Compiler and Runtime Support for Continuation Marks

Matthew Flatt
University of Utah

R. Kent Dybvig
Cisco Systems, Inc.

Why Continuation Marks

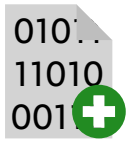
```
open "data.txt"
```

Why Continuation Marks

```
open "data.txt"
     'create
```

Why Continuation Marks

```
open "data.txt"
     'create
     'binary
```



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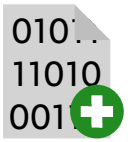


```
current-dir
    ➤
"/home/me"
```

Why Continuation Marks

```
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     'binary
```


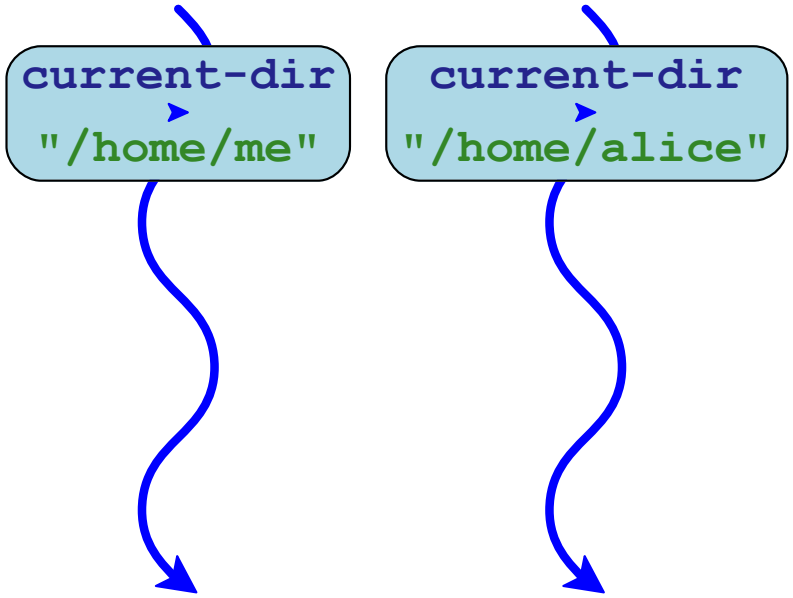

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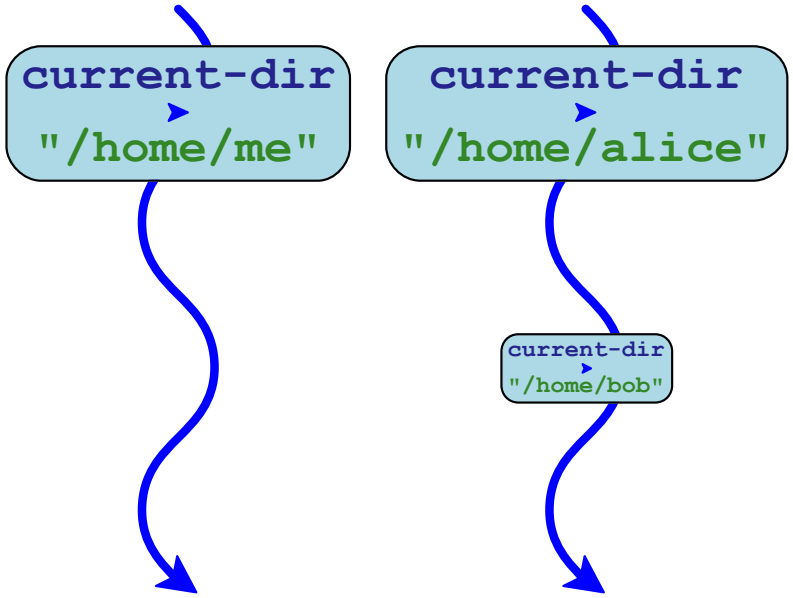

