

# Dynamic Locomotion and Whole-Body Control for Compliant Humanoids

Michael A. Hopkins

Dissertation submitted to the Faculty of the  
Virginia Polytechnic Institute and State University  
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy  
in  
Computer Engineering

Alexander Leonessa, Co-chair  
A. Lynn Abbott, Co-chair  
Dennis W. Hong  
Craig A. Woolsey  
William T. Baumann

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The following figures include content contributed by the listed authors:

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Figure 1.1, Figure 5.2 : DARPA

Figure 1.2, 2.1, 2.2-A : Joseph Holler

Figure 1.2 : Coleman Knabe

Figure 1.3-A, 1.3-D : Bryce Lee

Figure 1.3-B : Johannes Engelsberger

Figure 1.3-C : Jerry Pratt

Figure 2.1, 2.3 : Derek Lahr

Figure 2.2-B : Stephen Ressler

Figure 5.1 : Logan Wallace



Michael Hopkins <hopkns@vt.edu>

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## Permission for use of image

2 messages

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**Michael Hopkins** <hopkns@vt.edu>  
To: erichahn@vt.edu

Wed, Dec 10, 2014 at 8:03 PM

Hi Eric,

Could you grant me formal permission to use the attached photo of THOR in my dissertation document? If so, you can just respond with an email stating that I "may use the image with permission".

Thanks,  
Mike



**DSC\_2092.png**  
7027K

---

**Eric Hahn** <erichahn@vt.edu>  
To: Michael Hopkins <hopkns@vt.edu>

Wed, Dec 10, 2014 at 9:21 PM

Dr. Hopkins,  
You have my permission to use the attached image of THOR for your dissertation document.

[Quoted text hidden]



Michael Hopkins <hopkns@vt.edu>

---

## Permission for use of images

2 messages

---

**Michael Hopkins** <hopkns@vt.edu>  
To: Eric Hahn <erichahn@vt.edu>

Thu, Dec 18, 2014 at 10:56 PM

Hi Eric,

Could you grant me formal permission to use the attached photos of THOR in my dissertation document? If so, you can just respond with an email stating that I "may use the images with permission".

Thanks,  
Mike



**thor\_unmodeled\_terrain.png**  
96K

---

**Eric Hahn** <erichahn@vt.edu>  
To: Michael Hopkins <hopkns@vt.edu>

Thu, Dec 18, 2014 at 10:59 PM

Dr. Hopkins,  
I formally grant you permission to use the attached photos of THOR in your dissertation.

[Quoted text hidden]

# News

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Michael Hopkins &lt;hopkns@vt.edu&gt;

---

## Permission for use of images

5 messages

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**Michael Hopkins** <hopkns@vt.edu>  
To: joe.holler87@gmail.com

Wed, Dec 10, 2014 at 8:41 PM

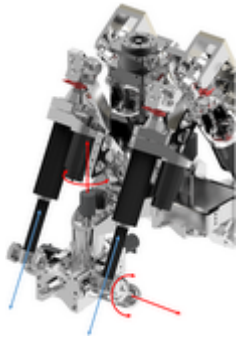
Hi Joe,

Could you grant me formal permission to use the attached images in my dissertation document? If so, you can just respond with an email stating that I "may use the images with permission".

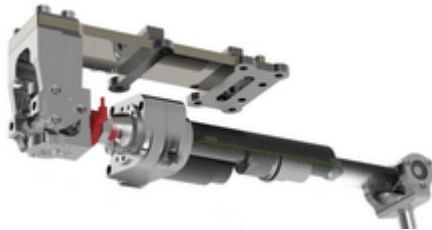
Thanks,  
Mike

---

### 2 attachments



**parallel\_hip.png**  
385K



**linear\_actuator.png**  
220K

---

**Joseph Holler** <joe.holler87@gmail.com>  
To: Michael A Hopkins <hopkns@vt.edu>

Wed, Dec 10, 2014 at 8:48 PM

Good evening Mike,

First off, congrats on all of the awesome THOR walking I've been hearing about /seeing online. It is really, really awesome to see THOR walking. Wish I was there in person to see it!

