

# Gaming is a hard job, but someone has to do it!

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July 26, 2013

## Abstract

We establish some general schemes relating the computational complexity of a video game to the presence of certain common elements or mechanics, such as destroyable paths, collectible items, doors opened by keys or activated by buttons or pressure plates, etc. Then we apply such “metatheorems” to several video games published between 1980 and 1998, including Pac-Man, Tron, Lode Runner, Boulder Dash, Deflektor, Mindbender, Pipe Mania, Skweek, Prince of Persia, Lemmings, Doom, Puzzle Bobble 3, and Starcraft. We obtain both new results, and improvements or alternative proofs of previously known results.

## 1 Introduction

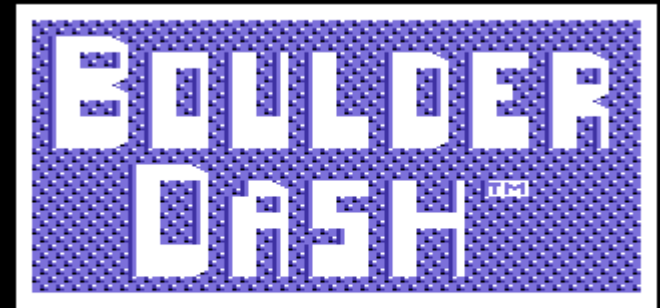
This work was inspired mainly by the recent papers on the computational complexity of video games by Forišek [4] and Cormode [2], along with the excellent surveys on related topics by Kendall et al. [8] and Demaine et al. [3, 7], and may be regarded as their continuation on the same line of research.

Our purpose is to single out certain recurring features or mechanics in a video game that enable general reduction schemes from known hard problems to the

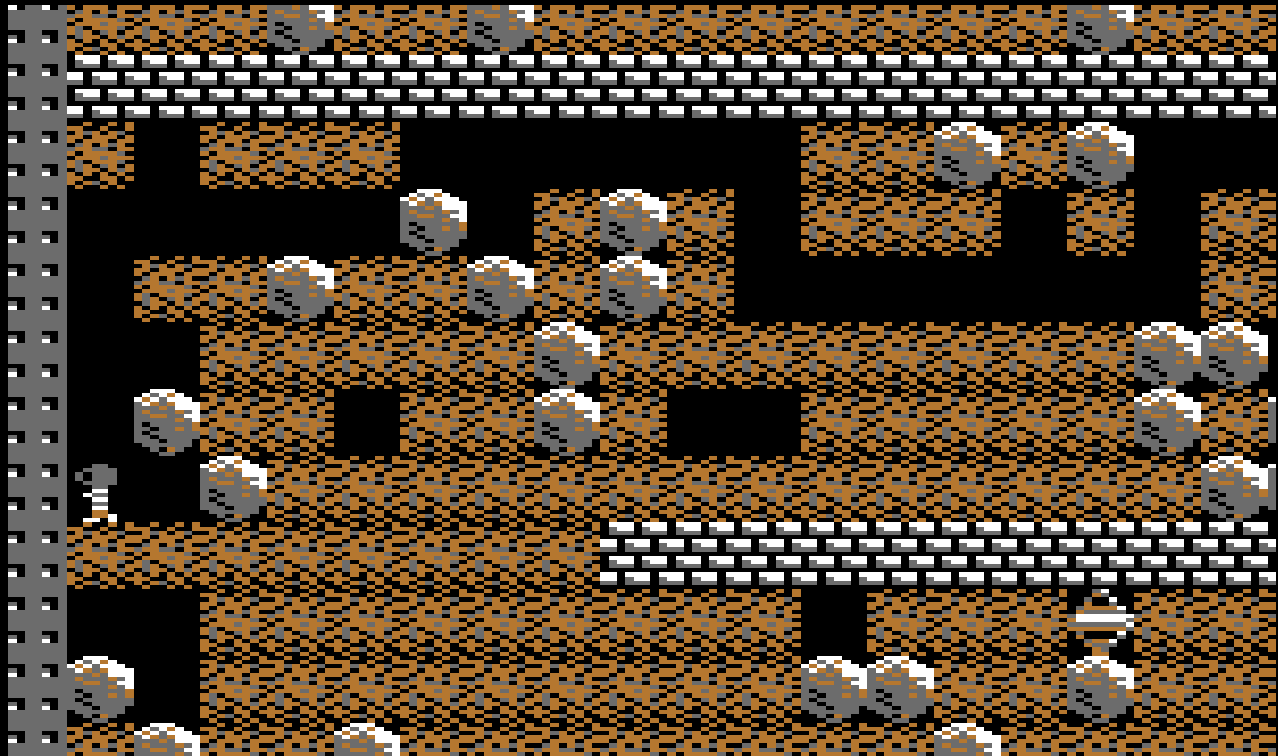


# Boulder Dash

[First Star Software, 1984]



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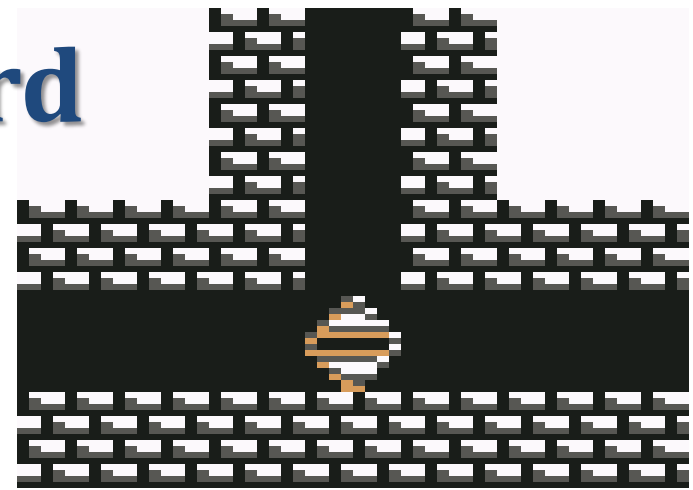




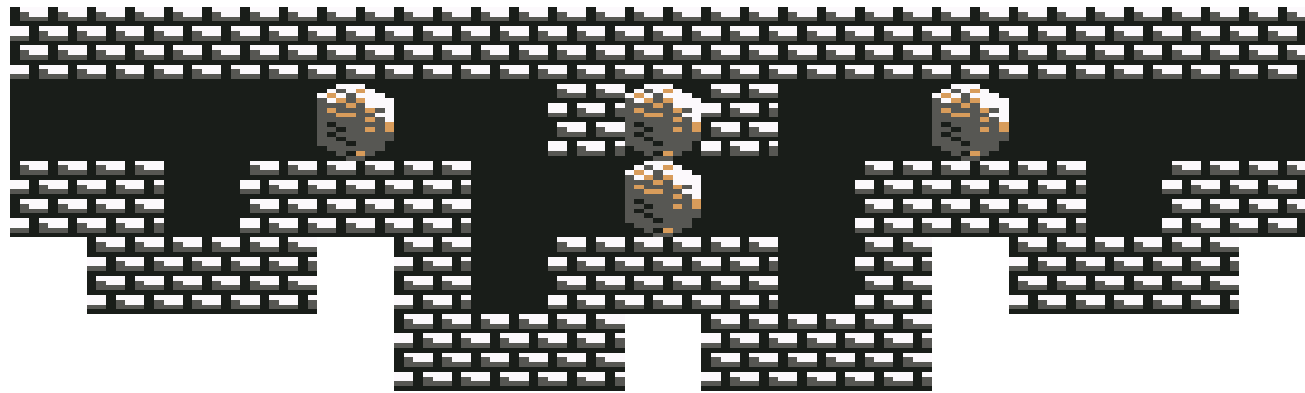


# Boulder Dash is NP-hard

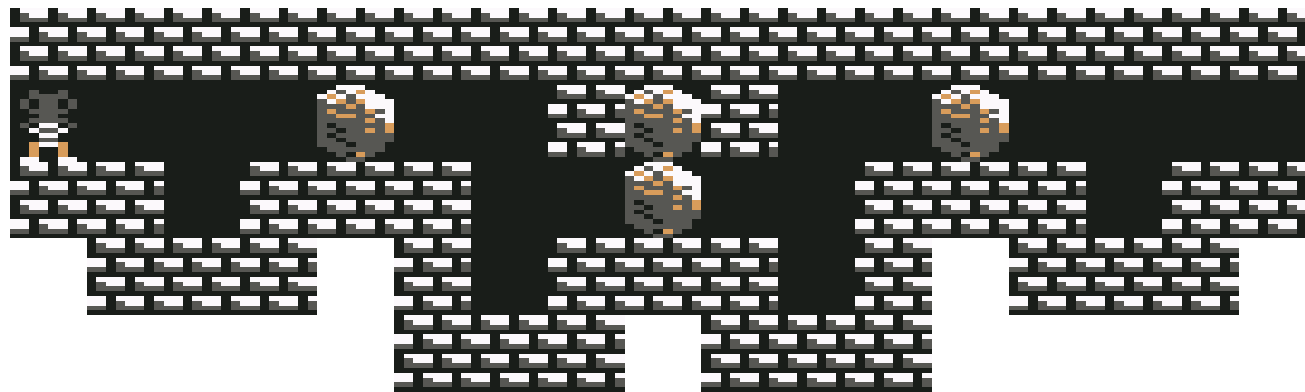
[Viglietta 2012]



location  
traversal



single-use  
path





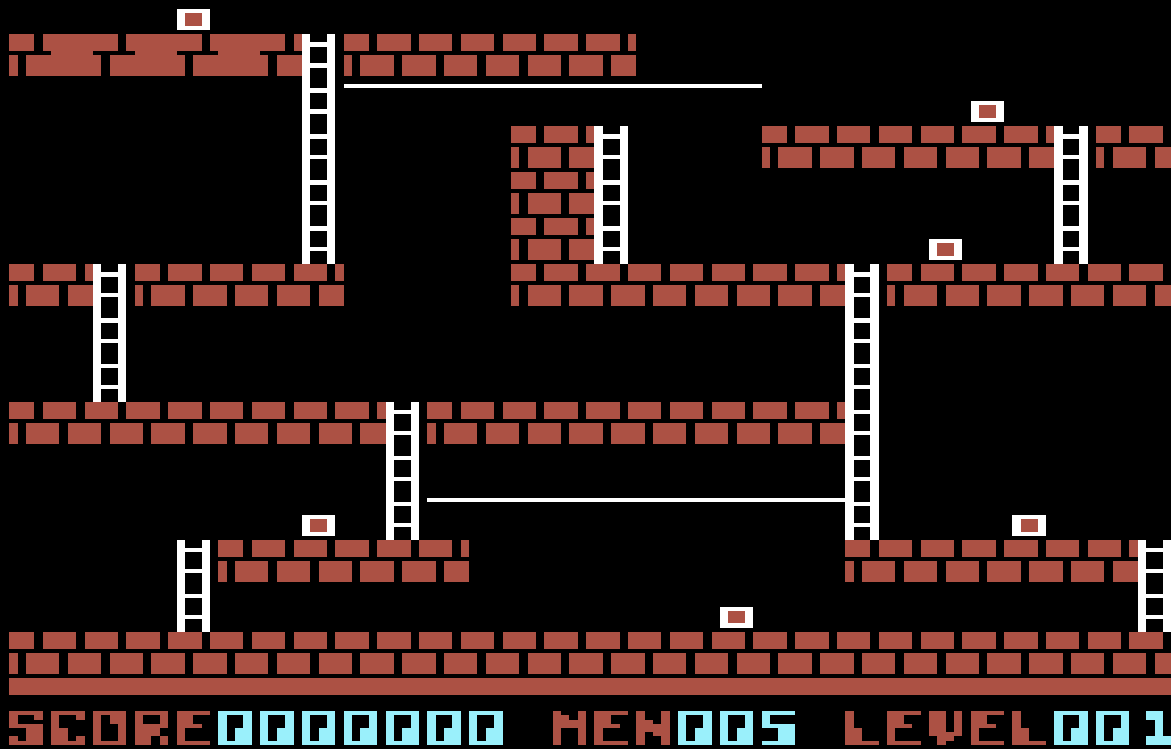
# Lode Runner

[Brøderbund 1983]