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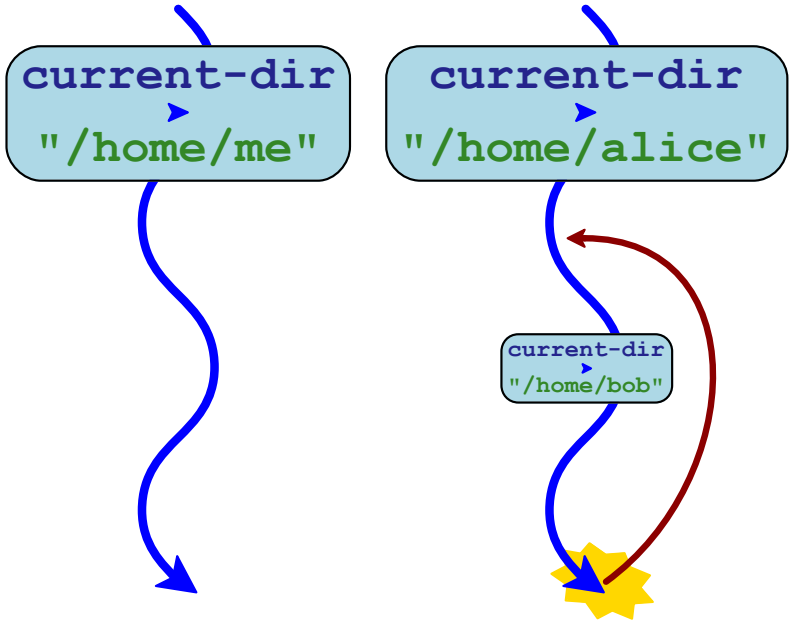

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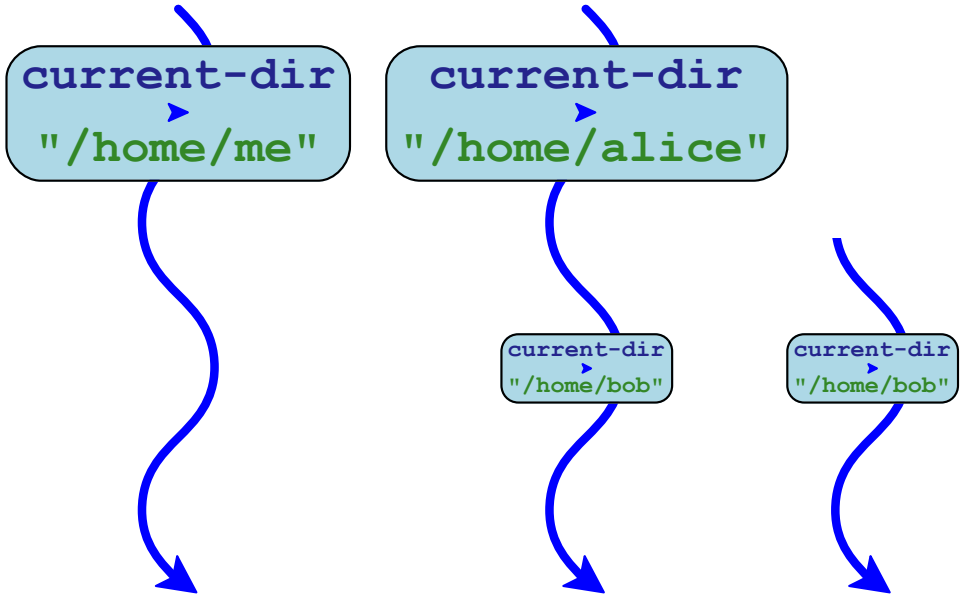

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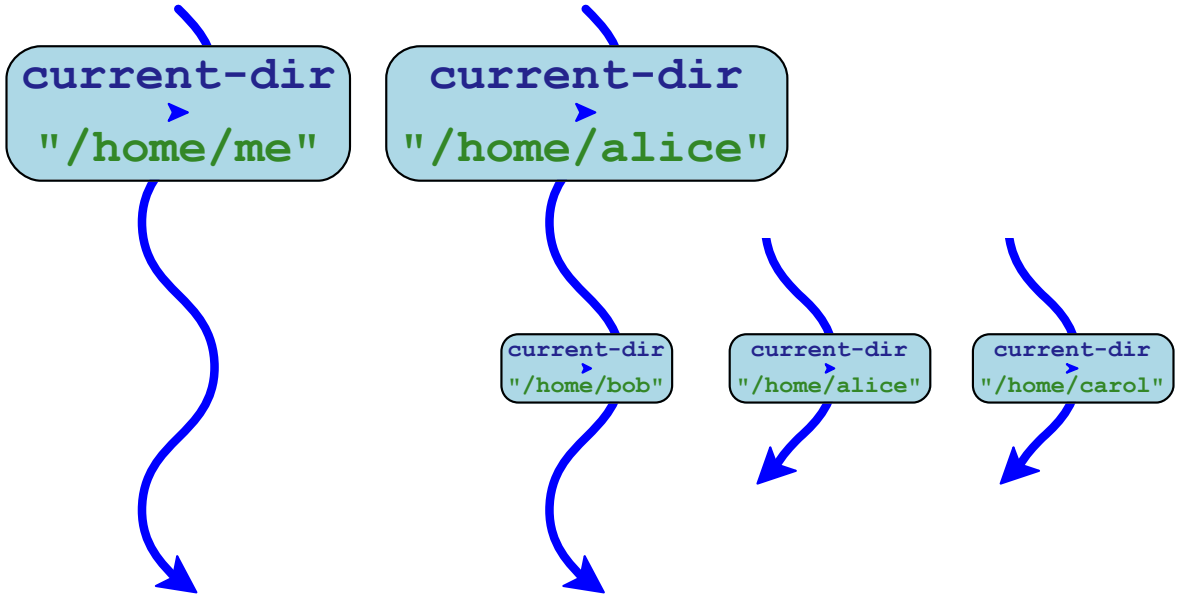

