article} and amslatex {amsart} styles, ie to reformat an existing article written in either of these styles.

To use gtart.cls to reformat an article written in latex {article} style, collect a copy and install it as above. Then replace the
\documentclass[XX]{article}
declaration at the start of your file (where [XX] is eg [12pt]) with the line:

\documentclass{gtart}.

To use gtart.cls as a replacement for {amsart} class collect and install a copy and then replace \documentclass{amsart} at the start of your file with the *two* lines:

\documentclass{gtart}
\usepackage{amsmath,amssymb}.

If you are using gtart.cls to format an article for *Geometry & Topology* or *Algebraic & Geometric Topology* then:

> *Delete all commands which alter page height or width or line-spacing*
> eg \texheight, \textwidth or \baselinestretch.

Apart from these changes, you may find that the title page or header material needs adjustment and you may wish to take advantage of the facilities provided by the amsthm package. For details here, see sections 2 and 3 respectively.

If you are using gtart.cls to reformat an existing article then you will probably have to deal with overful \hbox's caused by the new line widths. *Please do not redefine* \textwidth *to overcome this problem.* Deal with overful \hbox's by using optional hyphens, reordering the wording, replacing 1–line displays with 2–line displays etc. For details consult a tex or latex primer.

There are several useful abbreviations that are provided by gtart.cls which we list below. All these commands can redefined if they clash with your own \newcommands. There are however a few new commands which must not be redefined (or the final format of the article will be incorrect). Here are lists of both:

Commands which *must not* be redefined

`\stdskip` : the standard vertical skip,
`\stdspace` : the standard horizontal space,
`\ppar` : principal paragraph break (roughly the same as `\par\medskip`,)
`\sqr` : the square macro used to generate the end-of-proof symbol.

The journal titles :
`\gt` : *Geometry & Topology*,
`\gtm` : *Geometry & Topology Monographs*,
`\agt` : *Algebraic & Geometric Topology.*

And also the ingredients of the header material namely `\title`, `\author` etc (see next section).

Commands which you may find useful but which may be redefined

`\nocolon` : which suppresses the colon in the `{figure}` environment (use it before `\caption`'s which contain no text),

`\qua` : abbreviation for `\stdspace` — three-quarters of a quad,

`\sh` : for subheadings, which produces a subheading in the correct style without a number. Eg the above heading was typed:
`\sh{Commands which ... redefined}`

`\rk` : for remarks, notes etc, which produces a subheading in the correct style without a number such that the text follows on directly. Eg the note on page 2 was typed:
`\rk{Important note} "gtart.cls" can only be used ...`

`\sq` : abbreviation for `\sqr55` (the end-of-proof symbol) which can also be called via `\qed`,
`\co` : abbreviation for `\colon\thinspace` which is a colon with correct spacing for maps,

`\np` : abbreviation for `\newpage`,
`\nl` : abbreviation for `\hfil\break` ie new line,
`\cl` : abbreviation for `\centerline`.

2 Header material

Geometry & Topology article style has a separate title page as first page of each article (always an odd numbered page) which contains the title, authors names and addresses, abstract, AMS classification numbers and keywords. The journal adds other information (publication date, page range etc) to this page when the article is published.

Algebraic & Geometric Topology article style has a shorter header containing just the title, authors names, abstract (set small), AMS classification numbers and keywords. The journal adds publication date and page range at publication. Authors addresses and the received date are given at the end of the article.

The layout of the *Geometry & Topology* header material is controlled by the `\maketitlepage` macro. To generate the title page, replace the normal `latex` command `\maketitle` with `\maketitlepage` which must come *after* the abstract, AMS classification numbers and keywords.

When the article is published, the journal will take the same information into a modified `\maketitlepage` macro which then adds the other information and the journal logo, and creates the published title page.