BRODERBUND SOFTWARE PRESENTS

# LODE RUNNER

© 1983 DOUG SMITH  
DANE BIGHAM



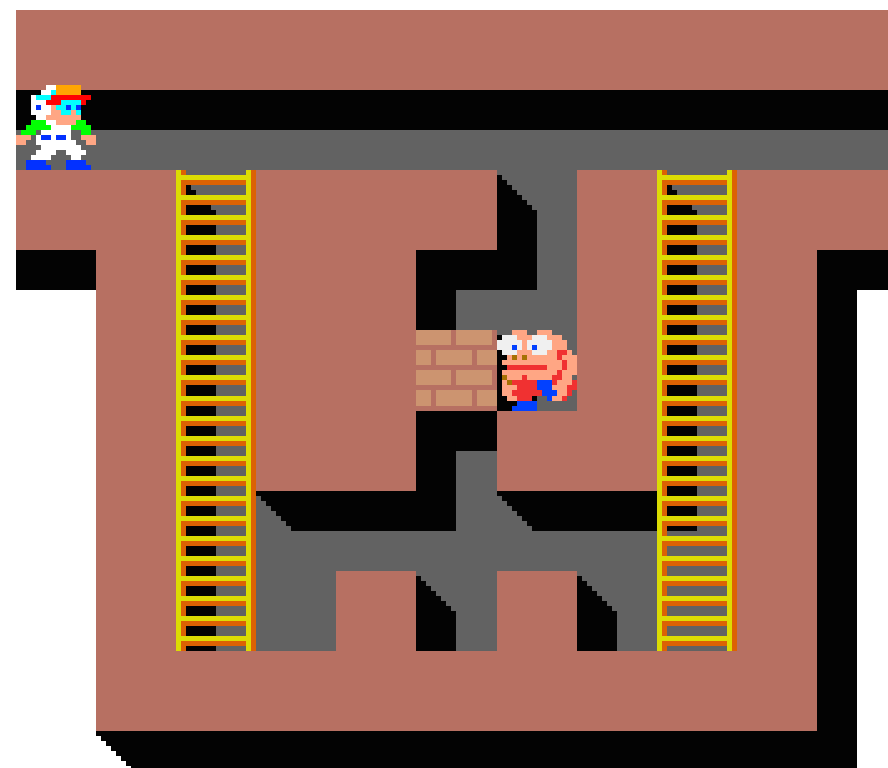
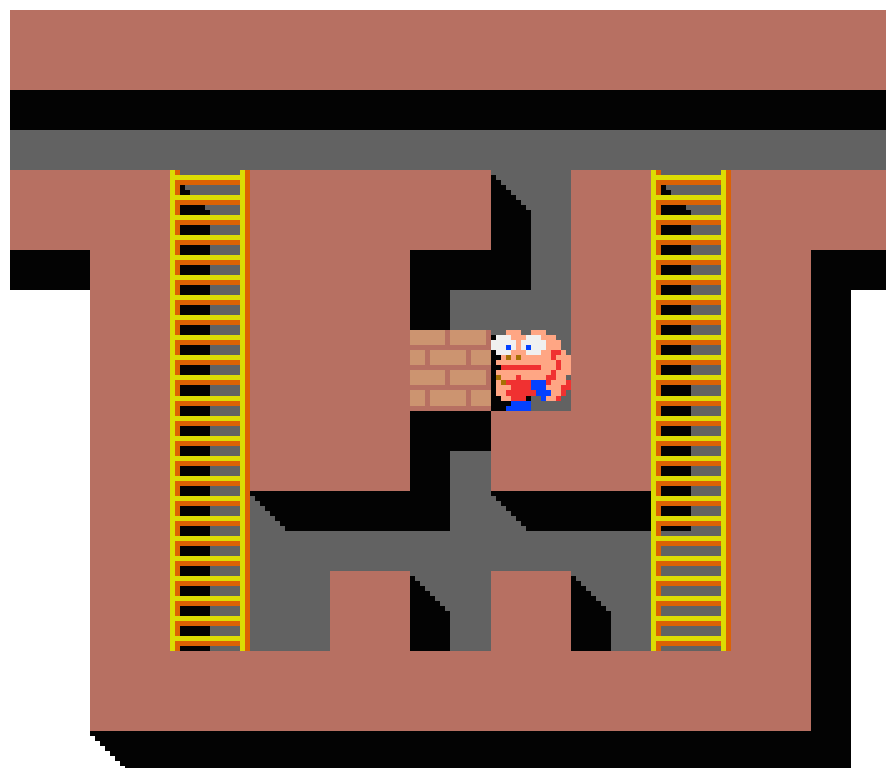
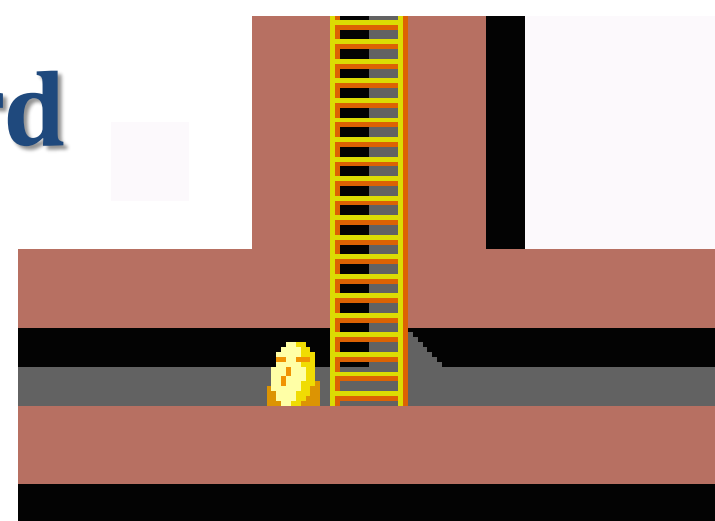


# Lode Runner is NP-hard

[Viglietta 2012]

single-use  
path

location  
traversal



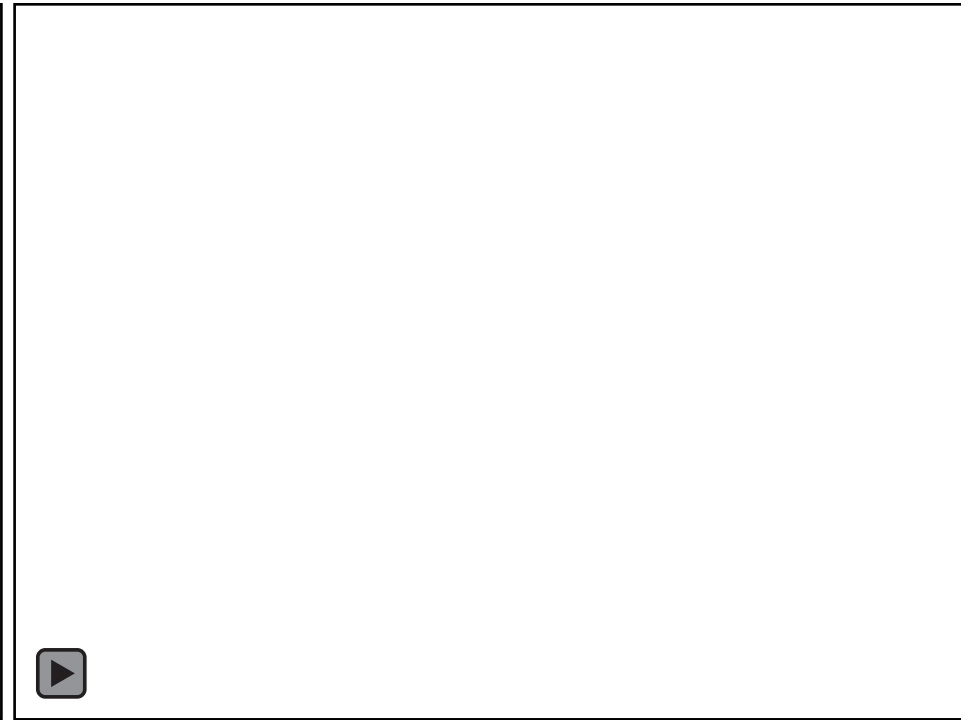
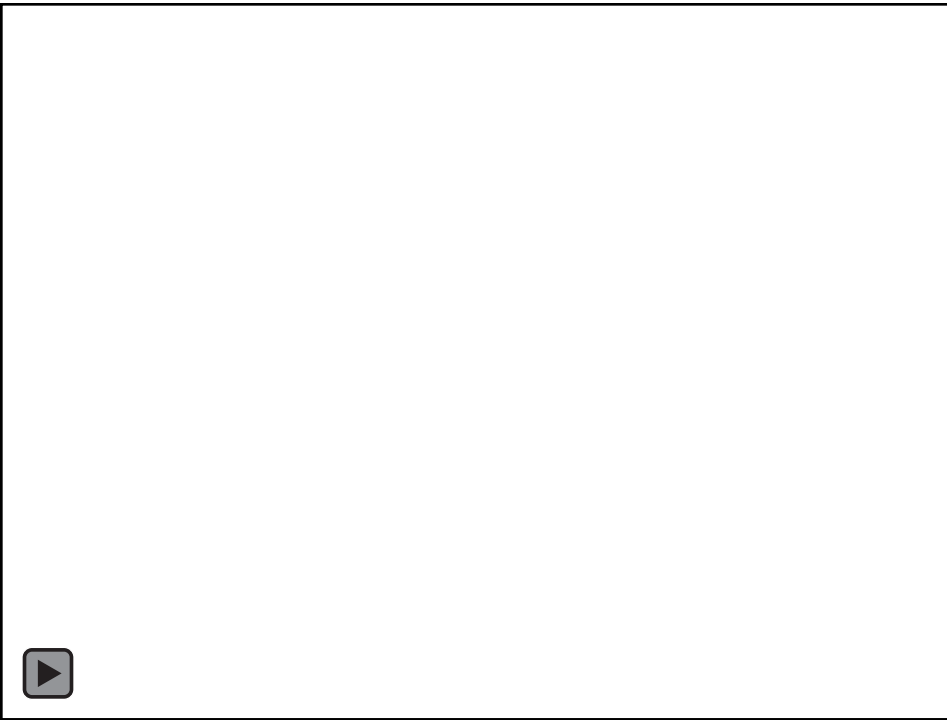


# Zelda II is NP-hard

[Aloupis, Demaine, Guo, Viglietta 2014]

single-use  
path

location  
traversal



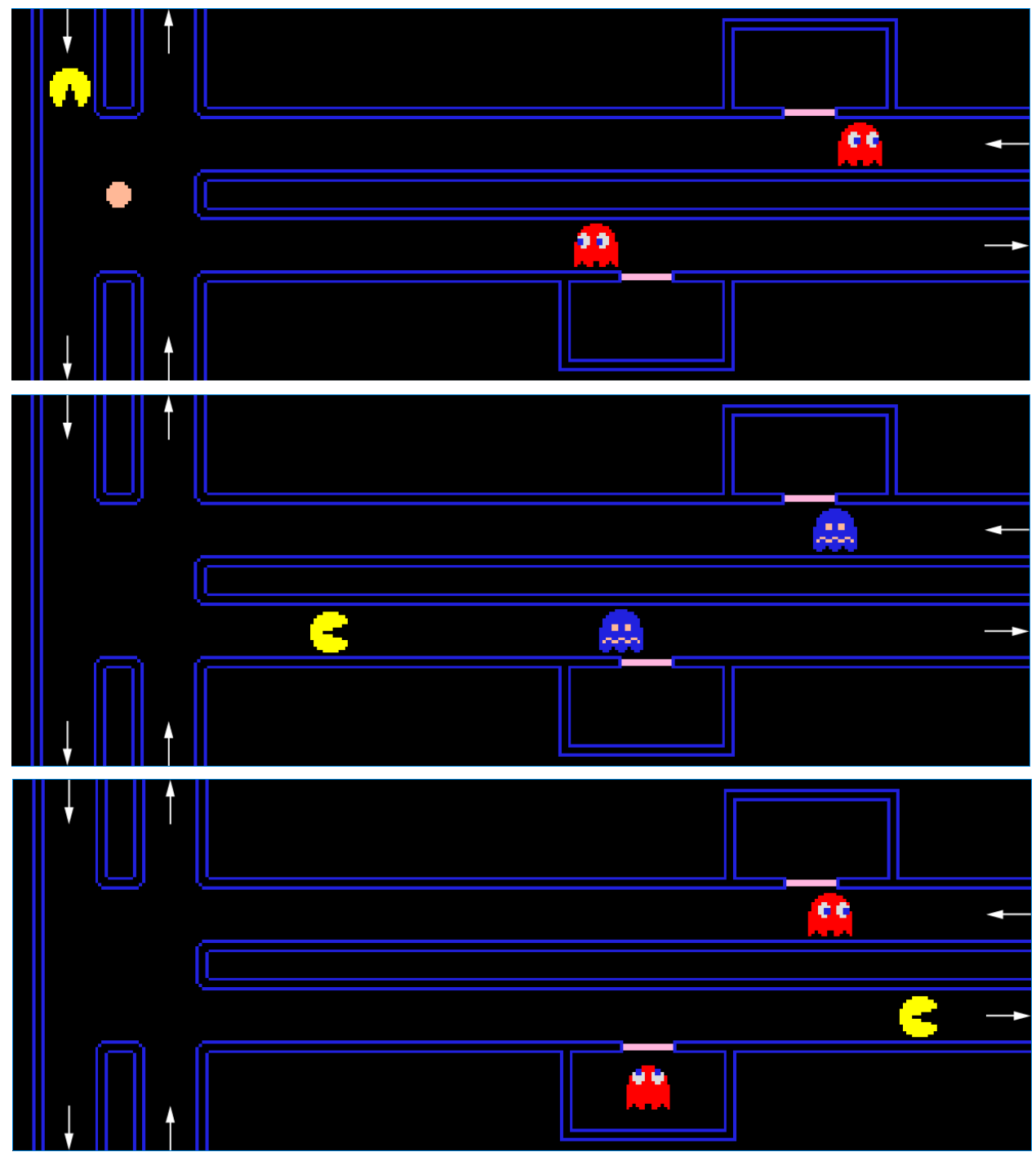
TAS Legend of Zelda 2 Adventure of Link NES in 47:57 by Rising Tempest & Inzult  
<http://youtu.be/6Y666I8W5B4>



# Pac-Man is NP-hard

[Viglietta 2012]