You may absolutely use the images with permission. Good luck with your dissertation! Let me know if there's anything else I can do!

Take care Mike,

Joe

[Quoted text hidden]

---

**Michael Hopkins** <hopkns@vt.edu>  
To: Joseph Holler <joe.holler87@gmail.com>

Wed, Dec 10, 2014 at 9:43 PM

Thanks Joe! I don't THOR would have gotten this far without your help. I hope everything's going great for you and Kelly.

Sincerely,  
Mike

[Quoted text hidden]

---

**Michael Hopkins** <hopkns@vt.edu>  
To: Joseph Holler <joe.holler87@gmail.com>

Mon, Dec 15, 2014 at 3:57 PM

Hi Joe,

Could I also have permission to use the attached image of THOR?

Thanks!  
Mike

On Wed, Dec 10, 2014 at 8:48 PM, Joseph Holler <joe.holler87@gmail.com> wrote:  
[Quoted text hidden]



**thor.png**  
5966K

---

**Joseph Holler** <joe.holler87@gmail.com>  
To: Michael Hopkins <hopkns@vt.edu>

Mon, Dec 15, 2014 at 6:15 PM

Hey Mike,

Feel free to use the attached image!

Good luck!

Joe

[Quoted text hidden]





michael hopkins <mkhopkins87@gmail.com>

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## Permission for use of image

2 messages

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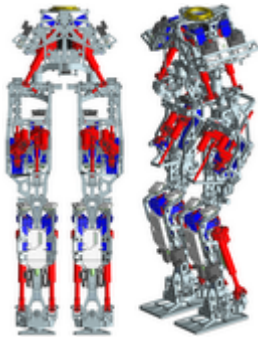
**michael hopkins** <mkhopkins87@gmail.com>  
To: Coleman Knabe <knabe@vt.edu>

Mon, Dec 15, 2014 at 3:28 PM

Hi Coleman,

Could you grant me formal permission to use the attached image of the THOR lower body in my dissertation document? If so, you can just respond with an email stating that I "may use the image with permission".

Thanks,  
Mike



**THOR\_Legs\_Actuators\_Highlighted.png**  
802K

---

**Coleman Knabe** <csknabe@gmail.com>  
To: michael hopkins <mkhopkins87@gmail.com>

Mon, Dec 15, 2014 at 3:30 PM

You may use the image with permission.  
[Quoted text hidden]



Michael Hopkins <hopkns@vt.edu>

---

## Permission for use of image

2 messages

---

**Michael Hopkins** <hopkns@vt.edu>

Wed, Dec 10, 2014 at 6:13 PM

To: Bryce Lee <bryce.kt.lee@gmail.com>

Hi Bryce,

Could you grant me formal permission to use Figure 2-2 (A) and Figure 2-2 (B) from your thesis, "Design of a Humanoid Robot for Disaster Response," in my dissertation document? If so, you can just respond with an email stating that I "may use the image with permission".

Thanks,  
Mike

---

**Bryce Lee** <bryce.kt.lee@gmail.com>

Wed, Dec 10, 2014 at 7:28 PM

To: Michael A Hopkins <hopkns@vt.edu>

Mike,  
You may use those figures with permission.  
Thanks,  
Bryce

[Quoted text hidden]



michael hopkins <mkhopkins87@gmail.com>

---

## TORO picture

5 messages

---

**michael hopkins** <mkhopkins87@gmail.com>  
To: Johannes.Englsberger@dlr.de

Sun, Nov 23, 2014 at 3:50 PM

Hey Johannes,

Would you be able to send me the picture of TORO from your interactive session poster? Also, could you provide permission for me to include the image in my dissertation?

Thanks!  
Mike

---

**Johannes.Englsberger@dlr.de** <Johannes.Englsberger@dlr.de>  
To: mkhopkins87@gmail.com

Mon, Nov 24, 2014 at 3:33 AM

Hey Mike!