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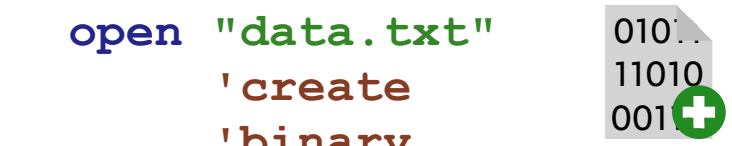

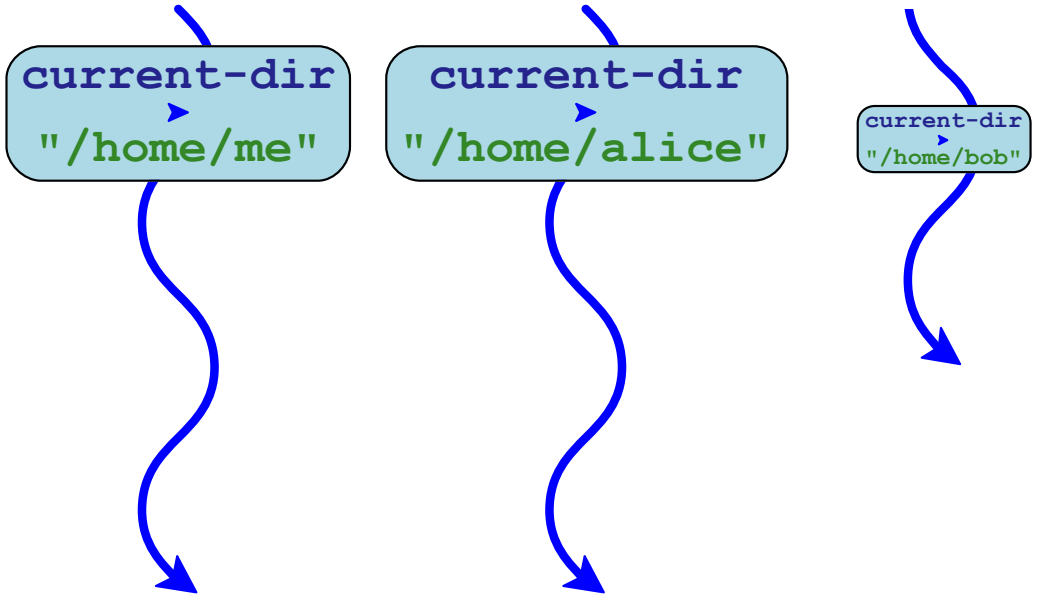

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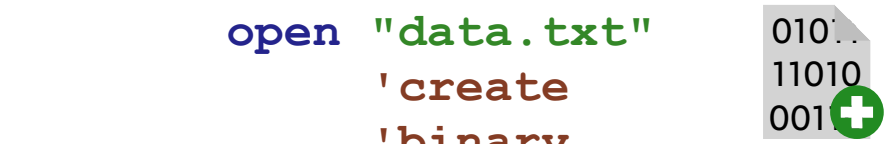