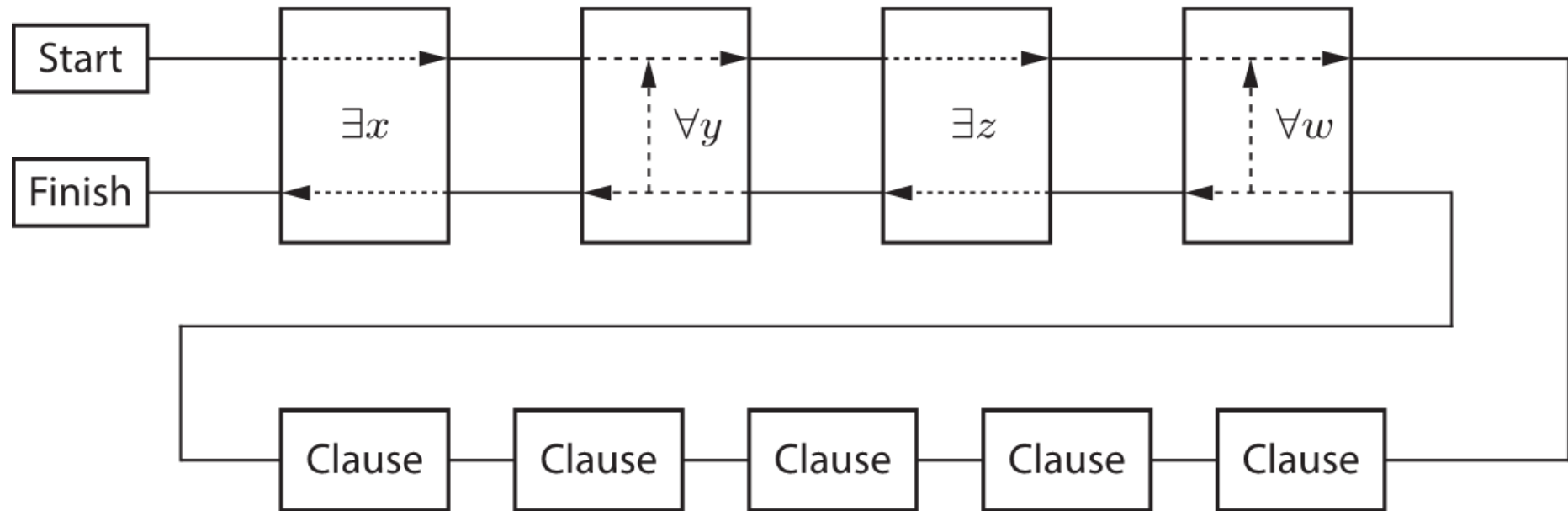
token &  
toll road





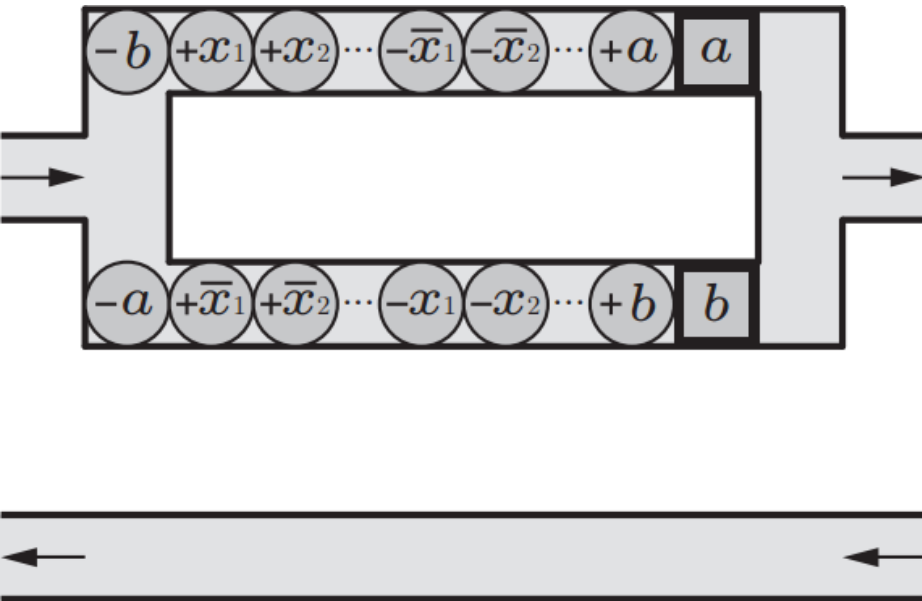
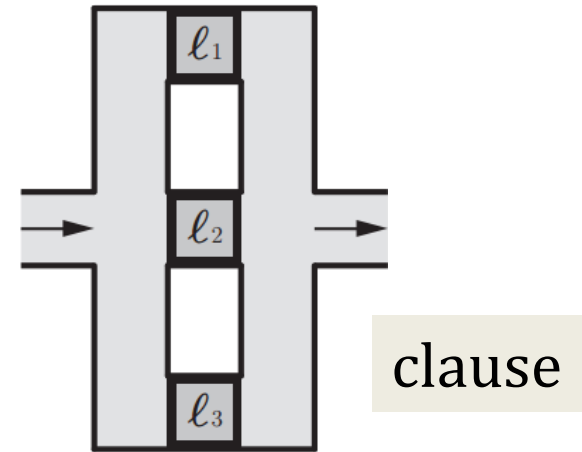
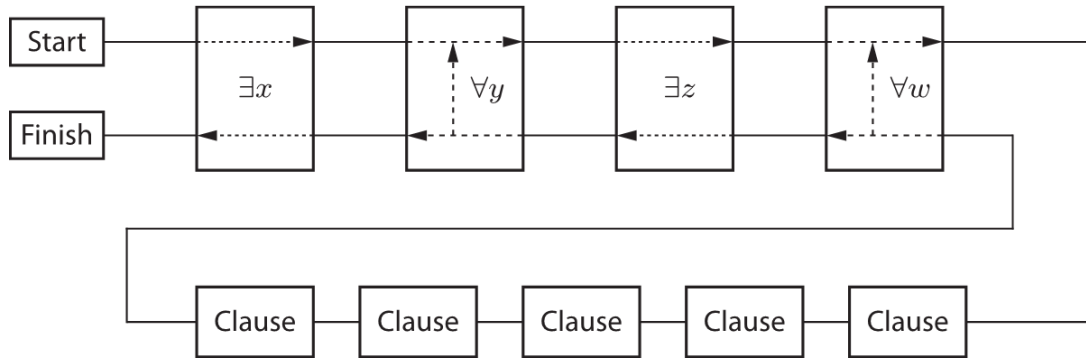
# Reduction from Q3SAT

[Viglietta 2014]

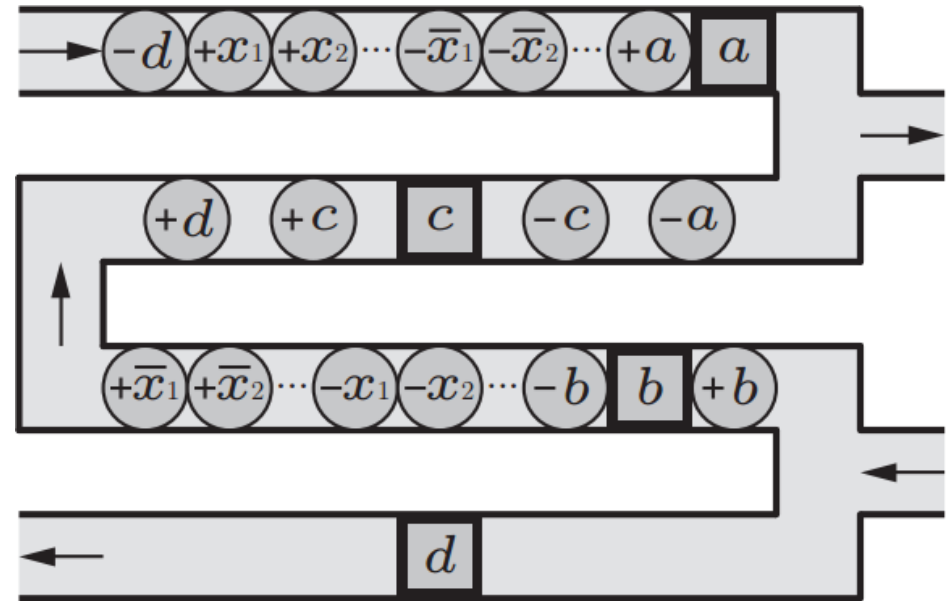


# Pressure Plates are PSPACE-complete

[Viglietta 2014]



existential quantifier



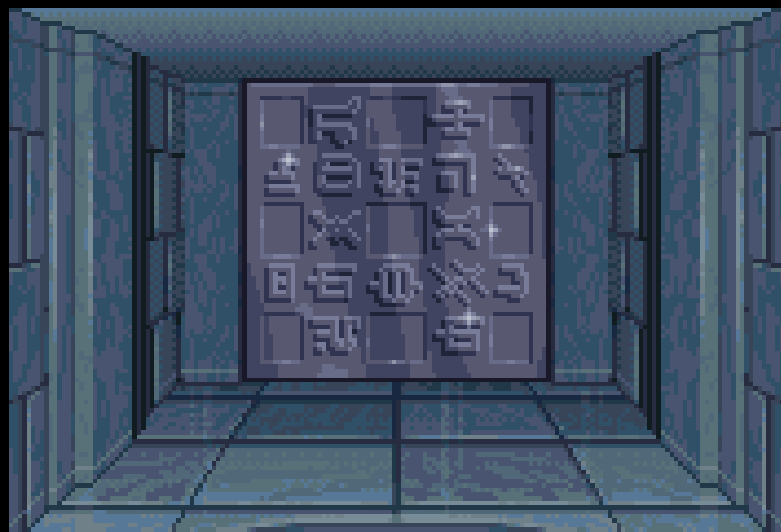
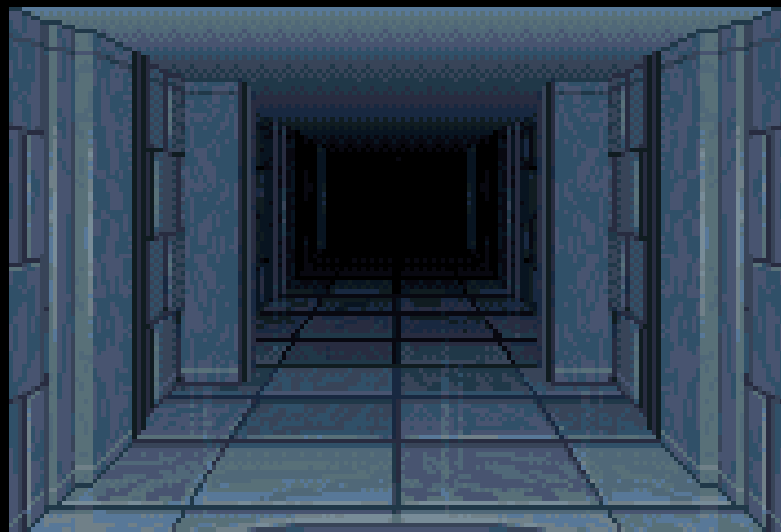
universal quantifier





# Eye of the Beholder II

[Westwood Associates 1991]





# Quake

[id Software 1996]



“Quake 1 – Episode 1 – Level 3” by Nights147  
<http://youtu.be/iF5Ci65WJul?t=1m23s>



