Autonomous Robots

Disambiguation of Human Intent Through Control Space Selection

--Manuscript Draft--

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Abstract:	Assistive shared-control robots have the potential to transform the lives of millions of people afflicted with severe motor impairments as a result of spinal cord or brain injuries. The effectiveness and usefulness of shared-control robots is closely related to their ability to infer the user's needs and intentions and is often a limiting factor for providing appropriate assistance quickly, confidently and accurately. The contributions of this paper are three-fold: first, we propose a goal disambiguation algorithm which enhances the intent inference and assistive capabilities of a shared-control assistive robotic arm. Second, we introduce a novel intent inference algorithm that works in conjunction with the disambiguation scheme, inspired by dynamic field theory in which the time evolution of the probability distribution over goals is specified as a dynamical system. Third, we present a pilot human subject study to evaluate the efficacy of the disambiguation system. This study was performed with eight subjects. Our results suggest that (a) the disambiguation system has a greater utility value as the control interface becomes more limited and the task becomes more complex, (b) subjects demonstrated a diverse range of disambiguation request behavior with a greater concentration in the earlier parts of the trial and (c) there are no differences in the onset of robot assistance between different mode switching paradigms across tasks or across interfaces.
Response to Reviewers:	Response to Reviewers – Paper Submission (AURO-D-17-00250) Title: Disambiguation of Human Intent Through Control Space Selection We sincerely thank all the reviewers for taking the time to provide us with useful feedback and insight. We will be responding to all the major concerns raised by each reviewer separately and will discuss the relevant changes that have been incorporated in the revised version of the document. All minor comments (e.g. grammar typos) have been incorporated into the text. Please also find attached to this letter a version of the article with all changes marked in blue. The summary of our major changes are as follows. (1) We have made significant

changes to the text that aim to improve the clarity and rigor of our writing, and to motivate the problem more clearly. (2) We have clarified the intuition behind our approach and choice of disambiguation metric. (3) We have presented new results, that compare our dynamic field theory based intent inference approach to a Bayesian inference approach used widely in shared autonomy settings. (4) We have included previously omitted survey results from our subject study, highlighting users' perception of our disambiguation system. We believe these changes to have significantly improved the quality of the paper. We again thank the reviewers, and look forward to their feedback.

Response to Guest Editor:

(1) Improve clarity and rigor

Throughout the text, we have made significant changes with the aim of addressing clarity, rigor and motivation. (To help spot these changes, all modifications to the text are marked in the version of the article attached to this letter.) We have also provided more explanation as to the intuition behind our approach, thereby addressing some of the concerns raised by Reviewers #1 and #3 (Section 3.1).

(2) Baseline comparison

In this version of the article, we have implemented a Bayesian inference approach often used in the shared autonomy literature, and provide a qualitative comparison to our dynamic field theory based intent inference approachWe provide intuition on under what conditions the approaches perform similarly and differently, and provide data on an illustrative example (Section 4.2).

Regarding information gain, we agree that an information theoretic notion of entropy could also be used to solve the disambiguation problem---and towards this end, we have added text to this revision on the topic of information theory. In this article we introduce the idea of control subspace selection for the purpose of intent disambiguation. As a first exploration of this idea, we took the approach of investigating what features of shape of the probability distribution over goals can be most beneficial for intent disambiguation purposes. We note that a change in entropy of a distribution is typically accompanied by a change in the contour/shape of the distribution. Therefore, by designing a disambiguation heuristic such as the one presented in this paper, we get to have a closer look at which low-level features of the distribution contribute the most to the intent disambiguation. Using information theoretic ideas would be the next step in our work.

(3) Intuition and clarity

We have added and revised text with the aim of providing more intuition for our choice of metrics and approach (Section 3.1). (Again, this text is marked in blue in the attached document.)

(4) Discussion addressing Reviewer #2's concerns regarding the experimental validation

We have presented clarifications for Reviewer #2's concerns regarding the experimental validations, especially with respect to baseline comparison of our intent inference approach to Bayesian schemes (Section 4.2). We have also included survey results that support some of our claims regarding how the disambiguation system helped in easier task execution (Section 7.4).

Reviewer #1

a. Further analysis is required

In the current version of the paper, we have supplemented our analysis by including previously omitted user survey results, which indicate that the users generally found task execution to be easier when controlling the robot in the disambiguating control modes that the algorithm selected (Section 7.4). In the revised version, we also

supplement our analysis of the efficacy of the intent inference algorithm by presenting some baseline comparisons to a standard Bayesian approach found used commonly in shared-control domain (Section 4.2).

b. Detailed analysis for intent inference

In this revised version, we have included a baseline comparison of our dynamic field theory based intent inference approach to a standard Bayesian inference scheme (Dragan et al., 2013) widely used in the shared autonomy literature (Section 4.2). This comparison includes both a qualitative discussion, as well as an illustrative example in which there are three discrete goals and the user teleoperates and moves the robot to each one of the objects sequentially. In general, we found performance between the two approaches to be similar, except in scenarios where the Bayesian approach's delta function collapsed (as in the figure shown in the paper). We were unable to uncover any scenarios in which our DFT approach performed worse than the Bayesian appoach.

c. User perception of disambiguation system

We have included the results of a user survey from our subject study, highlighting users' perception of our disambiguation system. Subjects were asked to fill out a questionnaire after each task in which they evaluated the system and reported how much they liked to operate the robot in the control modes selected by the algorithm (section 7.4).

d. The paper states that "a higher value [of the mode of the probability distribution] implies that the robot has a good idea," however this is not always true.

We agree with the reviewer, and believe that there in fact has been a misinterpretation due to a lack of clarity on our part, which we hope has been resolved in the current revision of the text. Our claim is that higher probability indicates a higher confidence in the robot's prediction (and not that a higher distribution mode will result in better disambiguation). It is precisely because of the reasons mentioned by the reviewer that we consider other features (the remaining 3 components/features) of the probability distribution as well, to determine which control mode has higher disambiguation capabilities. In the current version of the text we have clarified the intuition behind the choice of the different features that inform the disambiguation metric (Section 3.5). (In short, a single feature by itself is unlikely to disambiguate the goals. But by considering multiple features in a combined fashion, it adds to the disambiguation power.)

e. In Fig. 3..., One way to improve it might be to visualize only one goal and illustrate the change of confidence for one goal.

We thank the reviewer for this suggestion. After careful consideration however, in the present version of the document have decided to retain the three goals, because disambiguation is more relevant when there are multiple goals (or else there is nothing to disambiguate between). The shaded bars indicate how the probabilities vary for robot motion along each dimension. For this illustration we use a simple directedness-based heuristic to determine the probabilities.

f. Fig. 4 is not clear; why is best control dimension x in the right column? I suggest simplifying it using only two goals. Also, how are the C1 and C2 specified? It appears that some information was omitted from the RSS version of this work.

Our reason for choosing four goals is to illustrate the robustness of the disambiguation algorithm in identifying disambiguating control dimensions effectively in a scene with higher number of goals. Intent disambiguation typically becomes harder as the number of potential goals in the scene increase. With two goals, the disambiguation problem in many cases becomes trivial. As mentioned in the figure caption, the right column shows those parts of the workspace in which the best disambiguating control dimension is Z. Due to space constraints we have referred our readers to our original RSS paper for detailed specifications of what the two confidence functions (C1 and C2) are. However, the figure caption does mention that C1 and C2 correspond to an

instantaneous proximity-based and directedness-based heuristic confidence function.

g. I suggest that the authors extend their related work section with recent studies on shared autonomy (see recent survey by Javdani et al., "Shared Autonomy via Hindsight Optimization for Teleoperation and Teaming").