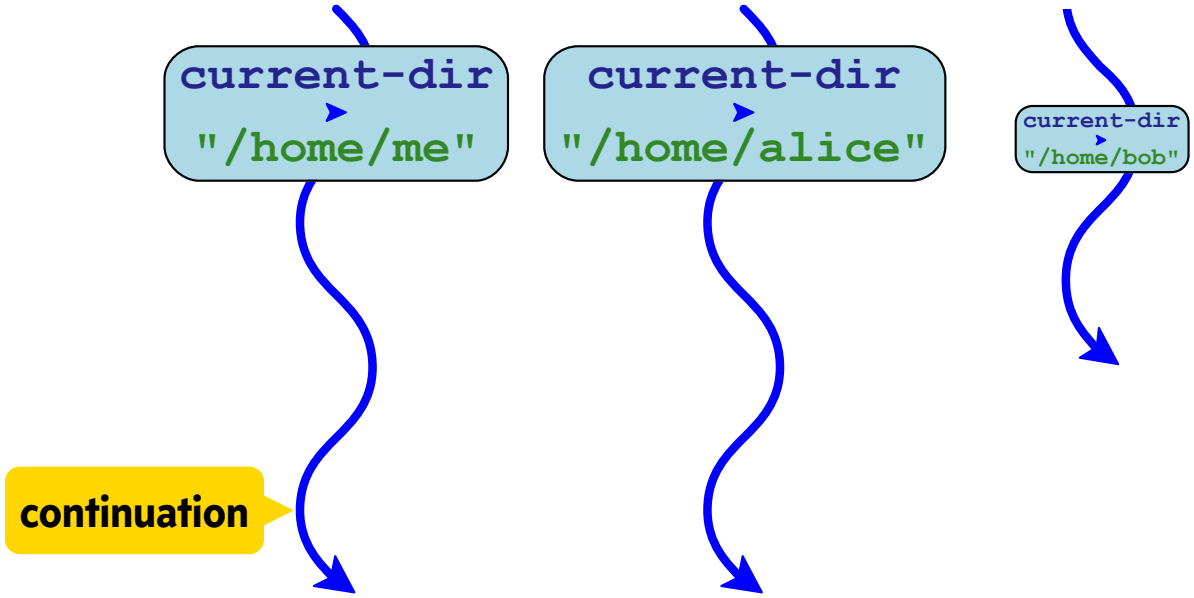

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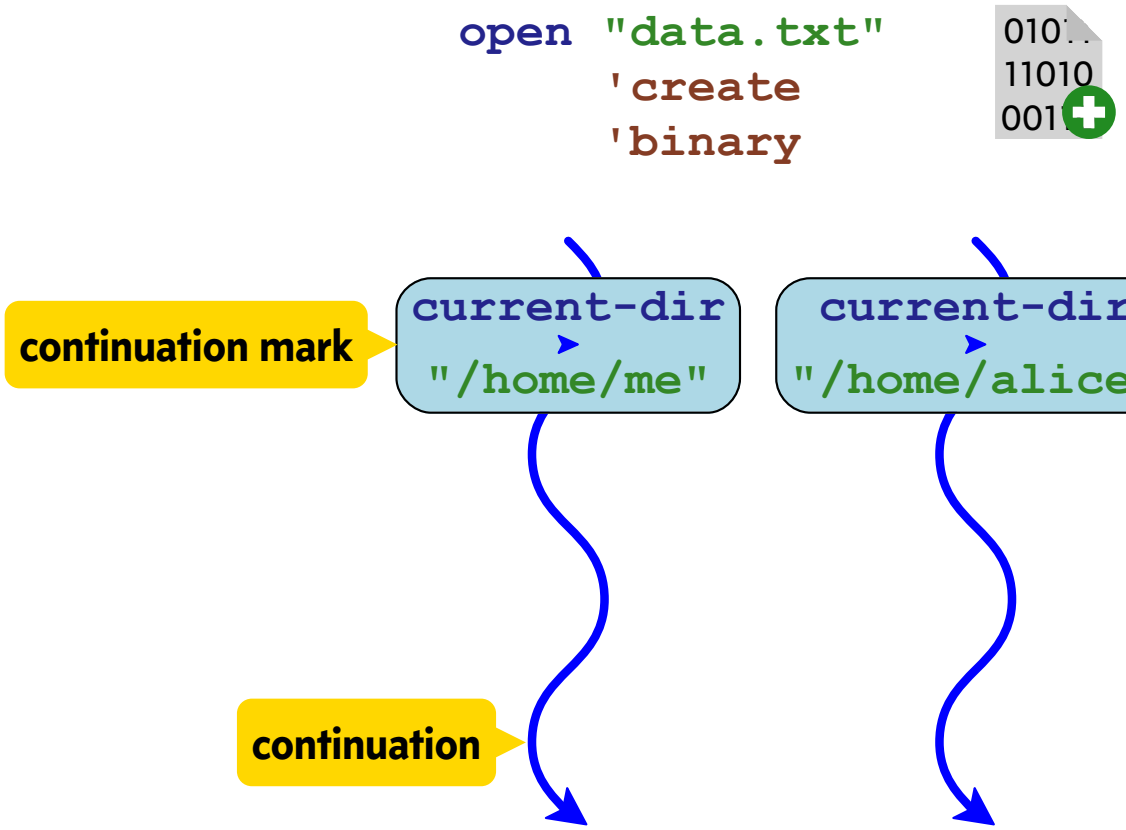