The layout of the *Algebraic & Geometric Topology* header material is controlled by the `\makeagttitle`. To generate the header, replace the normal `latex` command `\maketitle` with `\makeagttitle`, which again must come *after* the abstract, AMS classification numbers and keywords. You can also force `latex` to use *Geometry & Topology* or *Algebraic & Geometric Topology* style for the header material and also to produce running heads and feet similar to those which appear on the published article. This allows you to check the final appearance of your article. To do this type `\gtart` or `\agtart` near the start of the file (after `\documentclass{gtart}`). You do not need to replace your `\maketitle` command if you do this.

The information for the header material for both journal layouts is supplied in exactly the same way, which we now discuss.

Header information can be suplied in a number of equivalent ways, including both `latex {article}` style and `amsart` style. Here is a complete sample:

```
\begin{document}

\title[A short spoof paper]{A short spoof paper\\
with a two-line title}
\authors{Albert Einstein\\Leonardo da Vinci}

\address{IAS, Princeton}
\secondaddress{Renaissance\\Venice}
\email{ae@ias.princeton.edu}
\secondemail{ldv@ren.ven.hist}
```

```
\begin{abstract}

This is a short spoof paper typed on the template
{\tt gtlatex.tem} purely in order to illustrate its use.
As this is a rather short summary, here is some nonsense to
spin it out.

We prove that colours come in fifteen primary hyperbands; each
hyperband being supported by a James product \cite{James} and
controlled by a colour changing macro \cite{Knuth}.

\end{abstract}

\primaryclass{00-01, 00-02}
\secondaryclass{68-00, 68-01}
\keywords{Spoof, template, colour, hyperband, James product}

\maketitlepage
```

You can see the result by looking at the title page of [6] which is one of our sample files.

We now examine this sample in detail. First a general point; the control sequence \\ is used as standard “separator” — to separate lines in `\title` and `\address`, and to separate multiple authors, email addresses and URL's (see below). Turning now to the items in order. The title has an an optional parameter (in square brackets) which is the “short title” to be used for running heads. If this is not given, then the full title is used instead. You can also supply the short title separately thus:

```
\title{A short spoof paper\\with a two-line title}
\shorttitle{A short spoof paper}
```

The authors and addresses can be supplied singly or combined and in any order. Thus the following produces exactly the same effect:

```
\author{Albert Einstein}
\address{IAS, Princeton}
\email{ae@ias.princeton.edu

\secondauthor{Leonardo da Vinci}
\secondaddress{Renaissance\\Venice}
\secondemail{ldv@ren.ven.hist}
```

Web addresses (URL's) can also be given:

```
\url{http://www.ias.edu/~al\\http://www.ven.hist/~lvd}
```

and there are a variety of aliases. Eg `\author`, `\authors`, `\secondauthor` are all aliases thus

```
\secondauthor{Leonardo da Vinci}\author{Albert Einstein}
```

produces exactly the same result as

```
\authors{Leonardo da Vinci\\Albert Einstein}
```

with Leonardo first ! Similarly `\addresses` and `\address` are aliases, as are `\emails`, `\email`, `\emailaddr` and `\emailaddress` and `\url`, `\urls`, `\urladdr` and `\urladdress`. However `\secondaddress`, `\secondemail` and `\secondurl` behave slightly differently. In each case they produce the word "and" to separate the adresses. They are specifically intended for when there are precisely two authors (as in the example above). If there are three or more authors then either supply the information in one set or in three similar sets. Thus:

```
\authors{John Major\\Margaret Thatcher\\Harold Wilson}
\addresses{First\\Address\smallskip Second\\Address etc}
\emails{jm@11.downing.st\\mt@11.downing.st\\hw@11.downing.st}
```

or

```
\author{John Major}\address{First\\Address}\email{jm@11.d.s}
\author{M Thatcher}\address{First\\Address}\email{mt@11.d.s}
\author{H Wilson}\address{First\\Address}\email{hw@11.d.s}
```

Important note `\secondaddress`, `\secondemail` and `\secondurl` must not be used *except* as the final (usually the second) address etc. The macros will generate some very odd looking `tex` errors if you ignore this advice!