We have taken this into account and revised our related work section accordingly.

Reviewer #2

a. Why not Information Theoretic alternatives?

We agree with the reviewer about the utility of information theoretic concepts in relation to the problem posed in our article, and have expanded the discussion information theoretic concepts for the purposes of active learning and information gathering actions in the related work section.

In this article we introduce the idea of control subspace selection for the purpose of intent disambiguation. As a first exploration of this idea, our motivation is to investigate what aspects/features of the probability distribution over goals (more precisely, the shape of the distribution) inform intent disambiguation the most. A change in entropy is typically accompanied by a change in the shape of the probability distribution over goals. We take a bottom-up approach wherein we investigate how the shape of the probability distribution evolves as the user operates the robot and moves it in space. We hand-engineer four different features (components) that characterize different aspects of the shape of the distribution based on empirical insights we had during our algorithm design phase. The combination of these individual components into a single disambiguation metric is also a design decision, but carefully done in such a way that higher values of the disambiguation metric would imply greater disambiguation capability. Using information theoretic ideas would be the next step in our work.

b. Erroneous claims regarding the metric?

We respectfully disagree with the statement that this is erroneous. By virtue of design, a higher value of the metric indeed corresponds to better intent disambiguation and therefore the intent inference mechanism will be able to infer the human's intent unambiguously and accurately. We have made this aspect clear in the revised text to avoid any potential misunderstanding in interpretation (Section 3.5 – 5)).

c. Why not Bayesian?

We agree that a clear motivation for the development of our new intent inference approach was missing from the article, and thank the reviewer for pointing this out. The proposed dynamic field theory based system for intent inference is an alternative to Bayesian and other heuristic approaches. We have added text to the beginning of Section 4.1 that motivates our development of this alternative, as well as a comparison in Section 4.2 to a Bayesian approach from the shared control literature.

In addition to the new text in Section 4.1, we note that while it is true that if a process is truly finite-order Markovian then the state is a 'sufficient statistic', for human-robot interaction in the context of assistive robotics this assumption is not always correct. Furthermore, in a Bayesian scheme, if at any time-step the likelihood is peaked (a delta function), it can result in the collapse of the posterior to a single value, thereby eliminating any memory trace.
By framing the evolution of the probability distribution as a dynamical system, our method is similar to approaches in which recurrent neural nets are used for intent inference purposes (except in our case we hand-engineer the features that drive the dynamical system).

d. Benchmarking of proposed work.

In the revised version we have provided baseline comparison of our intent inference mechanism and a Bayesian approach that is widely used in shared autonomy setting

	(proposed by Dragan et al. (2013)). We have provided a qualitative comparison through an illustrative example, and discussion of the mathematical underpinings of each approach (Section 4.2). In essence, our approach, relies on the features of the raw input to determine how the probability distribution should evolve in time and does not assume that the human behaves optimally. This is crucial in the setting of assistive robotic manipulation, in which subjects have inherent motor limitations that make optimal behavior an unrealistic assumption. e. Experimental Validation In the present version of the work, we have included previously omitted user survey results from our subject study (Section 7.4). The survey results indicate that the subjects did find task execution to be easier when operating the robot in disambiguating control modes. Reviewer #3 a. There are a few run-on sentences throughout the work. Please make sure all sentences are clear and concise. Similarly, there are a few very long paragraphs that could be broken up to best present one idea at a time. There are a few widows and orphans (hanging words or phrases). For aesthetic purposes, please watch for unnecessary white space. Thank you for the suggestions. We have taken them into consideration and have revised our work accordingly. b. Mathematical Notation We have clarified our math notation to avoid ambiguity. c. There are a lot of equations that were selected to fit the task / goals of this work, but it might be nice to add a little intuition about how you selected these parameters (and maybe what didn't work) so readers can get useful insight from your work. We have included text throughout the article with the aim of providing more intuition. Please see in particular Sections 3.5, and also Section 8 for a discussion of what did not work well. (d) Can you compare your methods to some baseline techniques for intent / goal inference? The results show how well your approach works, but doesn't give compare to baselines. We have provided a baseline comparison to a standard heuristic Bayesian approach (Dragan et al. (2013)). A qualitative comparison through an illustrative example, and discussion of the mathematical underpinings of each approach, can now be found in Section 4.2. (e) Please discuss how this would be useful in other applications (e.g. how would this extend to cases where there are less discrete goals) so readers can gain insight and use it in their work. We thank the reviewer for the suggestion, and have included the discussion in Section 8.

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\origjot=\skip59
\l_MT_shortvdotswithinadjustabove_dim=\dimen136
\l_MT_shortvdotswithinadjustbelow_dim=\dimen137
\l_MT_above_intertext_sep=\dimen138
\l_MT_below_intertext_sep=\dimen139
\l_MT_above_shortintertext_sep=\dimen140
\l_MT_below_shortintertext_sep=\dimen141
) (c:/TeXLive/2015/texmf-dist/tex/latex/bbm-macros/bbm.sty
Package: bbm 1999/03/15 V 1.2 provides fonts for set symbols - TH
```

```
LaTeX Font Info:    Overwriting math alphabet `\mathbbm' in version
`bold'
(Font)                  U/bbm/m/n --> U/bbm/bx/n on input line 33.
LaTeX Font Info:    Overwriting math alphabet `\mathbbmss' in version
`bold'
(Font)                  U/bbmss/m/n --> U/bbmss/bx/n on input line 35.
) (c:/TeXLive/2015/texmf-dist/tex/latex/lipsum/lipsum.sty
Package: lipsum 2014/07/27 v1.3 150 paragraphs of Lorem Ipsum dummy text
\c@lips@count=\count135
) (c:/TeXLive/2015/texmf-dist/tex/latex/adjustbox/adjustbox.sty
Package: adjustbox 2012/05/21 v1.0 Adjusting TeX boxes (trim, clip, ...)
(c:/TeXLive/2015/texmf-dist/tex/latex/adjustbox/adjcalc.sty
Package: adjcalc 2012/05/16 v1.1 Provides advanced setlength with
multiple back
-ends (calc, etex, pgfmath)
) (c:/TeXLive/2015/texmf-dist/tex/latex/adjustbox/trimclip.sty
Package: trimclip 2012/05/16 v1.0 Trim and clip general TeX material
(c:/TeXLive/2015/texmf-dist/tex/latex/collectbox/collectbox.sty
Package: collectbox 2012/05/17 v0.4b Collect macro arguments as boxes
\collectedbox=\box36
)
\tc@llx=\dimen142
\tc@lly=\dimen143
\tc@urx=\dimen144
\tc@ury=\dimen145
Package trimclip Info: Using driver 'tc-pdftex.def'.
(c:/TeXLive/2015/texmf-dist/tex/latex/adjustbox/tc-pdftex.def
File: tc-pdftex.def 2012/05/13 v1.0 Clipping driver for pdftex
))
\adjbox@Width=\dimen146
\adjbox@Height=\dimen147
\adjbox@Depth=\dimen148
\adjbox@Totalheight=\dimen149
(c:/TeXLive/2015/texmf-dist/tex/latex/ifoddpage/ifoddpage.sty
Package: ifoddpage 2011/09/13 v1.0 Conditionals for odd/even page
detection
\c@checkoddpage=\count136
) (c:/TeXLive/2015/texmf-dist/tex/latex/varwidth/varwidth.sty
Package: varwidth 2009/03/30 ver 0.92;  Variable-width minipages
\@vwid@box=\box37
\sift@deathcycles=\count137
\@vwid@loff=\dimen150
\@vwid@roff=\dimen151
)) (c:/TeXLive/2015/texmf-dist/tex/latex/wrapfig/wrapfig.sty
\wrapoverhang=\dimen152
\WF@size=\dimen153
\c@WF@wrappedlines=\count138
\WF@box=\box38
\WF@everypar=\toks29
Package: wrapfig 2003/01/31  v 3.6
) (c:/TeXLive/2015/texmf-dist/tex/latex/multirow/multirow.sty
\bigstrutjot=\dimen154
) (c:/TeXLive/2015/texmf-dist/tex/latex/preprint/balance.sty
Package: balance 1999/02/23 4.3 (PWD)
```