It was such a pleasure meeting you again during Humanoids!

This is really one of the best conferences of all! (I only like Dynamic Walking even better J).

Attached, I send you the picture of TORO.

Yes, I hereby provide you permission to include the picture in your dissertation!

Good luck for your PhD defense!

Cheers,

Johannes

**Von:** michael hopkins [mailto:mkhopkins87@gmail.com]

**Gesendet:** Sonntag, 23. November 2014 21:51

**An:** Englsberger, Johannes

**Betreff:** TORO picture

**Von:** michael hopkins [mailto:[mkhopkins87@gmail.com](mailto:mkhopkins87@gmail.com)]

**Gesendet:** Sonntag, 23. November 2014 21:51

**An:** Engelsberger, Johannes

**Betreff:** TORO picture

[Quoted text hidden]



**Toro\_with\_bars.jpg**  
857K



Michael Hopkins &lt;hopkns@vt.edu&gt;

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**Permission to use image of M2V2**

2 messages

---

**Michael Hopkins** <hopkns@vt.edu>

Mon, Dec 15, 2014 at 3:06 PM

To: jpratt@ihmc.us

Dear Dr. Pratt,

This is Mike Hopkins from the TREC lab at Virginia Tech. It was great meeting you at the Humanoids conference in November. If possible, would you be able to provide formal permission for me to use the attached image of M2V2 (from <http://robots.ihmc.us/humanoid-robots/>) in my dissertation document as an example of a biped with series elastic actuation? If so, you would just need to state that I may "use the image with permission". Thank you.

Sincerely,  
Mike Hopkins



**M2V2.jpg**  
106K

---

**Jerry Pratt** <jpratt@ihmc.us>

Tue, Dec 16, 2014 at 10:04 AM

To: Michael Hopkins &lt;hopkns@vt.edu&gt;

Mike,

Good meeting you too.

Sure thing. Feel free to use the image with permission. Same with any other image on our web site or publications.

- Jerry

[Quoted text hidden]



Michael Hopkins &lt;hopkns@vt.edu&gt;

## Permission for use of diagrams

2 messages

Michael Hopkins <hopkns@vt.edu>  
To: derek.lahr@gm.com

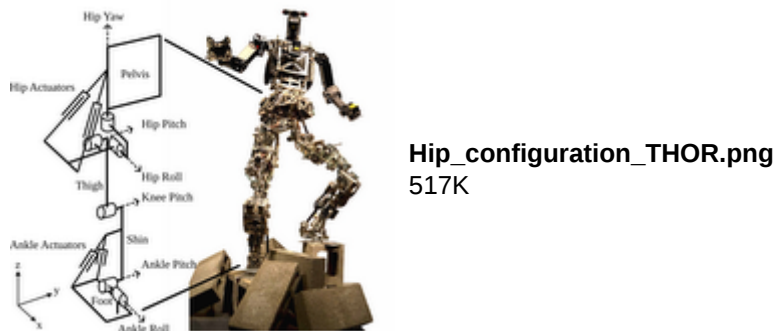
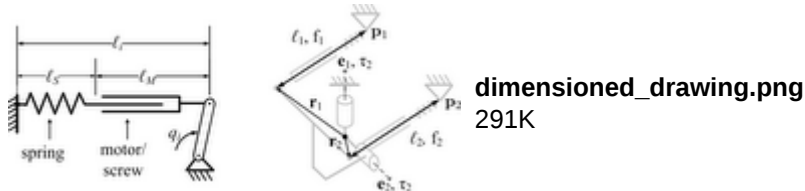
Wed, Dec 10, 2014 at 8:20 PM

Hi Derek,

Could you grant me formal permission to use the attached diagrams in my dissertation document? If so, you can just respond with an email stating that I "may use the images with permission".

Thanks,  
Mike

### 2 attachments



Derek F Lahr <derek.lahr@gm.com>  
To: "hopkns@vt.edu" <hopkns@vt.edu>

Thu, Dec 11, 2014 at 9:26 AM

I permit Mike to use the attached images .