# SCUMM Engine

## [Sierra]



Use  
Push  
Pull  
Give  
key  
dime

Open  
Close  
Read

Walk to  
Pick up  
What is

New Key  
Unlock  
Use  
record  
paint r

Maniac Mansion

## Secret of Monkey Island



Space Quest II - Vohaul's Revenge II

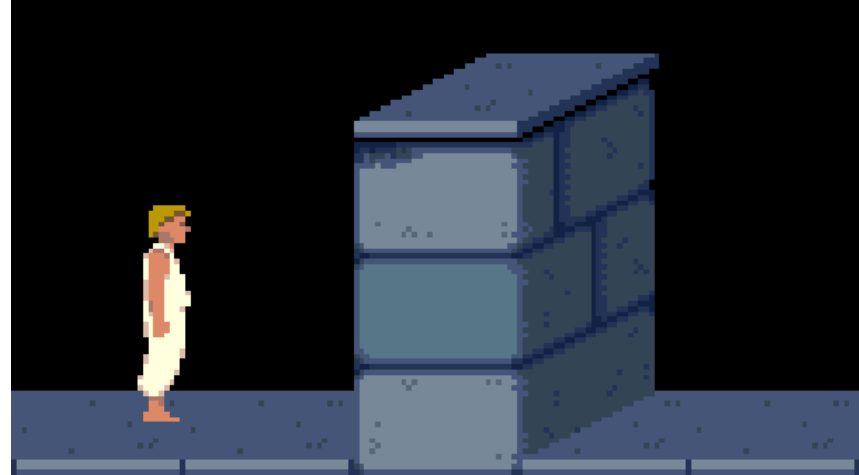


Space Quest IV

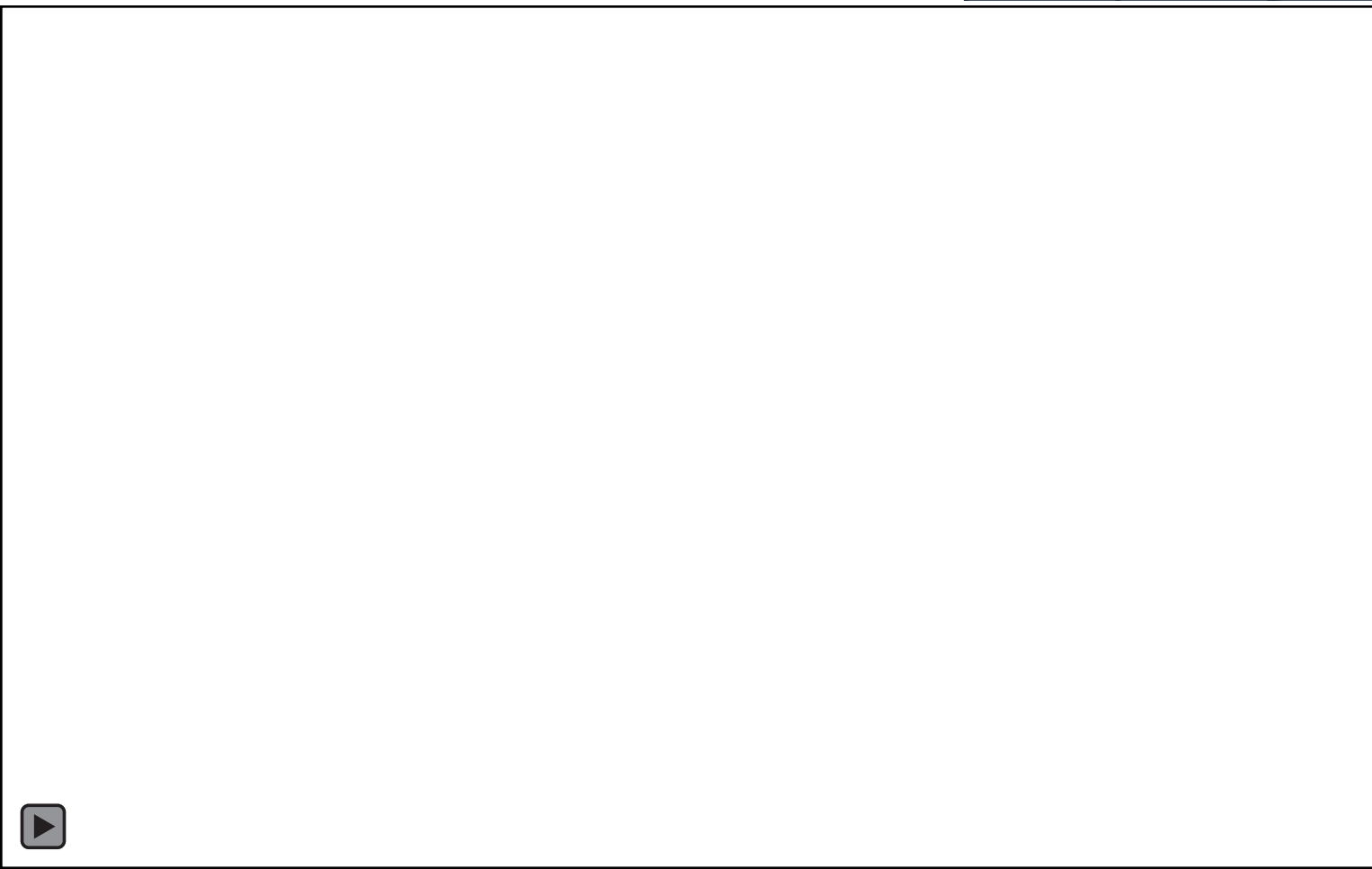


# Prince of Persia

[Brøderbund 1989]



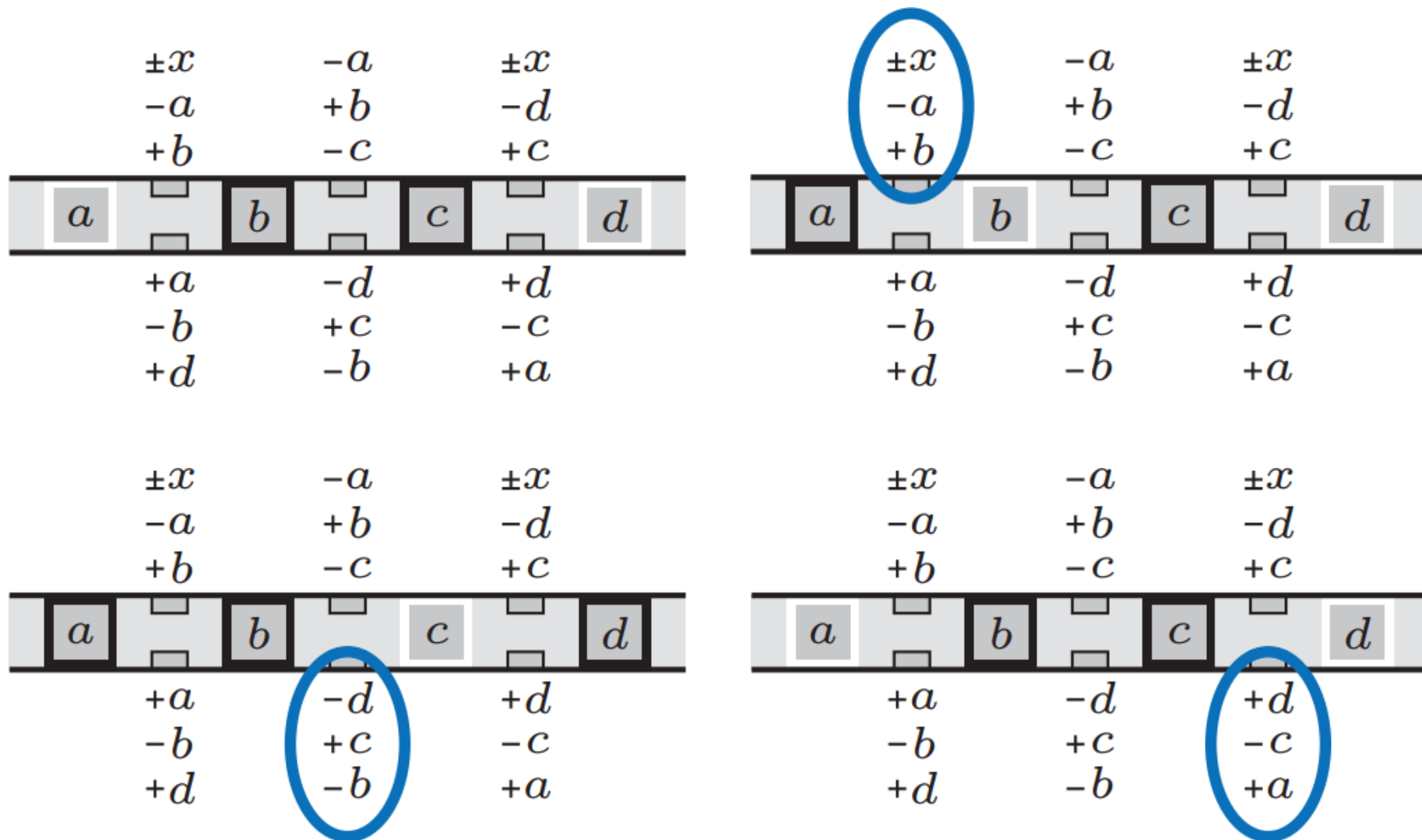
[Viglietta 2014]



<http://youtu.be/Xv20j8ChtRY>

# Buttons are PSPACE-complete

[Viglietta 2014]





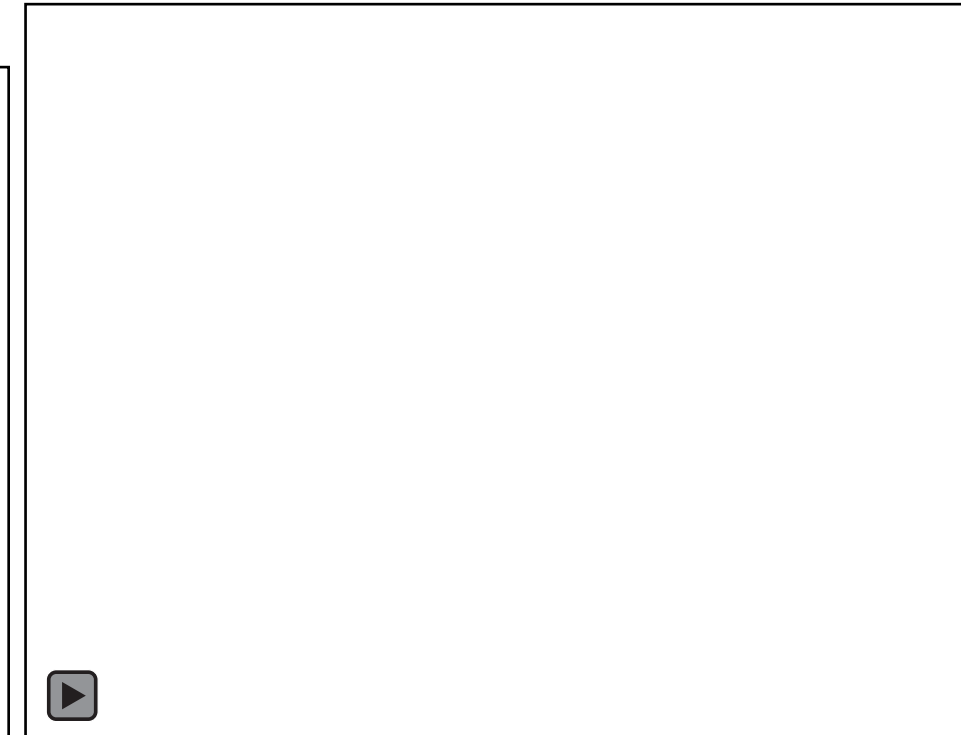
# Buttons are PSPACE- complete

[Viglietta 2014]

Sonic the  
Hedgehog



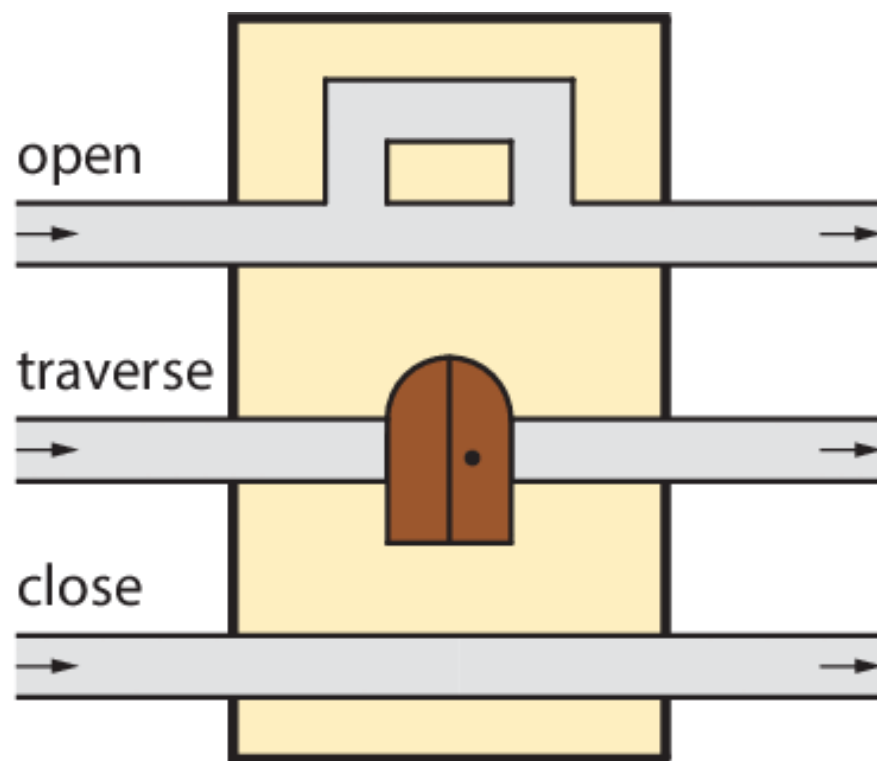
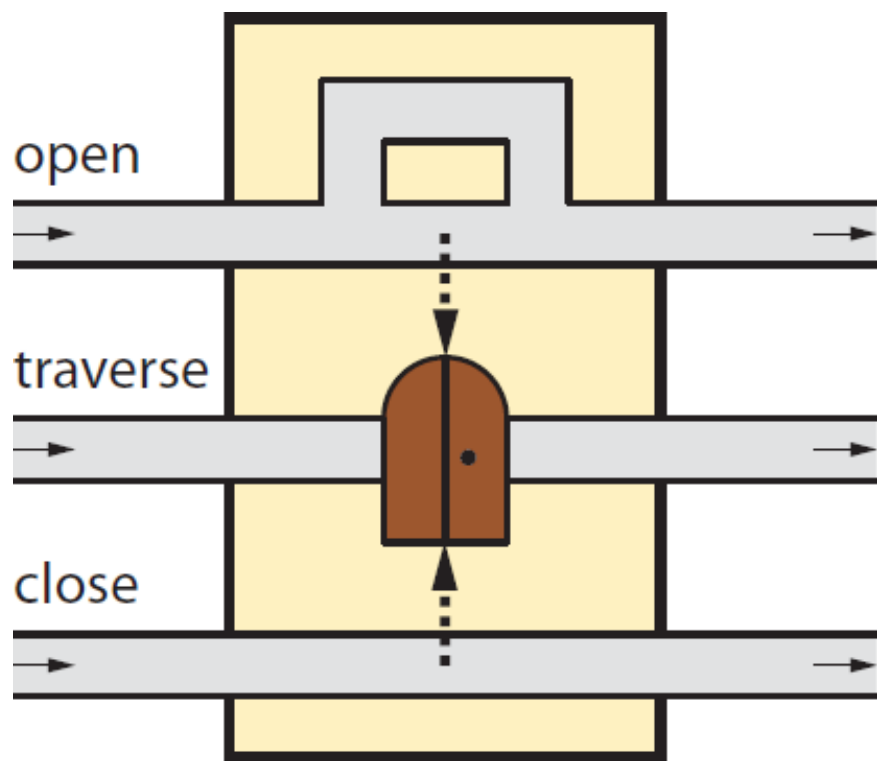
The Lost Vikings