```
\oldvsize=\dimen155
) (c:/TeXLive/2015/texmf-dist/tex/latex/url/url.sty
\Urlmuskip=\muskip11
Package: url 2013/09/16  ver 3.4  Verb mode for urls, etc.
) (c:/TeXLive/2015/texmf-dist/tex/latex/microtype/microtype.sty
Package: microtype 2013/05/23 v2.5a Micro-typographical refinements (RS)
\MT@toks=\toks30
\MT@count=\count139
LaTeX Info: Redefining \textls on input line 766.
\MT@outer@kern=\dimen156
LaTeX Info: Redefining \textmicrotypecontext on input line 1285.
\MT@listname@count=\count140
(c:/TeXLive/2015/texmf-dist/tex/latex/microtype/microtype-pdftex.def
File: microtype-pdftex.def 2013/05/23 v2.5a Definitions specific to
pdftex (RS)

LaTeX Info: Redefining \lsstyle on input line 915.
LaTeX Info: Redefining \lslig on input line 915.
\MT@outer@space=\skip60
)
Package microtype Info: Loading configuration file microtype.cfg.
(c:/TeXLive/2015/texmf-dist/tex/latex/microtype/microtype.cfg
File: microtype.cfg 2013/05/23 v2.5a microtype main configuration file
(RS)
! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
                                                  \def #3{#6}\expandafter
\e...
l.64    }

I'm ignoring this; it doesn't match any \if.

! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
                                                  \def #3{#6}\expandafter
\e...
l.64    }

I'm ignoring this; it doesn't match any \if.

! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
                                                  \def #3{#6}\expandafter
\e...
l.64    }

I'm ignoring this; it doesn't match any \if.

! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
                                                  \def #3{#6}\expandafter
\e...
l.64    }
```

```
I'm ignoring this; it doesn't match any \if.

! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
                                                 \def #3{#6}\expandafter
\e...
l.64    }

I'm ignoring this; it doesn't match any \if.

! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
                                                 \def #3{#6}\expandafter
\e...
l.71    }

I'm ignoring this; it doesn't match any \if.

! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
                                                 \def #3{#6}\expandafter
\e...
l.71    }

I'm ignoring this; it doesn't match any \if.

! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
                                                 \def #3{#6}\expandafter
\e...
l.71    }

I'm ignoring this; it doesn't match any \if.

! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
                                                 \def #3{#6}\expandafter
\e...
l.71    }

I'm ignoring this; it doesn't match any \if.

! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
                                                 \def #3{#6}\expandafter
\e...
l.71    }

I'm ignoring this; it doesn't match any \if.

! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
                                                 \def #3{#6}\expandafter
\e...
```

```
l.81    }

I'm ignoring this; it doesn't match any \if.

! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
                                                    \def #3{#6}\expandafter
\e...
l.81    }

I'm ignoring this; it doesn't match any \if.

! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
                                                    \def #3{#6}\expandafter
\e...
l.81    }

I'm ignoring this; it doesn't match any \if.

! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
                                                    \def #3{#6}\expandafter
\e...
l.81    }

I'm ignoring this; it doesn't match any \if.

! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
                                                    \def #3{#6}\expandafter
\e...
l.81    }

I'm ignoring this; it doesn't match any \if.

! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
                                                    \def #3{#6}\expandafter
\e...
l.86    }

I'm ignoring this; it doesn't match any \if.

! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
                                                    \def #3{#6}\expandafter
\e...
l.86    }

I'm ignoring this; it doesn't match any \if.

! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
```

```
                                                  \def #3{#6}\expandafter
\e...
l.86    }

I'm ignoring this; it doesn't match any \if.

! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
                                                  \def #3{#6}\expandafter
\e...
l.86    }

I'm ignoring this; it doesn't match any \if.

! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
                                                  \def #3{#6}\expandafter
\e...
l.86    }

I'm ignoring this; it doesn't match any \if.

! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
                                                  \def #3{#6}\expandafter
\e...
l.89    { font = */*/*/*/* }

I'm ignoring this; it doesn't match any \if.

! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
                                                  \def #3{#6}\expandafter
\e...
l.89    { font = */*/*/*/* }

I'm ignoring this; it doesn't match any \if.

! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
                                                  \def #3{#6}\expandafter
\e...
l.89    { font = */*/*/*/* }

I'm ignoring this; it doesn't match any \if.

! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
                                                  \def #3{#6}\expandafter
\e...
l.89    { font = */*/*/*/* }

I'm ignoring this; it doesn't match any \if.
```

```
! Extra \else.
\XKV@wh@list ...r \expandafter \XKV@wh@list \else
                                                  \def #3{#6}\expandafter
\e...
l.89    { font = */*/*/*/* }

I'm ignoring this; it doesn't match any \if.

)) (c:/TeXLive/2015/texmf-dist/tex/latex/algorithms/algorithm.sty
Package: algorithm 2009/08/24 v0.1 Document Style `algorithm' - floating
enviro
nment
\@float@every@algorithm=\toks31
\c@algorithm=\count141
) (c:/TeXLive/2015/texmf-dist/tex/latex/algorithms/algorithmic.sty
Package: algorithmic 2009/08/24 v0.1 Document Style `algorithmic'
\c@ALC@unique=\count142
\c@ALC@line=\count143
\c@ALC@rem=\count144
\c@ALC@depth=\count145
\ALC@tlm=\skip61
\algorithmicindent=\skip62
) (c:/TeXLive/2015/texmf-dist/tex/latex/breqn/breqn.sty
(c:/TeXLive/2015/texmf-
dist/tex/latex/l3kernel/expl3.sty
Package: expl3 2016/03/28 v6468 L3 programming layer (loader)
(c:/TeXLive/2015/texmf-dist/tex/latex/l3kernel/expl3-code.tex
Package: expl3 2016/03/28 v6468 L3 programming layer (code)
L3 Module: l3bootstrap 2016/02/12 v6412 L3 Bootstrap code
L3 Module: l3names 2016/03/11 v6433 L3 Namespace for primitives
L3 Module: l3basics 2015/11/22 v6315 L3 Basic definitions
L3 Module: l3expan 2015/09/10 v5983 L3 Argument expansion
L3 Module: l3tl 2016/03/26 v6465 L3 Token lists
L3 Module: l3str 2016/03/24 v6441 L3 Strings
L3 Module: l3seq 2015/08/05 v5777 L3 Sequences and stacks
L3 Module: l3int 2016/03/24 v6441 L3 Integers
\c_max_int=\count146
\l_tmpa_int=\count147
\l_tmpb_int=\count148
\g_tmpa_int=\count149
\g_tmpb_int=\count150
L3 Module: l3quark 2015/08/17 v5855 L3 Quarks
L3 Module: l3prg 2015/11/01 v6216 L3 Control structures
\g__prg_map_int=\count151
L3 Module: l3clist 2015/09/02 v5901 L3 Comma separated lists
L3 Module: l3token 2016/03/26 v6465 L3 Experimental token manipulation
L3 Module: l3prop 2016/01/05 v6366 L3 Property lists
L3 Module: l3msg 2016/03/26 v6464 L3 Messages
L3 Module: l3file 2016/03/25 v6458 L3 File and I/O operations
\l_iow_line_count_int=\count152
\l__iow_target_count_int=\count153
\l__iow_current_line_int=\count154
\l__iow_current_word_int=\count155
\l__iow_current_indentation_int=\count156
```