Derek

Sent from my Android phone using TouchDown ([www.nitrodesk.com](http://www.nitrodesk.com))

[Quoted text hidden]

[Quoted text hidden]

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Michael Hopkins <hopkns@vt.edu>

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## Permission for use of image

2 messages

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**Michael Hopkins** <hopkns@vt.edu>

Wed, Dec 10, 2014 at 6:02 PM

To: resseller@vt.edu

Hi Steve,

Could you grant me formal permission to use Figure 4.13 from your thesis, "Design and Implementation of a Dual Axis Motor Controller for Parallel and Serial Series Elastic Actuators," in my dissertation document? If so, please respond with an email stating that I "may use the image with permission".

Thanks,  
Mike

---

**Stephen Ressler** <ressler@vt.edu>

Wed, Dec 10, 2014 at 6:07 PM

To: Michael Hopkins <hopkns@vt.edu>

Dr. Hopkins,  
Of course you may use this image with my permission.

-Steve Ressler  
[Quoted text hidden]





Michael Hopkins &lt;hopkns@vt.edu&gt;

---

**Including SAFFiR demo images in dissertation**

4 messages

---

**Michael Hopkins** <hopkns@vt.edu>  
To: "Mackay, Steven" <smackay@vt.edu>

Wed, Dec 10, 2014 at 10:50 PM

Hi Steven,

Do you think I could include some of the images from the SAFFiR demo in my dissertation document? I'm planning to delay the publication to avoid releasing any images prior to the Navy press release.

If so, I would also need to get permission from the photographer. I attached the collection of images that I'd be using. Could you let me know who took each photo? Should I contact Logan Wallace too?

Thanks,  
Mike Hopkins



saffir\_demo.png  
1881K

---

**Mackay, Steven** <smackay@vt.edu>  
To: "Wallace, Logan" <loganw@vt.edu>, "Hopkins, Michael" <hopkns@vt.edu>

Thu, Dec 11, 2014 at 9:14 AM

Logan

Mike on the TREC Mobile team wishes to use the attached images as part of his dissertation. He needs your official permission to do so first and would give photo credit. Is this cool? Many thanks,

**Steven Mackay****Communications Manager**

Virginia Tech College of Engineering

2160F Torgersen Hall (Mail code: 0217)

620 Drillfield Drive

Blacksburg, Va. 24061

Phone: (540) 231-4787

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**From:** Michael Hopkins [mailto:[hopkns@vt.edu](mailto:hopkns@vt.edu)]  
**Sent:** Wednesday, December 10, 2014 10:51 PM  
**To:** Mackay, Steven  
**Subject:** Including SAFFiR demo images in dissertation

[Quoted text hidden]



saffir\_demo.png  
1881K

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**Logan Wallace** <[loganw@vt.edu](mailto:loganw@vt.edu)>  
To: Steven Mackay <[smackay@vt.edu](mailto:smackay@vt.edu)>  
Cc: "Hopkins, Michael" <[hopkns@vt.edu](mailto:hopkns@vt.edu)>

Thu, Dec 11, 2014 at 10:57 AM

Yes he can absolutely use them in his dissertation. The credit should read something like "Photo Courtesy Virginia Tech/Logan Wallace"

---

Logan Wallace  
Senior Photographer  
Broadcast & Visual Communications  
Virginia Tech  
103A Media Building, Blacksburg, Va. 24061

540 231-6269  
[loganw@vt.edu](mailto:loganw@vt.edu)

Library Data Base:  
<http://www.photolibrary.unirel.vt.edu>

[Quoted text hidden]  
[Quoted text hidden]  
<saffir\_demo.png>

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**michael hopkins** <mkhopkins87@gmail.com>

Thu, Dec 11, 2014 at 2:01 PM

To: Logan Wallace <loganw@vt.edu>

Cc: Steven Mackay <smackay@vt.edu>, "Hopkins, Michael" <hopkns@vt.edu>

Thank you for your permission and for taking great photos!

Sincerely,  
Mike

[Quoted text hidden]