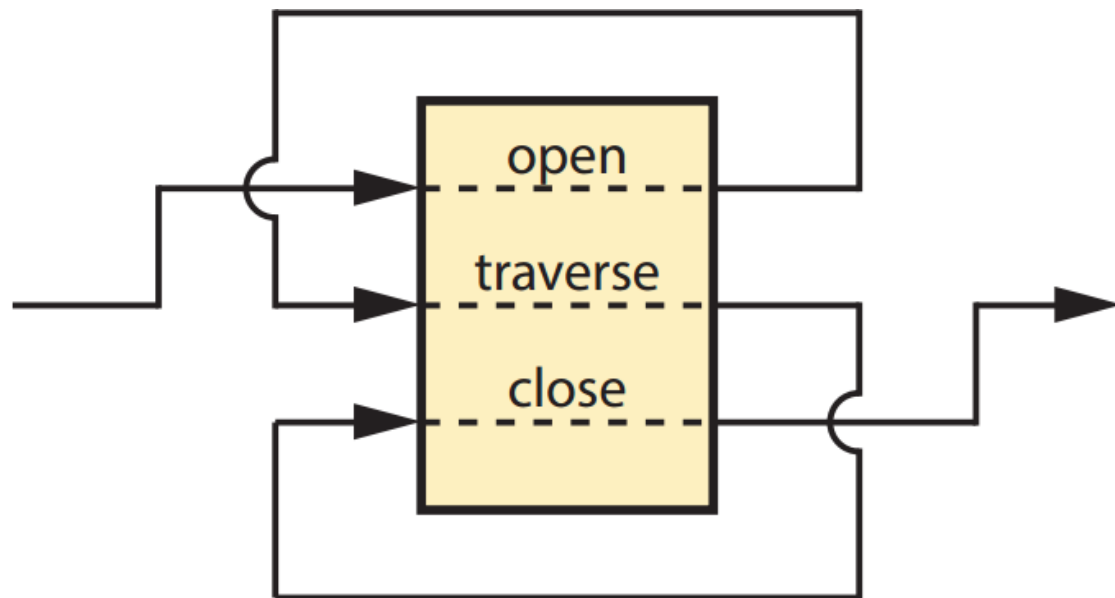
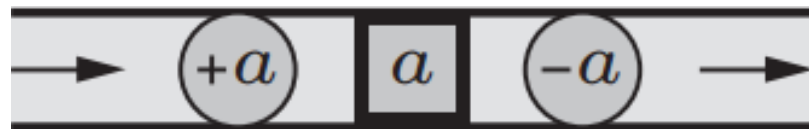
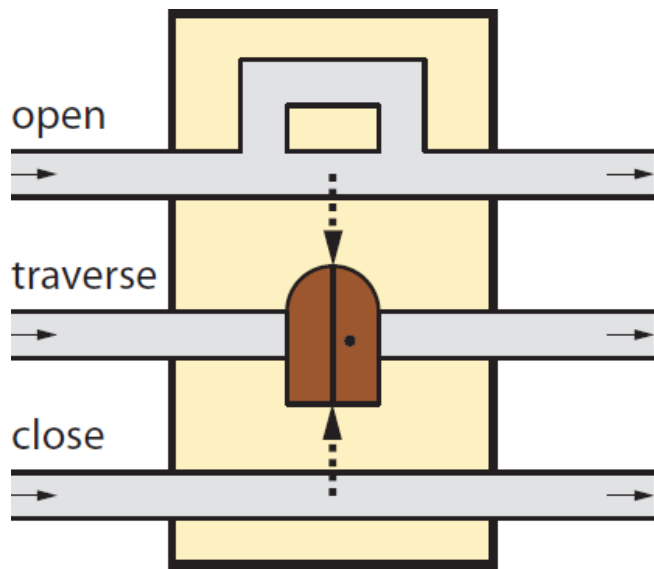
# Doors are PSPACE-complete

[Aloupis, Demaine, Guo, Viglietta 2014]



# Doors are PSPACE-complete

[Aloupis, Demaine, Guo, Viglietta 2014]

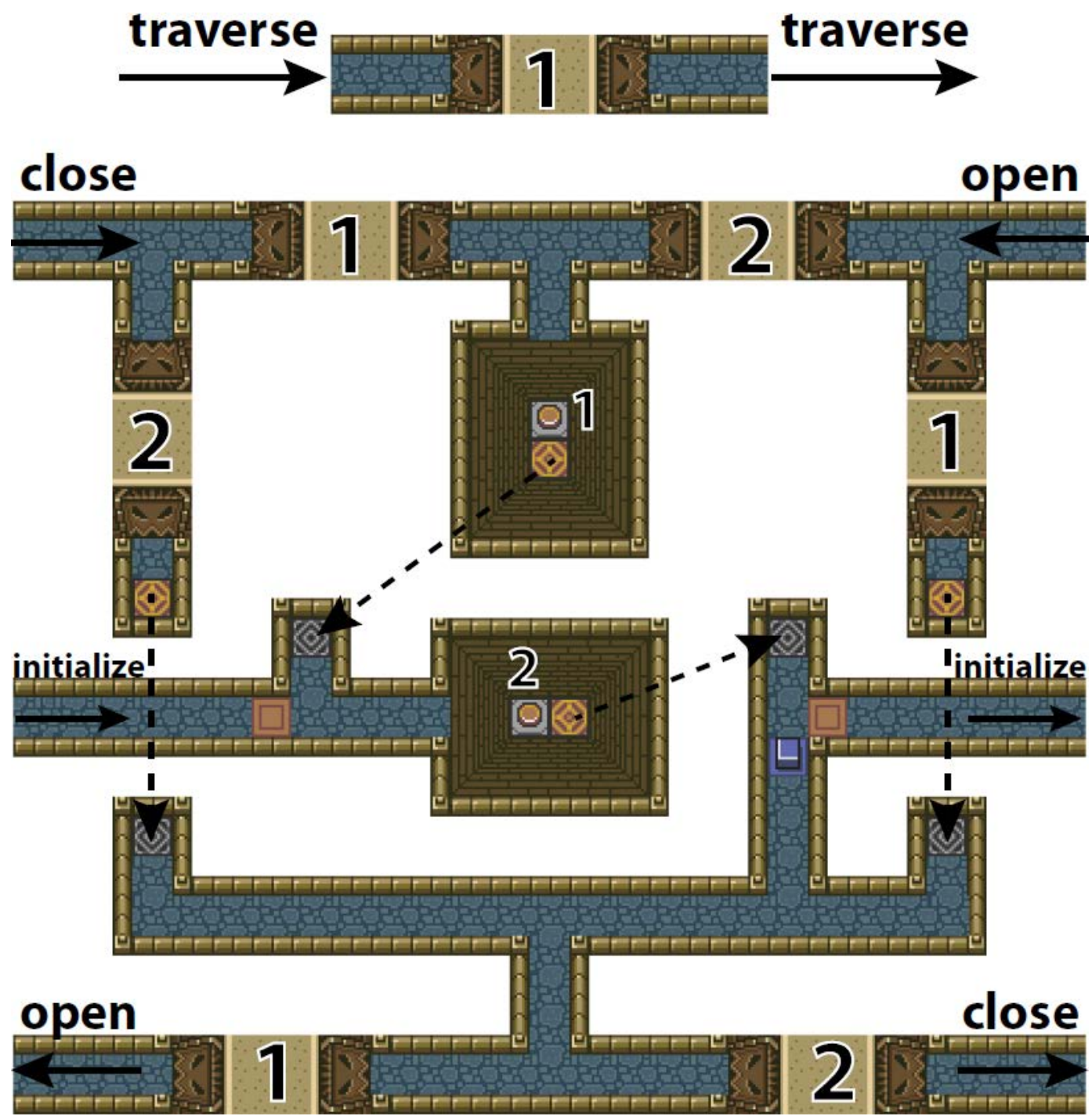






# Legend of Zelda: A Link to the Past

[Aloupis,  
Demaine, Guo,  
Viglietta 2014]





# Donkey Kong Country

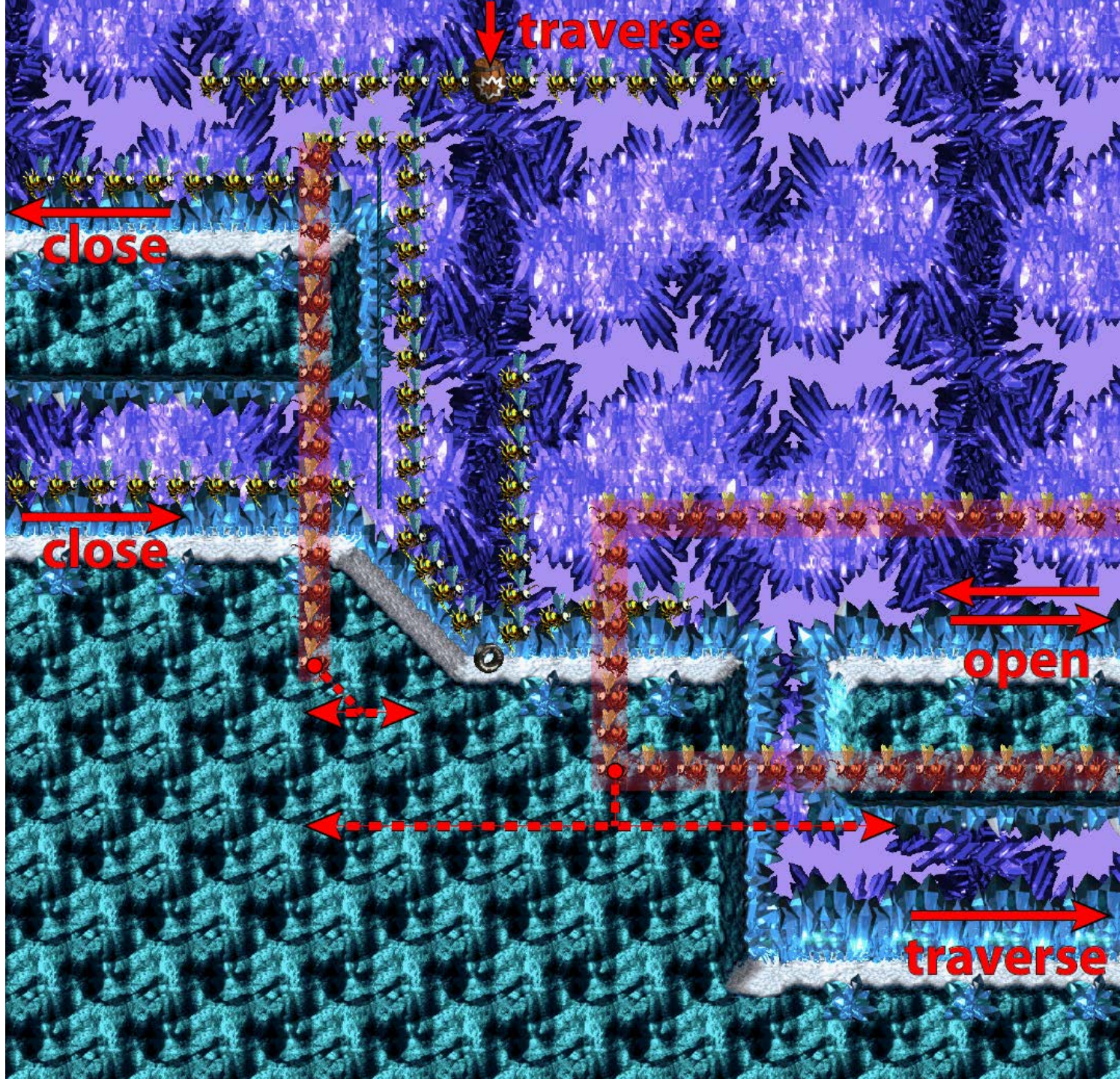


Metroid NES 100% walkthrough Part 1 Alternate Route  
by Timothy Cookson <http://youtu.be/INkHYcWvQag>