```
L3 Module: l3skip 2016/01/05 v6366 L3 Dimensions and skips
\c_zero_dim=\dimen157
\c_max_dim=\dimen158
\l_tmpa_dim=\dimen159
\l_tmpb_dim=\dimen160
\g_tmpa_dim=\dimen161
\g_tmpb_dim=\dimen162
\c_zero_skip=\skip63
\c_max_skip=\skip64
\l_tmpa_skip=\skip65
\l_tmpb_skip=\skip66
\g_tmpa_skip=\skip67
\g_tmpb_skip=\skip68
\c_zero_muskip=\muskip12
\c_max_muskip=\muskip13
\l_tmpa_muskip=\muskip14
\l_tmpb_muskip=\muskip15
\g_tmpa_muskip=\muskip16
\g_tmpb_muskip=\muskip17
L3 Module: l3keys 2015/11/17 v6284 L3 Key-value interfaces
\g__keyval_level_int=\count157
\l_keys_choice_int=\count158
L3 Module: l3fp 2016/03/26 v6465 L3 Floating points
\c__fp_leading_shift_int=\count159
\c__fp_middle_shift_int=\count160
\c__fp_trailing_shift_int=\count161
\c__fp_big_leading_shift_int=\count162
\c__fp_big_middle_shift_int=\count163
\c__fp_big_trailing_shift_int=\count164
\c__fp_Bigg_leading_shift_int=\count165
\c__fp_Bigg_middle_shift_int=\count166
\c__fp_Bigg_trailing_shift_int=\count167
L3 Module: l3box 2015/08/09 v5822 L3 Experimental boxes
\c_empty_box=\box39
\l_tmpa_box=\box40
\l_tmpb_box=\box41
\g_tmpa_box=\box42
\g_tmpb_box=\box43
L3 Module: l3coffins 2016/03/24 v6440 L3 Coffin code layer
\l__coffin_internal_box=\box44
\l__coffin_internal_dim=\dimen163
\l__coffin_offset_x_dim=\dimen164
\l__coffin_offset_y_dim=\dimen165
\l__coffin_x_dim=\dimen166
\l__coffin_y_dim=\dimen167
\l__coffin_x_prime_dim=\dimen168
\l__coffin_y_prime_dim=\dimen169
\c_empty_coffin=\box45
\l__coffin_aligned_coffin=\box46
\l__coffin_aligned_internal_coffin=\box47
\l_tmpa_coffin=\box48
\l_tmpb_coffin=\box49
\l__coffin_display_coffin=\box50
\l__coffin_display_coord_coffin=\box51
```

```
\l__coffin_display_pole_coffin=\box52
\l__coffin_display_offset_dim=\dimen170
\l__coffin_display_x_dim=\dimen171
\l__coffin_display_y_dim=\dimen172
L3 Module: l3color 2014/08/23 v5354 L3 Experimental color support
L3 Module: l3sys 2015/09/25 v6087 L3 Experimental system/runtime
functions
L3 Module: l3candidates 2016/03/25 v6456 L3 Experimental additions to
l3kernel
\l__box_top_dim=\dimen173
\l__box_bottom_dim=\dimen174
\l__box_left_dim=\dimen175
\l__box_right_dim=\dimen176
\l__box_top_new_dim=\dimen177
\l__box_bottom_new_dim=\dimen178
\l__box_left_new_dim=\dimen179
\l__box_right_new_dim=\dimen180
\l__box_internal_box=\box53
\l__coffin_bounding_shift_dim=\dimen181
\l__coffin_left_corner_dim=\dimen182
\l__coffin_right_corner_dim=\dimen183
\l__coffin_bottom_corner_dim=\dimen184
\l__coffin_top_corner_dim=\dimen185
\l__coffin_scaled_total_height_dim=\dimen186
\l__coffin_scaled_width_dim=\dimen187
L3 Module: l3luatex 2016/03/26 v6465 L3 Experimental LuaTeX-specific
functions
) (c:/TeXLive/2015/texmf-dist/tex/latex/l3kernel/l3pdfmode.def
File: l3pdfmode.def 2016/03/26 v6465 L3 Experimental driver: PDF mode
\l__driver_color_stack_int=\count168
))
Package: breqn 2015/08/11 v0.98d Breaking equations
(c:/TeXLive/2015/texmf-dist/tex/latex/breqn/flexisym.sty
Package: flexisym 2015/08/11 v0.98d Make math characters macros
LaTeX Info: Redefining \textprime on input line 299.
LaTeX Info: Redefining \not on input line 357.
(c:/TeXLive/2015/texmf-dist/tex/latex/breqn/cmbase.sym
File: cmbase.sym 2007/12/19 v0.92
LaTeX Info: Redefining \hbar on input line 324.
LaTeX Info: Redefining \surd on input line 326.
LaTeX Info: Redefining \angle on input line 334.
LaTeX Info: Redefining \neq on input line 335.
LaTeX Info: Redefining \mapsto on input line 336.
LaTeX Info: Redefining \cong on input line 337.
LaTeX Info: Redefining \notin on input line 340.
LaTeX Info: Redefining \rightleftharpoons on input line 341.
LaTeX Info: Redefining \doteq on input line 342.
LaTeX Info: Redefining \hookrightarrow on input line 343.
LaTeX Info: Redefining \hookleftarrow on input line 344.
LaTeX Info: Redefining \bowtie on input line 345.
LaTeX Info: Redefining \models on input line 346.
LaTeX Info: Redefining \Longrightarrow on input line 347.
LaTeX Info: Redefining \longrightarrow on input line 348.
LaTeX Info: Redefining \Longleftarrow on input line 349.
```