The author and address layout works well for one or two authors and (if addresses are short) for three authors. After that you will probably need to take some control "by hand". For example here is an excerpt from the title page information for a five-author paper which was formatted using `gtart.cls`:

```
\title{Ordering the braid groups}
\authors{Roger Fenn, Michael T~Greene, Dale Rolfsen\\
Colin Rourke, Bert Wiest}
\shortauthors{Fenn, Greene, Rolfsen, Rourke and Wiest}

\address{%
\rm Email:\stdspace \tt R.A.Fenn@sussex.ac.uk\ \
Michael.Greene@uk.radan.com\\rolfsen@math.ubc.ca\ \
cpr@maths.warwick.ac.uk\\ bertold@maths.warwick.ac.uk}
```

Here the five authors are displayed on two lines and only email addresses are given on the title page, with formatting controlled by hand. You can see the result at [5].

The abstract must be given inside the `abstract` environment as in the above example and finally AMS classification numbers (both primary and secondary) and keywords should be given. For compatibility with `amsart` style, `\subjclass` is an alias for `\primaryclass`, but at this point the file will probably have to be edited by hand, to separate out the primary and secondary classification numbers.

Notes (1) *Geometry & Topology* and *Algebraic & Geometric Topology* styles do not put thanks or dedications with the header material. Instead, you are recommended to collect these together with any other acknowlegdements at the end of your introduction.

If you use the commands `\thanks` or `\dedicatory`, you will get a helful message to this effect, and your thanks or dedications will not be printed.

(2) If you use multiple `\address` declarations then the addresses must contain only text and no control sequences other than `\\` or primitive commands. Thus if you want to format the addresses yourself, then make one single address including commands to specify your layout (as in the five-author example above). A similar remark applies to `\email` and `\url` declarations. Again you will get some very odd looking `tex` errors if you ignore this advice!

(3) To print author addresses (at the end of the paper for the *Algebraic & Geometric Topology* style) use the command `\Addresses`.

(4) There is a variant of the `\maketitlepage` macro, namely `\makeshorttitle` alias `\maketitle`. This typesets the heading material as a conventional head with author addresses and the abstract set small. If you are using these macros for typesetting an article not necessarily intended for *Geometry & Topology* or *Algebraic & Geometric Topology* then you will probably prefer to use this variant which produces a more conventional preprint. This set of instructions used `\makeshorttitle`.

3 Theorem style

Theorem style is set by the `amsthm` package. If you are familiar with the facilities offered by this package, then skim through this section and start reading again at section 3.

Using `amsthm`, the `\newtheorem` declarations are exactly the same as in other `latex` styles with one exception. There is a variant `\newtheorem*` which provides a theorem-like environment without numbering the theorem. This is useful for remarks, named theorems (eg Zorn's Lemma) etc. `\newtheorem` declarations are controlled by the current "theorem style". Thus if you type:

```
\theoremstyle{definition}
```

then subsequent `\newtheorem` declarations will define theorem-like environments in the "definition" style. There are two predefined theorem styles provided by `gtart.cls`:

(1) `\theoremstyle{plain}` which has heading bold and left justified, optional note bracketed in roman type and statement in slanted type.

(2) `\theoremstyle{definition}` alias `\theoremstyle{remark}` which has heading bold and left justified, optional note unbracketed in slanted type and statement in roman type.

`\theoremstyle{plain}` is recommended for theorems, lemmas, corollaries etc and is the default style, whilst `\theoremstyle{definition}` is recommended for definitions, remarks etc.