# Donkey Kong Country 1

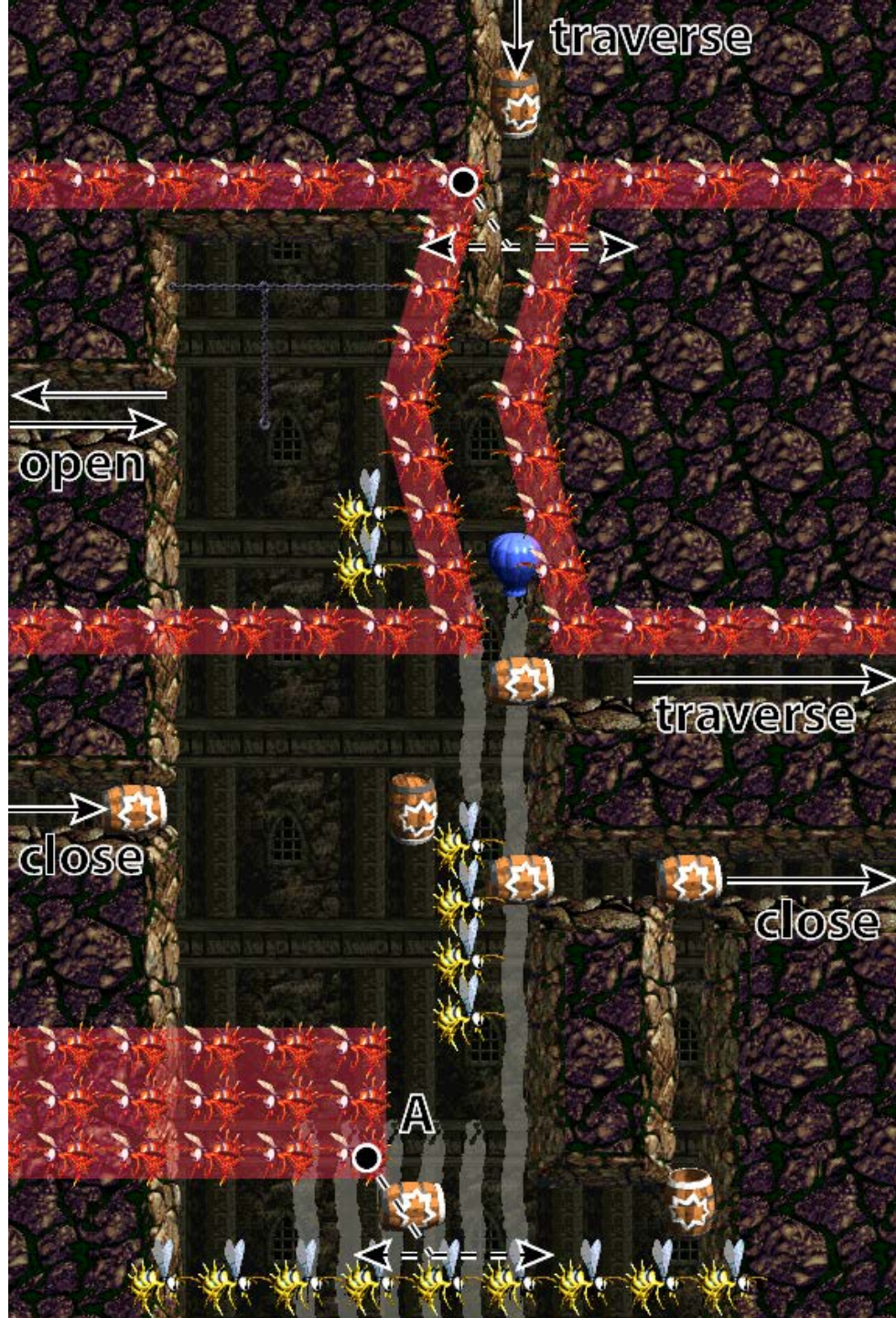
[Aloupis,  
Demaine, Guo,  
Viglietta 2014]





# Donkey Kong Country 2

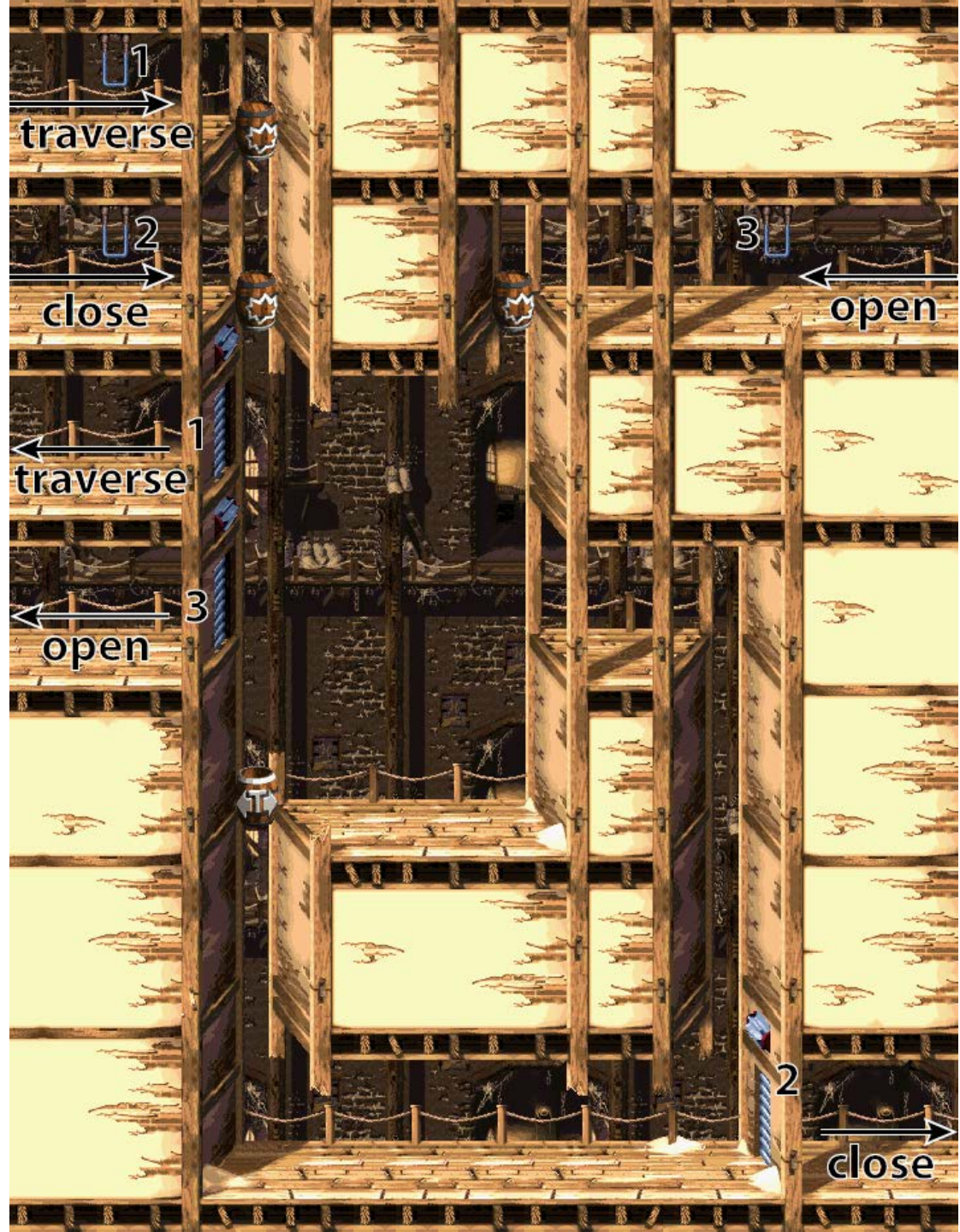
[Aloupis, Demaine, Guo, Viglietta 2014]





# Donkey Kong Country 3

[Aloupis, Demaine, Guo, Viglietta 2014]



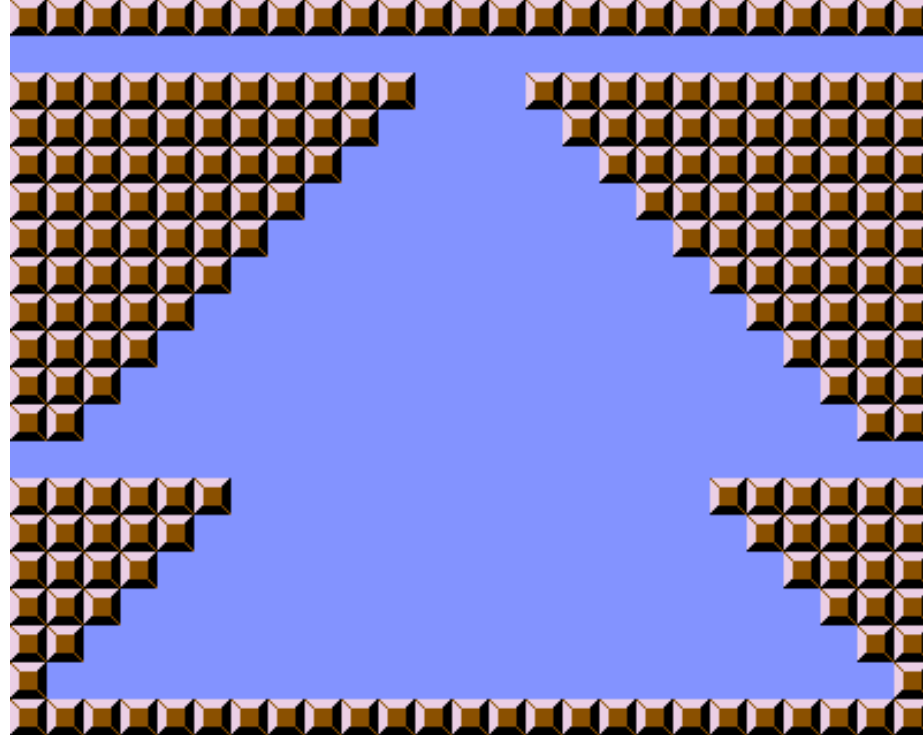


# Super Mario Bros. PSPACE-complete

[Demaine, Viglietta,  
Williams 2014]

crossover

door



traverse ←

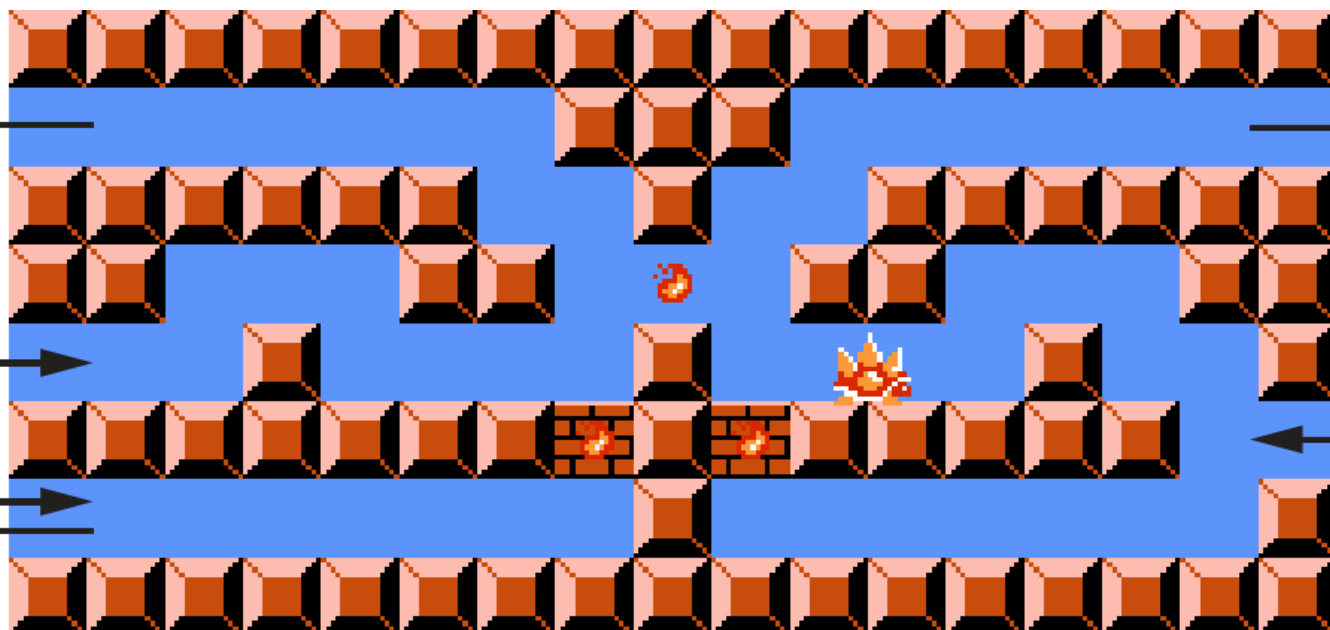
→ close

traverse →

← close

open →

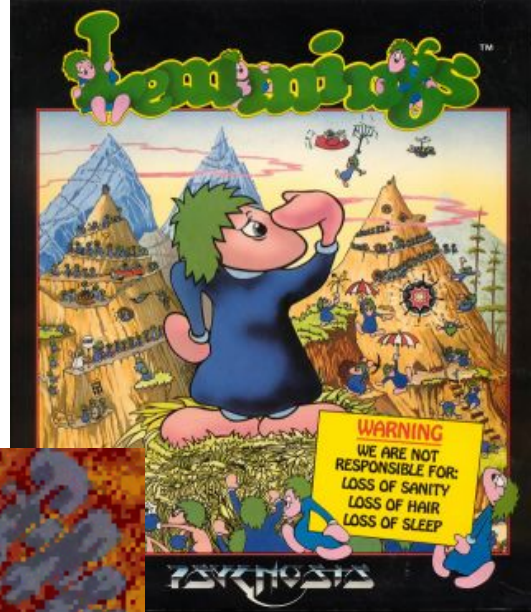
←





# Lemmings

[DMA Design, 1991]