Continuation Mark Primitives

```
(parameterize ([current-directory "/home/alice"])
  (shuffle-files))
```

```
(define (path->compete-path path)
  (build-path (current-directory)
              path))
```

Continuation Mark Primitives

```
(with-mark
  current-directory "/home/alice"
  (shuffle-files))
```

```
(define (path->compete-path path)
  (build-path (current-directory)
              path))
```

Continuation Mark Primitives

```
(with-mark
  current-directory "/home/alice"
  (shuffle-files))
```

```
(define (path->compete-path path)
  (build-path (current-mark current-directory)
              path))
```

Continuation Mark Primitives

```
(with-mark
  current-directory "/home/alice"
  (shuffle-files))
```

```
(define (path->compete-path path)
  (build-path (first
               (current-marks current-directory))
              path))
```

Uses of Continuation Marks

- dynamic binding [ICFP'07]
- exception handlers
- debugging [ESOP'01, SLE'17]
- profiling [TOPLAS'19]
- generators
- serializable continuations [ICFP'09]
- security checks [OOPSLA'16]
- avoiding reundant contracts [OOPSLA'18]

Running **Racket** on **Chez Scheme**

Racket	delimited continuations with marks	state-of-the-art **functionality**
Chez Scheme	continuations via `call/cc`	state-of-the-art **performace**

Running **Racket** on **Chez Scheme**

good performance via `call/cc`

Racket	delimited continuations with marks	state-of-the-art **functionality**
Chez Scheme	continuations via `call/cc`	state-of-the-art **performace**

Running **Racket** on **Chez Scheme**

mediocre peformance via `call/cc`

Racket	delimited continuations with marks	state-of-the-art **functionality**
Chez Scheme	continuations via `call/cc`	state-of-the-art **performace**

Adding Marks to Chez Scheme

speedup relative to using `call/cc`

continuation marks	*contracts*	*applications*
×3 – ×22	**×3.4**	**×1.10 – ×1.25**

Notation

$(v_1\ (((\lambda\ (x)\ x)\ v_3)\ v_2))$

"Adding Delimited and Composable Control to a Production Programming Environment"
ICFP'07 Flatt, Yu, Findler, and Felleisen

Notation

$(v_1\ ((\lambda\ (x)\ x)\ v_3)\ v_2)$

Notation

$((\lambda\ (x)\ x)\ v_3)$

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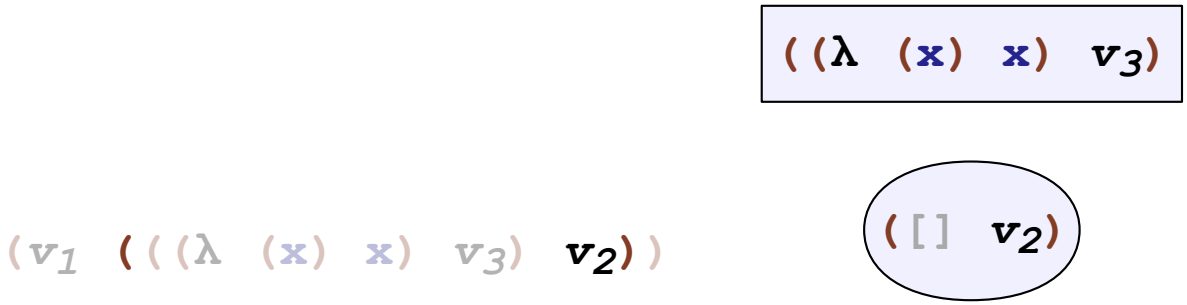