Here are some sample `\newtheorem` declarations:

```
\newtheorem{thm}{Theorem}[section]        % (1)
\newtheorem{lem}[thm]{Lemma}              % (2)
\newtheorem*{zlem}{Zorn's Lemma}          % (3)
\theoremstyle{definition}
\newtheorem{defn}[thm]{Definition}        % (4)
\newtheorem*{rem}{Remark}                 % (5)
```

In order these define:

(1) a standard theorem environment with numbering of the style **7.3** (result number 3 in section 7),

(2) a standard lemma environment with numbering consecutive to theorems,

(3) a special unnumbered lemma called **Zorn's lemma**,

(4) a numbered definition environment with numbering consecutive to theorems and lemmas,

(5) an unnumbered environment for remarks.

Note that (1), (2) and (3) are in default style `theoremstyle{plain}` and this does not need to be declared.

Here are some samples in order:

Theorem 3.1 (Sample (1)) *This is the first theorem.*

Lemma 3.2 (Sample (2)) *This is the first lemma.*

Zorn's Lemma *Sample (3)* Here is Zorn's lemma.

Definition 3.3 *Sample (4)* This is the first definition.

Remark *Sample (5)* This completes the samples.

These were typed:

```
\begin{thm}[Sample (1)]
This is the first theorem.\end{thm}
\begin{lem}[Sample (2)]
This is the first lemma.\end{lem}
\begin{zlem}[Sample (3)]
Here is Zorn's lemma.\end{zlem}
\begin{defn}[Sample (4)]
This is the first definition.\end{thm}
\begin{rem}[Sample (5)]
This completes the samples.\end{rem}
```

You can define your own theorem styles using a `\newtheoremstyle` declaration. Here is an example which you may find useful:

```
\newtheoremstyle{bold}{14pt plus6pt minus6pt}%
{6pt plus3pt minus3pt}{\bf}{}{\bf}{}{1em}%
{\thmname{#1}\thmnumber{#2}\thmnote{\bf\stdspace[#3]}}
```

which defines a theorem style similar to `remark` except that both the optional theorem note and the theorem statememts are set in bold type (with the note enclosed in square brackets) and there is no space between theorem name and number but there is a quad (1em) of space after the theorem head.

The nine parameters are in order: name `{bold}`, space before theorem, space after theorem,[2] font for theorem body (`\bf`), indent (zero), font for theorem head (`\bf`), punctuation (nothing), space after the theorem head (1em) and finally a detailed specification of how to set out the theorem head and optional note. The above sample specifies theorem name first, then the theorem number (with no space between) then (finally and optionally) a `\stdspace` (standard

[2]Note the `\parskip` (6pt) gets added to space after, so these spaces are nearly the same!

space of 0.75em) followed by the note square bracketed in bold type. For more examples, read the source code for `gtart.cls` where the theorem styles `plain`, `remark` and `definition` are defined.

Here is a example of the use of the `bold` style to provide subsection headings with numbering consecutive with theorems etc:

3.4 [Sample (6)] Sample subsection head

which was typed:

```
\theoremstyle{bold}
\newtheorem{sshead}[thm]{}
\begin{sshead}[Sample (6)]Sample subsection head\end{sshead}
```

The point is that the `\newtheorem` declaration provides an empty theorem name so the number comes directly at the left margin.

Proof style

The `amsthm` package also provides a flexible environment for proofs. If you type:

```
\begin{proof}
This is a sample proof.
\end{proof}
```

this is the result:

Proof This is a sample proof. □

But you can change the name of the proof without altering the layout by inserting an optional proof name thus:

```
\begin{proof}[Proof of sample theorem]
This is a sample proof.
\end{proof}
```

with this result:

Proof of sample theorem This is a sample proof. □

4 Bibliography style

Geometry & Topology has an established style for setting out the bibliography. References are numbered in alphabetical order. Authors are set in bold face. The principal title of the reference is set in italic face and all then rest is set in standard face. See any of our sample files for examples. If you use `bibtex` then you can automatically set your bibliography in house style by using the *Geometry & Topology* bibliography style file `gtart.bst` [3].

Algebraic & Geometric Topology has a more relaxed bibliography style but authors are still recommended to use `gtart.bst` if possible.

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