```
LaTeX Info: Redefining \longleftarrow on input line 350.
LaTeX Info: Redefining \longmapsto on input line 351.
LaTeX Info: Redefining \longleftrightarrow on input line 352.
LaTeX Info: Redefining \Longleftrightarrow on input line 353.
LaTeX Info: Redefining \cdots on input line 357.
LaTeX Info: Redefining \vdots on input line 360.
LaTeX Info: Redefining \ddots on input line 365.
) (c:/TeXLive/2015/texmf-dist/tex/latex/breqn/mathstyle.sty
Package: mathstyle 2015/08/11 v0.98d Tracking mathstyle implicitly
LaTeX Info: Redefining \displaystyle on input line 93.
LaTeX Info: Redefining \textstyle on input line 95.
LaTeX Info: Redefining \scriptstyle on input line 97.
LaTeX Info: Redefining \scriptscriptstyle on input line 99.
LaTeX Info: Redefining \genfrac on input line 145.
))
\inf@bad=\count169
\maxint=\count170
\listwidth=\dimen188
\eqnumsep=\dimen189
\eqmargin=\dimen190
\eqlinespacing=\skip69
\eqlineskip=\skip70
\eqlineskiplimit=\dimen191
\eqbinoffset=\muskip18
\eqdelimoffset=\muskip19
\eqindentstep=\dimen192
\eqstyle=\toks32
\eqbreakdepth=\count171
\eqinterlinepenalty=\count172
\intereqpenalty=\count173
\intereqskip=\skip71
\prerelpenalty=\count174
\prebinoppenalty=\count175
\Dmedmuskip=\muskip20
\Dthickmuskip=\muskip21
\eqleftskip=\skip72
\eqrightskip=\skip73
\eq@vspan=\skip74
\eq@binoffset=\muskip22
\EQ@box=\box54
\EQ@copy=\box55
\EQ@numbox=\box56
\eq@wdNum=\dimen193
\GRP@numbox=\box57
\grp@wdNum=\dimen194
\eq@lines=\count176
\eq@curline=\count177
\eq@badness=\count178
\EQ@vims=\count179
\eq@dp=\dimen195
\eq@wdL=\dimen196
\eq@wdT=\dimen197
\eq@wdMin=\dimen198
\grp@wdL=\dimen199
```

```
\grp@wdR=\dimen256
\grp@wdT=\dimen257
\eq@wdRmax=\dimen258
\eq@firstht=\dimen259
\eq@wdCond=\dimen260
\eq@indentstep=\dimen261
\eq@linewidth=\dimen262
\grp@linewidth=\dimen263
\eq@hshift=\dimen264
\eq@given@sidespace=\dimen265
\eq@final@linecount=\count180
\eq@wdR=\dimen266
\EQ@continue=\toks33
\lr@level=\count181
\GRP@queue=\toks34
\GRP@box=\box58
\GRP@wholebox=\box59
\darraycolsep=\skip75
\cur@row=\count182
\cur@col=\count183
\conditionsep=\skip76
) (c:/TeXLive/2015/texmf-dist/tex/latex/footmisc/footmisc.sty
Package: footmisc 2011/06/06 v5.5b a miscellany of footnote facilities
\FN@temptoken=\toks35
\footnotemargin=\dimen267
\c@pp@next@reset=\count184
Package footmisc Info: Declaring symbol style bringhurst on input line
855.
Package footmisc Info: Declaring symbol style chicago on input line 863.
Package footmisc Info: Declaring symbol style wiley on input line 872.
Package footmisc Info: Declaring symbol style lamport-robust on input
line 883.

Package footmisc Info: Declaring symbol style lamport* on input line 903.
Package footmisc Info: Declaring symbol style lamport*-robust on input
line 924
.
)
\c@Changes@AddCountde=\count185
\c@Changes@DeleteCountde=\count186
\c@Changes@ReplaceCountde=\count187
(./gopinathargallauro2017.aux)
\openout1 = `gopinathargallauro2017.aux'.

LaTeX Font Info:    Checking defaults for OML/cmm/m/it on input line 53.
LaTeX Font Info:    ... okay on input line 53.
LaTeX Font Info:    Checking defaults for T1/cmr/m/n on input line 53.
LaTeX Font Info:    ... okay on input line 53.
LaTeX Font Info:    Checking defaults for OT1/cmr/m/n on input line 53.
LaTeX Font Info:    ... okay on input line 53.
LaTeX Font Info:    Checking defaults for OMS/cmsy/m/n on input line 53.
LaTeX Font Info:    ... okay on input line 53.
LaTeX Font Info:    Checking defaults for OMX/cmex/m/n on input line 53.
LaTeX Font Info:    ... okay on input line 53.
```

```
LaTeX Font Info:    Checking defaults for U/cmr/m/n on input line 53.
LaTeX Font Info:    ... okay on input line 53.
LaTeX Font Info:    Checking defaults for TS1/cmr/m/n on input line 53.
LaTeX Font Info:    ... okay on input line 53.
(c:/TeXLive/2015/texmf-dist/tex/context/base/supp-pdf.mkii
[Loading MPS to PDF converter (version 2006.09.02).]
\scratchcounter=\count188
\scratchdimen=\dimen268
\scratchbox=\box60
\nofMPsegments=\count189
\nofMParguments=\count190
\everyMPshowfont=\toks36
\MPscratchCnt=\count191
\MPscratchDim=\dimen269
\MPnumerator=\count192
\makeMPintoPDFobject=\count193
\everyMPtoPDFconversion=\toks37
) (c:/TeXLive/2015/texmf-dist/tex/generic/oberdiek/pdftexcmds.sty
Package: pdftexcmds 2011/11/29 v0.20 Utility functions of pdfTeX for
LuaTeX (HO
)
(c:/TeXLive/2015/texmf-dist/tex/generic/oberdiek/ifluatex.sty
Package: ifluatex 2010/03/01 v1.3 Provides the ifluatex switch (HO)
Package ifluatex Info: LuaTeX not detected.
) (c:/TeXLive/2015/texmf-dist/tex/generic/oberdiek/ifpdf.sty
Package: ifpdf 2011/01/30 v2.3 Provides the ifpdf switch (HO)
Package ifpdf Info: pdfTeX in PDF mode is detected.
)
Package pdftexcmds Info: LuaTeX not detected.
Package pdftexcmds Info: \pdf@primitive is available.
Package pdftexcmds Info: \pdf@ifprimitive is available.
Package pdftexcmds Info: \pdfdraftmode found.
) (c:/TeXLive/2015/texmf-dist/tex/latex/oberdiek/epstopdf-base.sty
Package: epstopdf-base 2010/02/09 v2.5 Base part for package epstopdf
(c:/TeXLive/2015/texmf-dist/tex/latex/oberdiek/grfext.sty
Package: grfext 2010/08/19 v1.1 Manage graphics extensions (HO)
(c:/TeXLive/2015/texmf-dist/tex/generic/oberdiek/kvdefinekeys.sty
Package: kvdefinekeys 2011/04/07 v1.3 Define keys (HO)
)) (c:/TeXLive/2015/texmf-dist/tex/latex/oberdiek/kvoptions.sty
Package: kvoptions 2011/06/30 v3.11 Key value format for package options
(HO)
(c:/TeXLive/2015/texmf-dist/tex/generic/oberdiek/kvsetkeys.sty
Package: kvsetkeys 2012/04/25 v1.16 Key value parser (HO)
(c:/TeXLive/2015/texmf-dist/tex/generic/oberdiek/etexcmds.sty
Package: etexcmds 2011/02/16 v1.5 Avoid name clashes with e-TeX commands
(HO)
Package etexcmds Info: Could not find \expanded.
(etexcmds)             That can mean that you are not using pdfTeX 1.50
or
(etexcmds)             that some package has redefined \expanded.
(etexcmds)             In the latter case, load this package earlier.
)))
Package grfext Info: Graphics extension search list:
```