[Viglietta  
2014]

# Lemmings Results

[Cormode  
2014]

Climbers	$\infty$	poly	$\infty$			
Floater	$\infty$	poly	$\infty$			
Bombers		poly	$\infty$			
Blockers		poly	$\infty$			
Builders		poly	$\infty$			
Bashers		poly	$\infty$			poly
Miners		poly	$\infty$		poly	
Diggers		poly	$\infty$	poly		
Time	$\infty$	poly	$\infty$	poly	poly	poly
Hazards			✓			
1 lemming				✓		
	<b>P</b>	<b>NP</b>	<b>PSPACE</b>	<b>NP-hard</b>	<b>NP-hard</b>	<b>NP-hard</b>



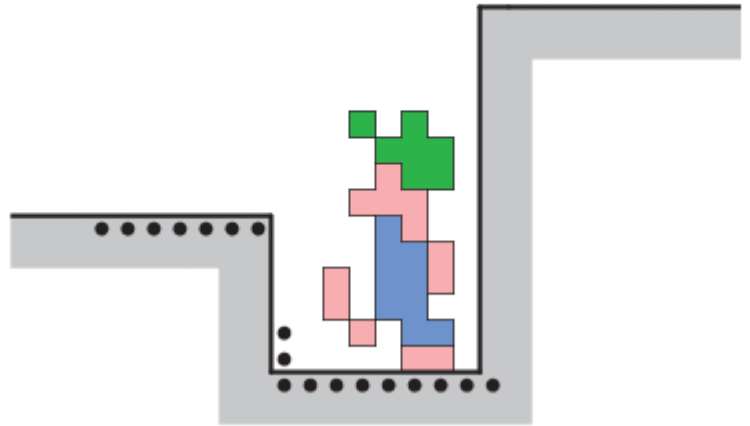
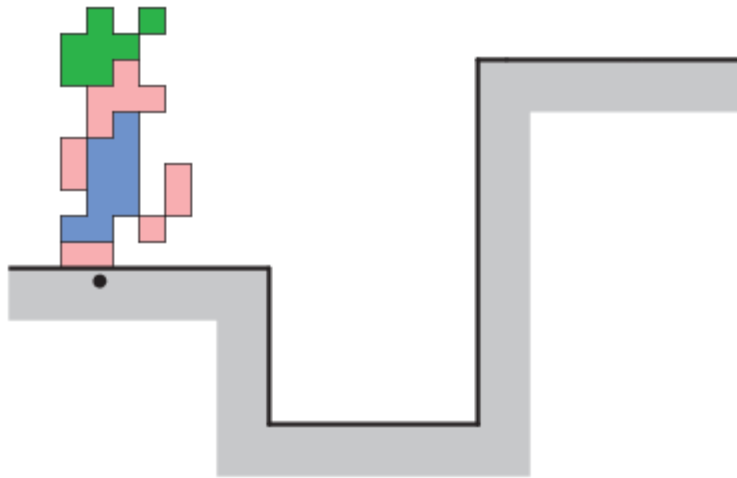
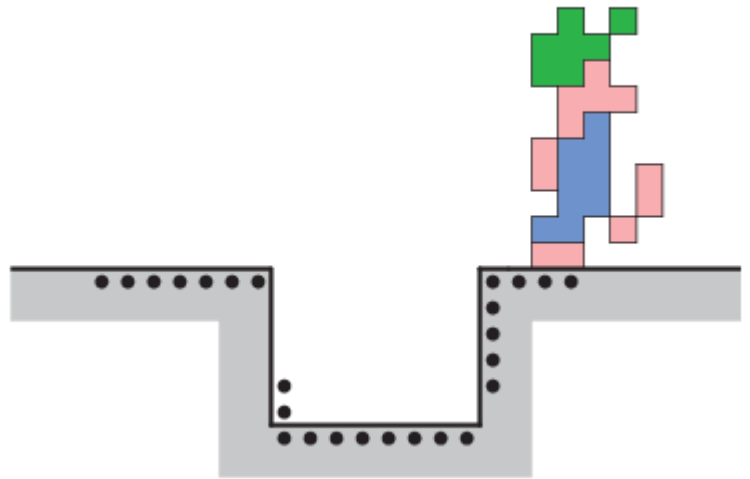
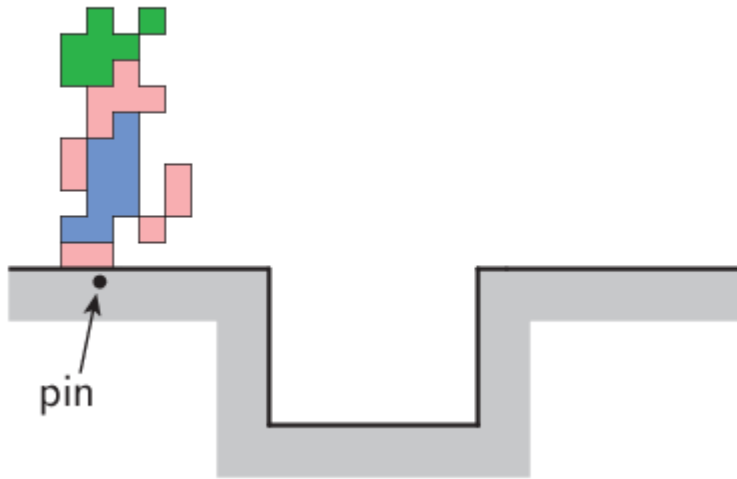




# Lemmings: Walker

[Viglietta 2014]

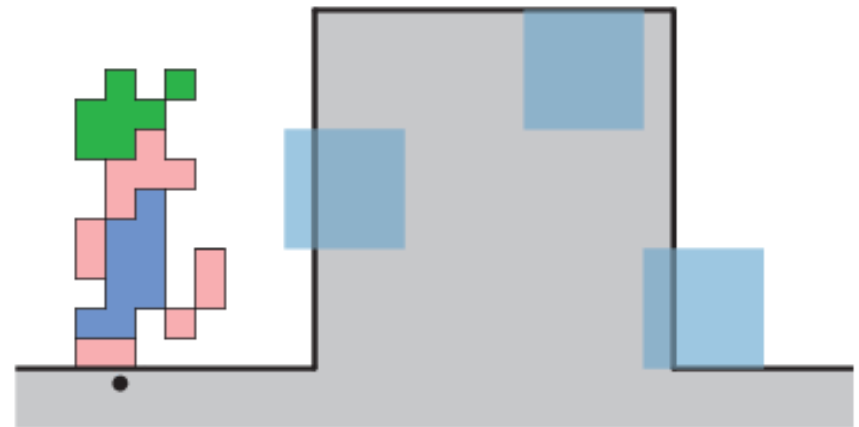
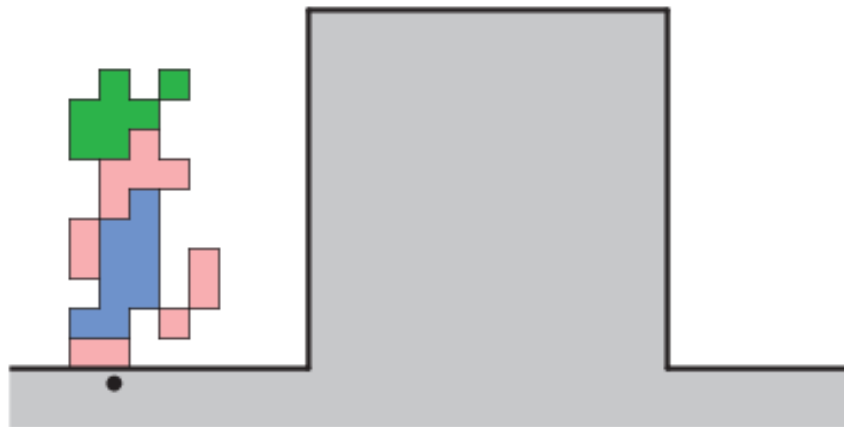
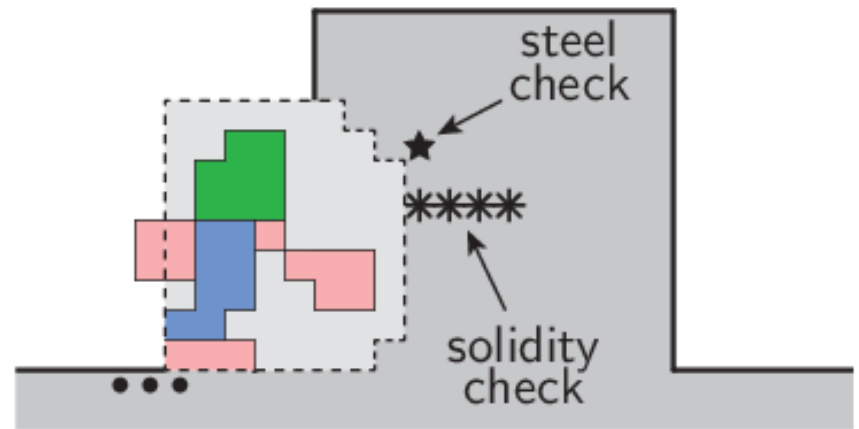
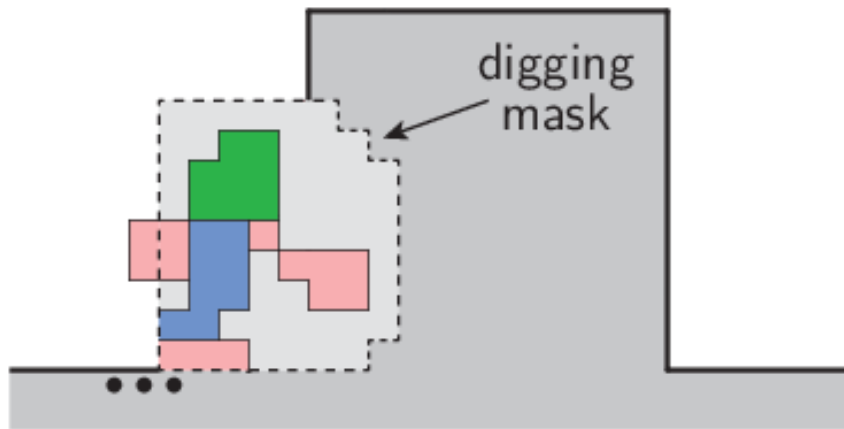
max climb = 8 pixels