```
(grfext)
[.png,.pdf,.jpg,.mps,.jpeg,.jbig2,.jb2,.PNG,.PDF,.JPG,.JPE
G,.JBIG2,.JB2,.eps]
(grfext)             \AppendGraphicsExtensions on input line 452.
(c:/TeXLive/2015/texmf-dist/tex/latex/latexconfig/epstopdf-sys.cfg
File: epstopdf-sys.cfg 2010/07/13 v1.3 Configuration of (r)epstopdf for
TeX Liv
e
))
LaTeX Info: Redefining \microtypecontext on input line 53.
Package microtype Info: Generating PDF output.
Package microtype Info: Character protrusion enabled (level 2).
Package microtype Info: Using default protrusion set `alltext'.
Package microtype Info: Automatic font expansion enabled (level 2),
(microtype)             stretch: 20, shrink: 20, step: 1, non-selected.
Package microtype Info: Using default expansion set `basictext'.
Package microtype Info: No adjustment of tracking.
Package microtype Info: No adjustment of interword spacing.
Package microtype Info: No adjustment of character kerning.
(c:/TeXLive/2015/texmf-dist/tex/latex/microtype/mt-cmr.cfg
File: mt-cmr.cfg 2013/05/19 v2.2 microtype config. file: Computer Modern
Roman
(RS)
)
LaTeX Font Info:    Try loading font information for U+msa on input line
87.
(c:/TeXLive/2015/texmf-dist/tex/latex/amsfonts/umsa.fd
File: umsa.fd 2013/01/14 v3.01 AMS symbols A
) (c:/TeXLive/2015/texmf-dist/tex/latex/microtype/mt-msa.cfg
File: mt-msa.cfg 2006/02/04 v1.1 microtype config. file: AMS symbols (a)
(RS)
)
LaTeX Font Info:    Try loading font information for U+msb on input line
87.
(c:/TeXLive/2015/texmf-dist/tex/latex/amsfonts/umsb.fd
File: umsb.fd 2013/01/14 v3.01 AMS symbols B
) (c:/TeXLive/2015/texmf-dist/tex/latex/microtype/mt-msb.cfg
File: mt-msb.cfg 2005/06/01 v1.0 microtype config. file: AMS symbols (b)
(RS)
)
LaTeX Font Info:    Font shape `U/lasy/b/n' in size <7> not available
(Font)              Font shape `U/lasy/m/n' tried instead on input line
87.
LaTeX Font Info:    Font shape `U/lasy/b/n' in size <5> not available
(Font)              Font shape `U/lasy/m/n' tried instead on input line
87.
LaTeX Font Info:    Calculating math sizes for size <8.5> on input line
87.
Package epstopdf Info: Source file: <Fig1.eps>
(epstopdf)                     date: 2018-05-04 22:51:44
(epstopdf)                     size: 3011293 bytes
(epstopdf)             Output file: <Fig1-eps-converted-to.pdf>
(epstopdf)                     date: 2018-05-04 22:52:01
(epstopdf)                     size: 1698620 bytes
```

```
(epstopdf)             Command: <repstopdf --outfile=Fig1-eps-converted-
to.pdf
Fig1.eps>
(epstopdf)             \includegraphics on input line 102.
Package epstopdf Info: Output file is already uptodate.
<Fig1-eps-converted-to.pdf, id=1, 1659.19875pt x 1281.78876pt>
File: Fig1-eps-converted-to.pdf Graphic file (type pdf)
<use Fig1-eps-converted-to.pdf>
Package pdftex.def Info: Fig1-eps-converted-to.pdf used on input line
102.
(pdftex.def)             Requested size: 420.75302pt x 325.04265pt.
LaTeX Font Info:    Font shape `U/lasy/b/n' in size <8.5> not available
(Font)              Font shape `U/lasy/m/n' tried instead on input line
103.
LaTeX Font Info:    Font shape `U/lasy/b/n' in size <5.94997> not
available
(Font)              Font shape `U/lasy/m/n' tried instead on input line
103.
LaTeX Font Info:    Font shape `U/lasy/b/n' in size <4.25> not available
(Font)              Font shape `U/lasy/m/n' tried instead on input line
103.
[1{c:/TeXLive/2015/texmf-var/fonts/map/pdftex/updmap/pdftex.map}


]
Package epstopdf Info: Source file: <Fig2.eps>
(epstopdf)                     date: 2018-05-04 22:51:44
(epstopdf)                     size: 125295 bytes
(epstopdf)             Output file: <Fig2-eps-converted-to.pdf>
(epstopdf)                     date: 2018-05-04 22:52:06
(epstopdf)                     size: 126768 bytes
(epstopdf)             Command: <repstopdf --outfile=Fig2-eps-converted-
to.pdf
Fig2.eps>
(epstopdf)             \includegraphics on input line 122.
Package epstopdf Info: Output file is already uptodate.
<Fig2-eps-converted-to.pdf, id=16, 663.47874pt x 478.78876pt>
File: Fig2-eps-converted-to.pdf Graphic file (type pdf)
<use Fig2-eps-converted-to.pdf>
Package pdftex.def Info: Fig2-eps-converted-to.pdf used on input line
122.
(pdftex.def)             Requested size: 173.25302pt x 125.02275pt.
[2]
Underfull \vbox (badness 10000) has occurred while \output is active []


Underfull \vbox (badness 10000) has occurred while \output is active []

[3 <./Fig1-eps-converted-to.pdf> <./Fig2-eps-converted-to.pdf>]
Underfull \vbox (badness 2426) has occurred while \output is active []