# Lemmings: Basher

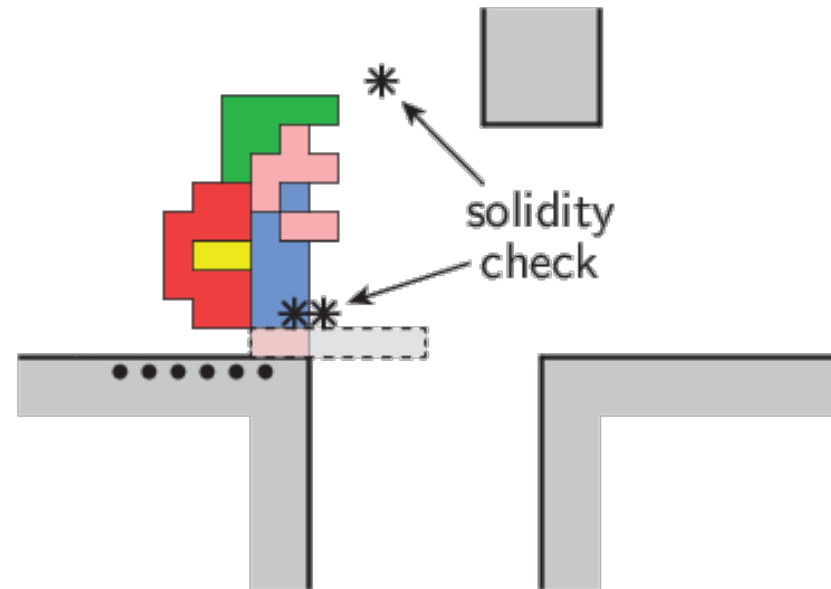
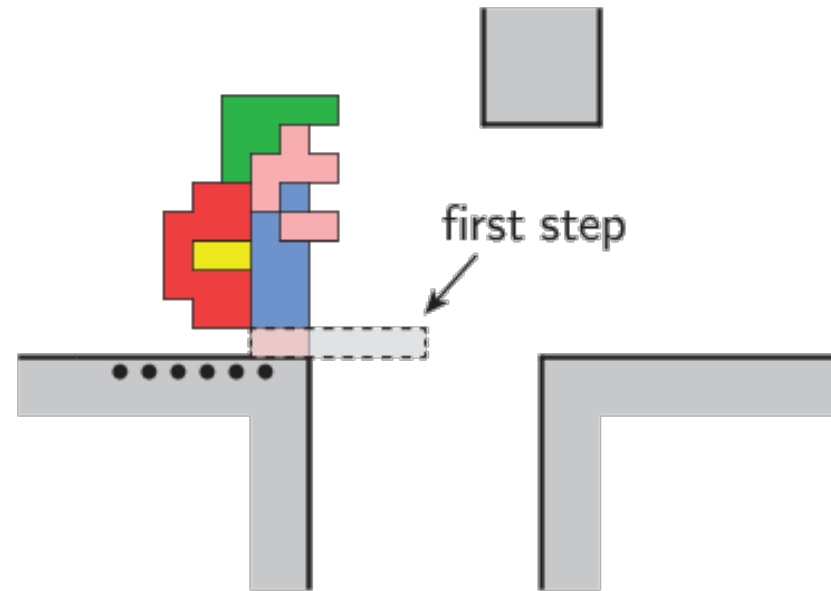
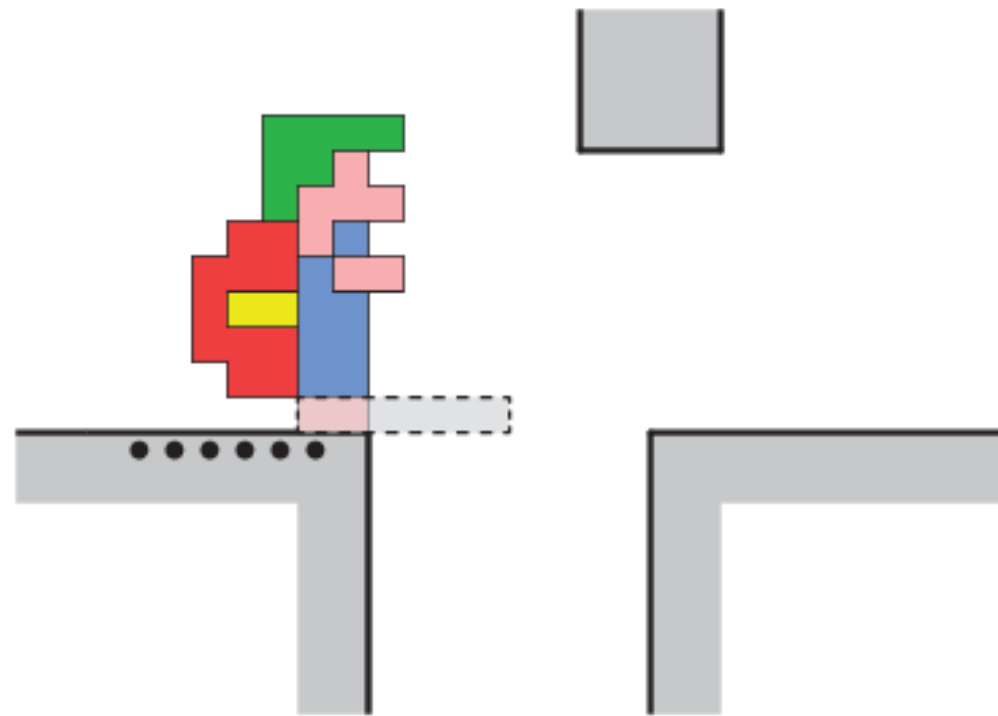
[Viglietta 2014]





# Lemmings: Builder

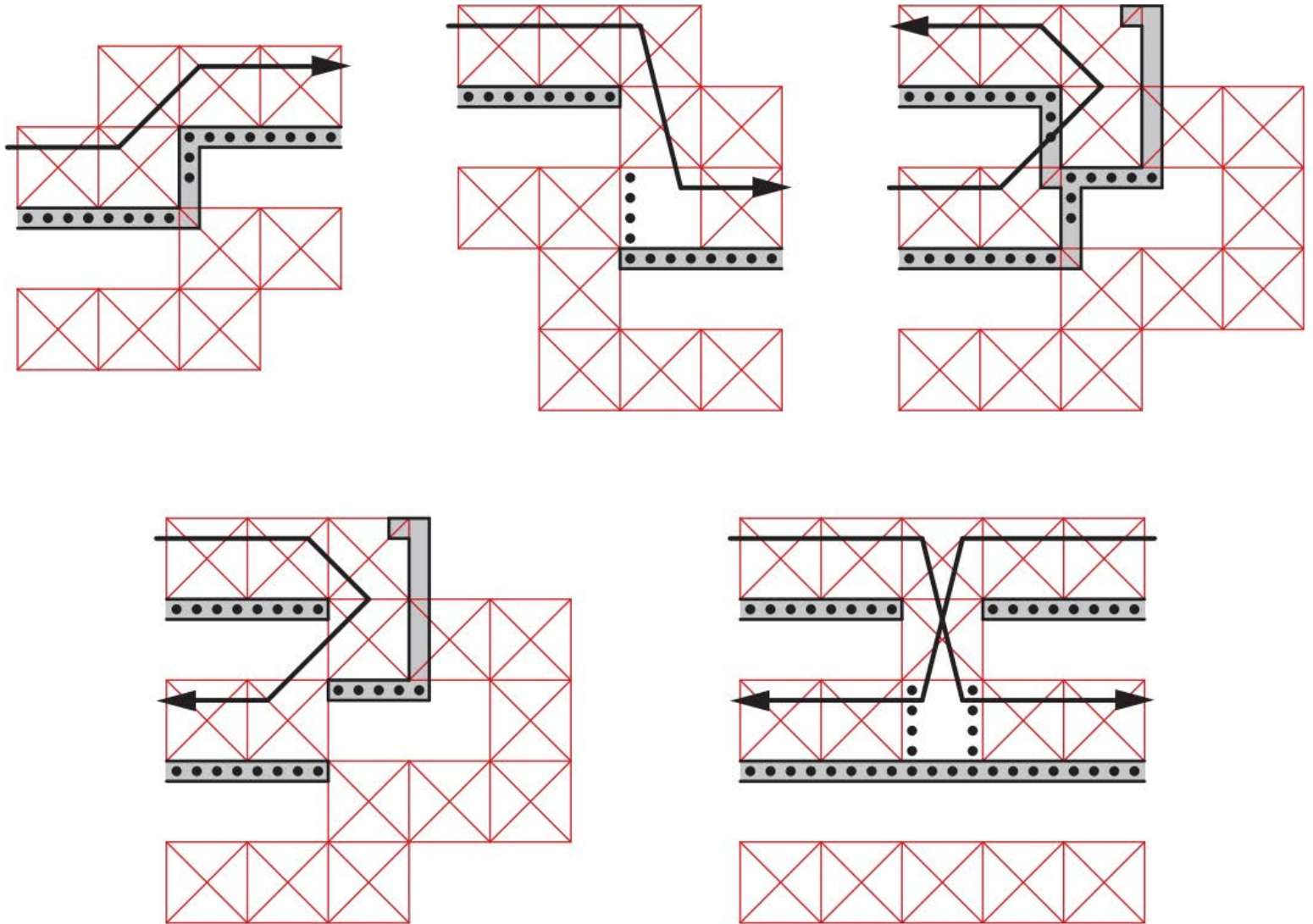
[Viglietta 2014]





# Lemmings: Paths

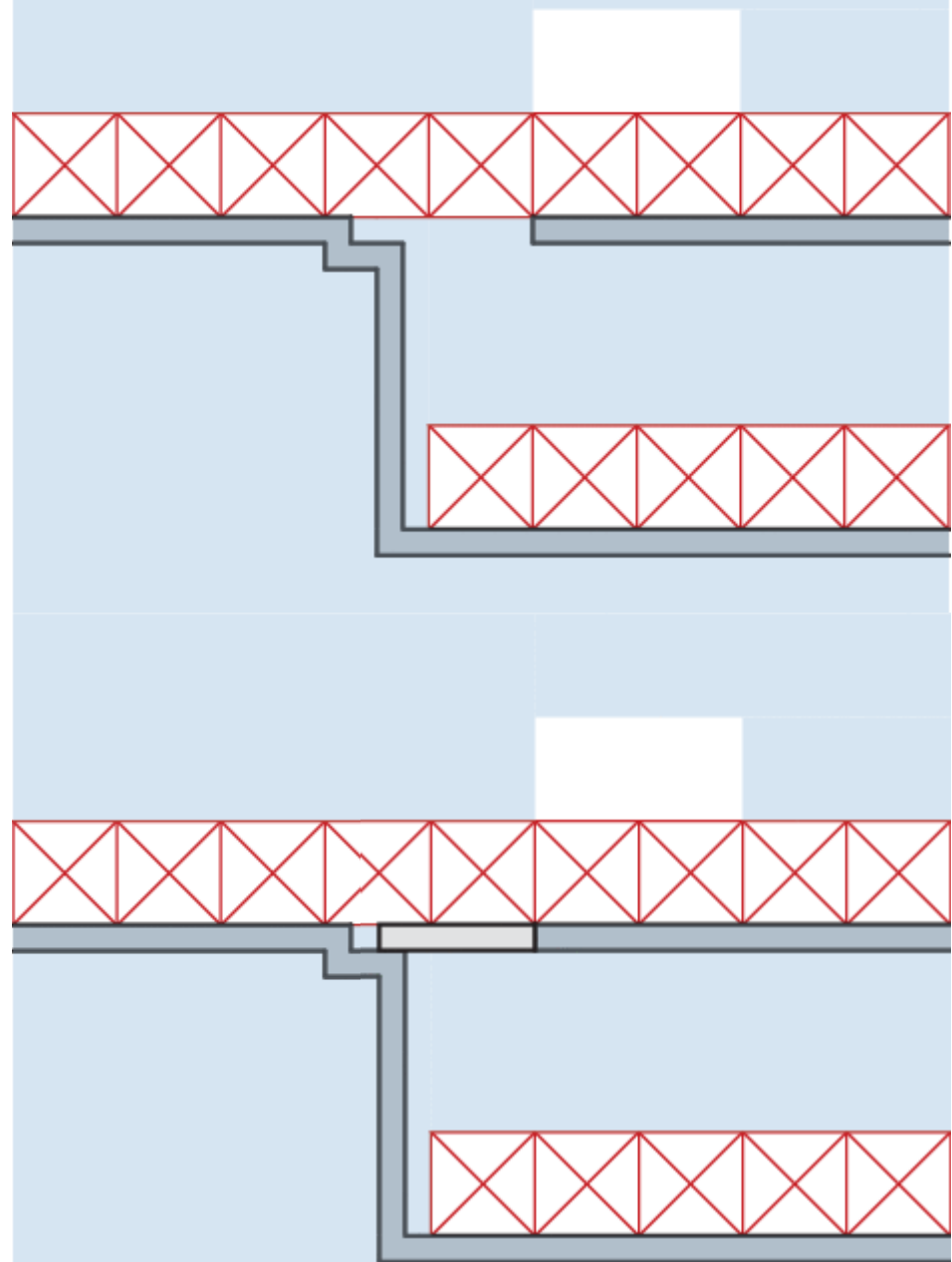
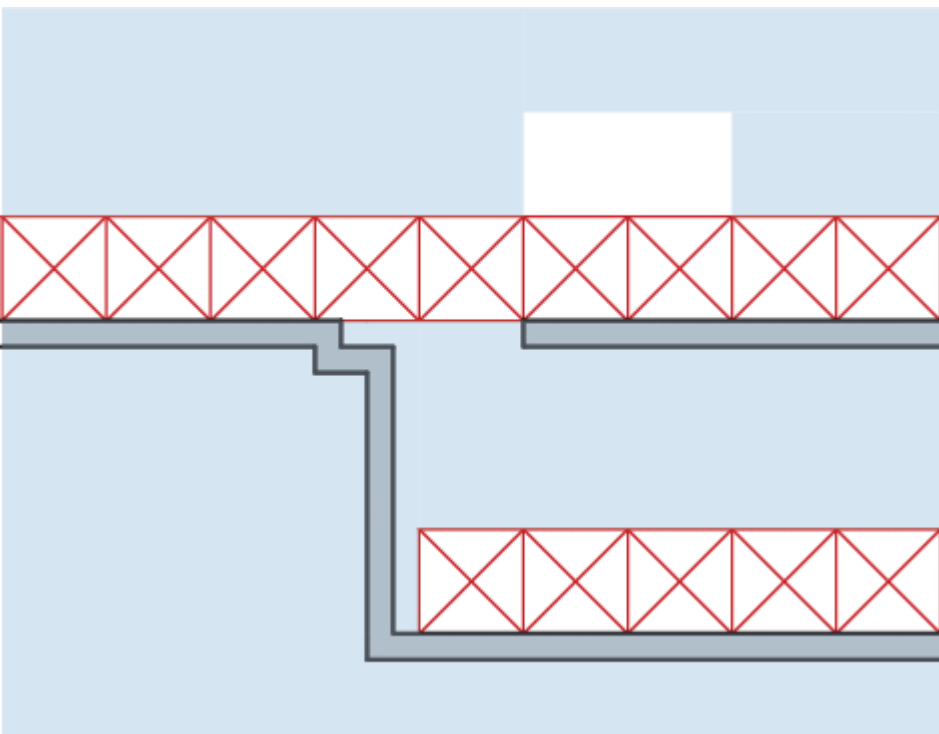
[Viglietta 2014]





# Lemmings: Fork

[Viglietta 2014]



# Lemmings: Door

[Viglietta 2014]