[4]
Package epstopdf Info: Source file: <Fig3.eps>
(epstopdf)                     date: 2018-05-04 22:51:44
```

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(epstopdf)                      size: 49232 bytes
(epstopdf)             Output file: <Fig3-eps-converted-to.pdf>
(epstopdf)                      date: 2018-05-04 22:52:11
(epstopdf)                      size: 39004 bytes
(epstopdf)             Command: <repstopdf --outfile=Fig3-eps-converted-
to.pdf
Fig3.eps>
(epstopdf)             \includegraphics on input line 166.
Package epstopdf Info: Output file is already uptodate.
<Fig3-eps-converted-to.pdf, id=38, 478.78876pt x 438.63875pt>
File: Fig3-eps-converted-to.pdf Graphic file (type pdf)
<use Fig3-eps-converted-to.pdf>
Package pdftex.def Info: Fig3-eps-converted-to.pdf used on input line
166.
(pdftex.def)             Requested size: 238.96417pt x 218.92393pt.

LaTeX Warning: `h' float specifier changed to `ht'.

[5 <./Fig3-eps-converted-to.pdf>]
Package epstopdf Info: Source file: <Fig4.eps>
(epstopdf)                      date: 2018-05-04 22:51:44
(epstopdf)                      size: 409307 bytes
(epstopdf)             Output file: <Fig4-eps-converted-to.pdf>
(epstopdf)                      date: 2018-05-04 22:52:16
(epstopdf)                      size: 804673 bytes
(epstopdf)             Command: <repstopdf --outfile=Fig4-eps-converted-
to.pdf
Fig4.eps>
(epstopdf)             \includegraphics on input line 217.
Package epstopdf Info: Output file is already uptodate.
<Fig4-eps-converted-to.pdf, id=52, 1396.21625pt x 753.81625pt>
File: Fig4-eps-converted-to.pdf Graphic file (type pdf)
<use Fig4-eps-converted-to.pdf>
Package pdftex.def Info: Fig4-eps-converted-to.pdf used on input line
217.
(pdftex.def)             Requested size: 569.2567pt x 281.47266pt.
[6] [7 <./Fig4-eps-converted-to.pdf>] [8]
LaTeX Font Info:    Try loading font information for U+bbm on input line
304.
(c:/TeXLive/2015/texmf-dist/tex/latex/bbm-macros/ubbm.fd
File: ubbm.fd 1999/03/15 V 1.2 Font definition for bbm font - TH
)
Package epstopdf Info: Source file: <Fig5.eps>
(epstopdf)                      date: 2018-05-04 22:51:44
(epstopdf)                      size: 32305 bytes
(epstopdf)             Output file: <Fig5-eps-converted-to.pdf>
(epstopdf)                      date: 2018-05-04 22:52:20
(epstopdf)                      size: 14357 bytes
(epstopdf)             Command: <repstopdf --outfile=Fig5-eps-converted-
to.pdf
Fig5.eps>
(epstopdf)             \includegraphics on input line 325.
Package epstopdf Info: Output file is already uptodate.
<Fig5-eps-converted-to.pdf, id=71, 528.97626pt x 306.14375pt>
```

```
File: Fig5-eps-converted-to.pdf Graphic file (type pdf)
<use Fig5-eps-converted-to.pdf>
Package pdftex.def Info: Fig5-eps-converted-to.pdf used on input line
325.
(pdftex.def)             Requested size: 238.96533pt x 133.15742pt.
[9]
Overfull \hbox (4.17566pt too wide) in paragraph at lines 334--335
\OT1/cmr/m/n/10 (-20) func-tion. In this ex-am-ple, the user's in-tended
goal c
hanges
 []


Underfull \vbox (badness 10000) has occurred while \output is active []


LaTeX Font Warning: Font shape `U/bbm/m/n' in size <8.5> not available
(Font)              size <8> substituted on input line 369.


LaTeX Font Warning: Font shape `U/bbm/m/n' in size <4.25> not available
(Font)              size <5> substituted on input line 369.

[10 <./Fig5-eps-converted-to.pdf>]
Package epstopdf Info: Source file: <Fig7.eps>
(epstopdf)                    date: 2018-05-04 22:51:45
(epstopdf)                    size: 6490402 bytes
(epstopdf)             Output file: <Fig7-eps-converted-to.pdf>
(epstopdf)                    date: 2018-05-04 22:52:25
(epstopdf)                    size: 337764 bytes
(epstopdf)             Command: <repstopdf --outfile=Fig7-eps-converted-
to.pdf
Fig7.eps>
(epstopdf)             \includegraphics on input line 381.
Package epstopdf Info: Output file is already uptodate.
<Fig7-eps-converted-to.pdf, id=89, 1927.2pt x 542.025pt>
File: Fig7-eps-converted-to.pdf Graphic file (type pdf)
<use Fig7-eps-converted-to.pdf>
Package pdftex.def Info: Fig7-eps-converted-to.pdf used on input line
381.
(pdftex.def)               Requested size: 495.0pt x 139.21115pt.
Package epstopdf Info: Source file: <Fig6.eps>
(epstopdf)                    date: 2018-05-04 22:51:44
(epstopdf)                    size: 310438 bytes
(epstopdf)             Output file: <Fig6-eps-converted-to.pdf>
(epstopdf)                    date: 2018-05-04 22:52:29
(epstopdf)                    size: 83448 bytes
(epstopdf)             Command: <repstopdf --outfile=Fig6-eps-converted-
to.pdf
Fig6.eps>
(epstopdf)             \includegraphics on input line 396.
Package epstopdf Info: Output file is already uptodate.
<Fig6-eps-converted-to.pdf, id=90, 1144.275pt x 418.56375pt>
File: Fig6-eps-converted-to.pdf Graphic file (type pdf)
```

```
<use Fig6-eps-converted-to.pdf>
Package pdftex.def Info: Fig6-eps-converted-to.pdf used on input line
396.
(pdftex.def)             Requested size: 238.9604pt x 86.55336pt.

Overfull \hbox (8.94446pt too wide) in paragraph at lines 404--406
[]\OT1/cmr/m/n/10 (-20) The switch-based head ar-ray con-sisted of three
switch
es
 []


Overfull \hbox (1.40538pt too wide) in paragraph at lines 427--428
$[]$\OT1/cmr/m/n/10 (-20) : In the sec-ond phase of train-ing, the
blending-
 []

[11]
Package epstopdf Info: Source file: <Fig8.eps>
(epstopdf)                    date: 2018-05-04 22:51:45
(epstopdf)                    size: 34226 bytes
(epstopdf)             Output file: <Fig8-eps-converted-to.pdf>
(epstopdf)                    date: 2018-05-04 22:52:33
(epstopdf)                    size: 10330 bytes
(epstopdf)             Command: <repstopdf --outfile=Fig8-eps-converted-
to.pdf
Fig8.eps>
(epstopdf)             \includegraphics on input line 450.
Package epstopdf Info: Output file is already uptodate.
<Fig8-eps-converted-to.pdf, id=94, 682.55pt x 371.3875pt>
File: Fig8-eps-converted-to.pdf Graphic file (type pdf)
<use Fig8-eps-converted-to.pdf>
Package pdftex.def Info: Fig8-eps-converted-to.pdf used on input line
450.
(pdftex.def)             Requested size: 450.45181pt x 245.0995pt.
[12 <./Fig7-eps-converted-to.pdf> <./Fig6-eps-converted-to.pdf>]
Package epstopdf Info: Source file: <Fig9.eps>
(epstopdf)                    date: 2018-05-04 22:51:45
(epstopdf)                    size: 193852 bytes
(epstopdf)             Output file: <Fig9-eps-converted-to.pdf>
(epstopdf)                    date: 2018-05-04 22:52:37
(epstopdf)                    size: 215176 bytes
(epstopdf)             Command: <repstopdf --outfile=Fig9-eps-converted-
to.pdf
Fig9.eps>
(epstopdf)             \includegraphics on input line 484.
Package epstopdf Info: Output file is already uptodate.
<Fig9-eps-converted-to.pdf, id=107, 716.6775pt x 541.02126pt>
File: Fig9-eps-converted-to.pdf Graphic file (type pdf)
<use Fig9-eps-converted-to.pdf>
Package pdftex.def Info: Fig9-eps-converted-to.pdf used on input line
484.
(pdftex.def)             Requested size: 415.79819pt x 313.8916pt.
[13 <./Fig8-eps-converted-to.pdf>]
```

```
Package epstopdf Info: Source file: <Fig10.eps>
(epstopdf)                   date: 2018-05-04 22:51:45
(epstopdf)                   size: 28366 bytes
(epstopdf)             Output file: <Fig10-eps-converted-to.pdf>
(epstopdf)                   date: 2018-05-04 22:52:41
(epstopdf)                   size: 8842 bytes
(epstopdf)             Command: <repstopdf --outfile=Fig10-eps-converted-
to.pdf
 Fig10.eps>
(epstopdf)             \includegraphics on input line 498.
Package epstopdf Info: Output file is already uptodate.
<Fig10-eps-converted-to.pdf, id=120, 619.31375pt x 447.6725pt>
File: Fig10-eps-converted-to.pdf Graphic file (type pdf)
<use Fig10-eps-converted-to.pdf>
Package pdftex.def Info: Fig10-eps-converted-to.pdf used on input line
498.
(pdftex.def)             Requested size: 238.96417pt x 172.73355pt.

LaTeX Warning: `!h' float specifier changed to `!ht'.

Package epstopdf Info: Source file: <Fig11.eps>
(epstopdf)                   date: 2018-05-04 22:51:45
(epstopdf)                   size: 2099967 bytes
(epstopdf)             Output file: <Fig11-eps-converted-to.pdf>
(epstopdf)                   date: 2018-05-04 22:52:46
(epstopdf)                   size: 157574 bytes
(epstopdf)             Command: <repstopdf --outfile=Fig11-eps-converted-
to.pdf
 Fig11.eps>
(epstopdf)             \includegraphics on input line 505.
Package epstopdf Info: Output file is already uptodate.
<Fig11-eps-converted-to.pdf, id=121, 619.31375pt x 257.96375pt>
File: Fig11-eps-converted-to.pdf Graphic file (type pdf)
<use Fig11-eps-converted-to.pdf>
Package pdftex.def Info: Fig11-eps-converted-to.pdf used on input line
505.
(pdftex.def)             Requested size: 396.00151pt x 164.95451pt.

Underfull \vbox (badness 10000) has occurred while \output is active []

[14 <./Fig9-eps-converted-to.pdf> <./Fig10-eps-converted-to.pdf>] [15
<./Fig11-
eps-converted-to.pdf>]
Underfull \hbox (badness 1496) in paragraph at lines 601--603
\OT1/cmr/m/n/8.5 (+20) inhibition type neu-ral fields. \OT1/cmr/m/it/8.5
(+20)
Bi-o-log-i-cal Cy-ber-net-ics
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Package balance Warning: You have called \balance in second column
(balance)                Columns might not be balanced.

[16]
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Underfull \vbox (badness 10000) has occurred while \output is active []


Overfull \vbox (3.37914pt too high) has occurred while \output is active
[]

[17]
Overfull \hbox (0.87498pt too wide) in paragraph at lines 858--861
\OT1/cmr/m/it/8.5 (-20) IEEE Transactions on Biomedical Engineering
\OT1/cmr/m/
n/8.5 (-20) 55(8):2050--
 []

Missing character: There is no â in font cmr8!
Missing character: There is no € in font cmr8!
Missing character: There is no œ in font cmr8!
Missing character: There is no â in font cmr8!
Missing character: There is no € in font cmr8!
Missing character: There is no  in font cmr8!
\Changes@OutFile=\write3
\openout3 = `gopinathargallauro2017.soc'.


Overfull \vbox (1.07639pt too high) has occurred while \output is active
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[18] (./gopinathargallauro2017.aux)

LaTeX Font Warning: Size substitutions with differences
(Font)              up to 0.75pt have occurred.

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Here is how much of TeX's memory you used:
 15858 strings out of 493027
 270002 string characters out of 6137679
 474675 words of memory out of 5000000
 18901 multiletter control sequences out of 15000+600000
 27395 words of font info for 199 fonts, out of 8000000 for 9000
 1141 hyphenation exceptions out of 8191
 38i,20n,51p,10404b,582s stack positions out of
5000i,500n,10000p,200000b,80000s
 <c:/Users/asynch/.texlive20
15/texmf-
var/fonts/pk/ljfour/public/bbm/bbm10.600pk><c:/TeXLive/2015/texmf-dist
/fonts/type1/public/amsfonts/cm/cmbsy10.pfb><c:/TeXLive/2015/texmf-
dist/fonts/t
ype1/public/amsfonts/cm/cmbx10.pfb><c:/TeXLive/2015/texmf-
dist/fonts/type1/publ
ic/amsfonts/cm/cmbx12.pfb><c:/TeXLive/2015/texmf-
dist/fonts/type1/public/amsfon
ts/cm/cmbx8.pfb><c:/TeXLive/2015/texmf-
dist/fonts/type1/public/amsfonts/cm/cmex
10.pfb><c:/TeXLive/2015/texmf-
dist/fonts/type1/public/amsfonts/cm/cmmi10.pfb><c
:/TeXLive/2015/texmf-
dist/fonts/type1/public/amsfonts/cm/cmmi5.pfb><c:/TeXLive/
2015/texmf-
dist/fonts/type1/public/amsfonts/cm/cmmi7.pfb><c:/TeXLive/2015/texmf
-dist/fonts/type1/public/amsfonts/cm/cmmi8.pfb><c:/TeXLive/2015/texmf-
dist/font
s/type1/public/amsfonts/cm/cmmib10.pfb><c:/TeXLive/2015/texmf-
dist/fonts/type1/
public/amsfonts/cmextra/cmmib7.pfb><c:/TeXLive/2015/texmf-
dist/fonts/type1/publ
```

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ic/amsfonts/cm/cmr10.pfb><c:/TeXLive/2015/texmf-
dist/fonts/type1/public/amsfont
s/cm/cmr5.pfb><c:/TeXLive/2015/texmf-
dist/fonts/type1/public/amsfonts/cm/cmr7.p
fb><c:/TeXLive/2015/texmf-
dist/fonts/type1/public/amsfonts/cm/cmr8.pfb><c:/TeXL
ive/2015/texmf-
dist/fonts/type1/public/amsfonts/cm/cmsy10.pfb><c:/TeXLive/2015/
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dist/fonts/type1/public/amsfonts/cm/cmsy5.pfb><c:/TeXLive/2015/texmf-dist
/fonts/type1/public/amsfonts/cm/cmsy7.pfb><c:/TeXLive/2015/texmf-
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e1/public/amsfonts/cm/cmsy8.pfb><c:/TeXLive/2015/texmf-
dist/fonts/type1/public/
amsfonts/cm/cmti10.pfb><c:/TeXLive/2015/texmf-
dist/fonts/type1/public/amsfonts/
cm/cmti8.pfb><c:/TeXLive/2015/texmf-
dist/fonts/type1/public/amsfonts/symbols/ms
bm10.pfb>
Output written on gopinathargallauro2017.pdf (18 pages, 3825294 bytes).
PDF statistics:
 227 PDF objects out of 1000 (max. 8388607)
 145 compressed objects within 2 object streams
 0 named destinations out of 1000 (max. 500000)
 14392 words of extra memory for PDF output out of 14400 (max. 10000000)
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Biography – Deepak E. Gopinath

Deepak E. Gopinath is a third-year doctoral student in the Mechanical Engineering Department at Northwestern University and works with Dr. Brenna Argall in the Assistive and Rehabilitation Robotics Laboratory at the Shirley Ryan AbilityLab in Chicago. He completed his B.Tech in Engineering Physics from IIT Bombay in 2007, after which he moved to Boston, USA to pursue a Professional Diploma in Music at Berklee College of Music majoring in Composition and Jazz Performance. Prior to coming to Northwestern, he completed an M.S in Music Technology at Georgia Tech under Dr. Gil Weinberg where he worked in field of Robotic Musicianship. His current research interests are in developing mathematical formalisms for shared-control architectures for assistive robotic manipulators and information theoretic approaches to characterize human-robot interaction.

Bio-Dr. Brenna Argall

Brenna Argall is an Associate Professor of Electrical Engineering & Computer Science, Mechanical Engineering and Physical Medicine & Rehabilitation at Northwestern University. She is also a Faculty Research Scientist at the Shirley Ryan AbilityLab, the premier rehabilitation hosptial in the United States. She is the director of the **a**ssistive & **r**ehabilitation robotics **lab**oratory (**ar**gal**lab**). Her research lies in the intersection of robotics, machine learning and human rehabilitation. The mission of the **ar**gal**lab** is to advance human ability by leveraging autonomy. Dr. Argall is a 2016 recipient of the NSF CAREER award, and her Ph.D. in Robotics (2009) was received from the Robotics Institute at Carnegie Mellon University, as well as her M.S in Robotics (2006) and B.S in Mathematics (2002). Prior to joining Northwestern, she was a postdoctoral fellow (2009-2011) at the École polytechnique fédérale de Lausanne (EPFL), and prior to graduate school she held a Computational Biology position at the National Institutes of Health (NIH).

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