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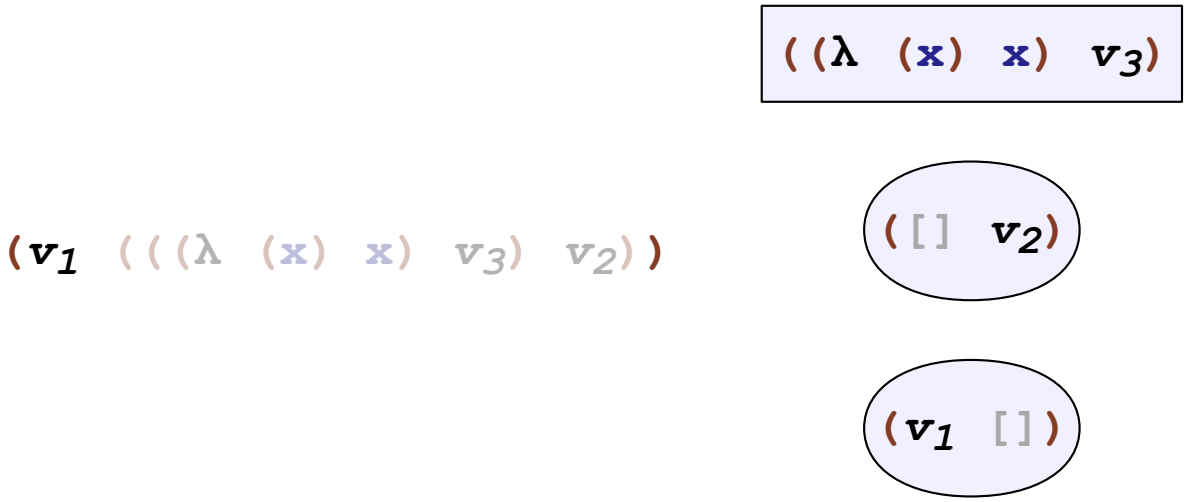
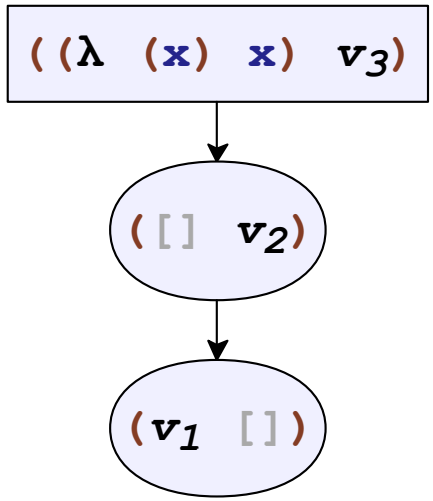
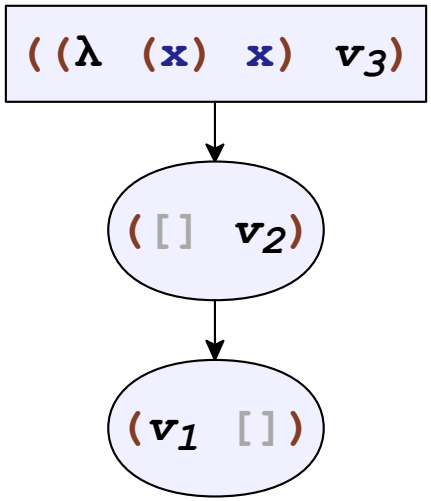


Notation

$(v_1\ ((\lambda\ (x)\ x)\ v_3)\ v_2)) =$



Reductions



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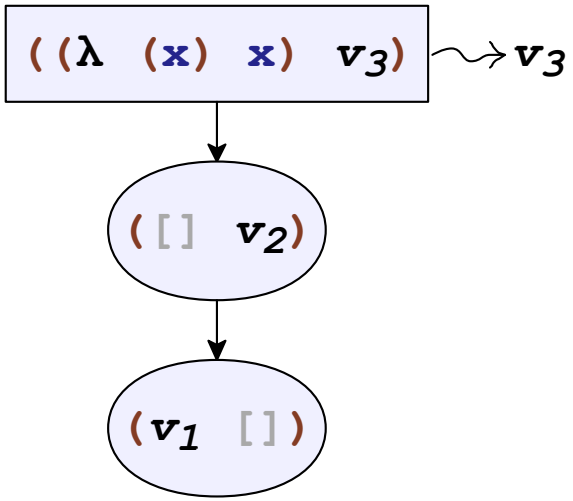

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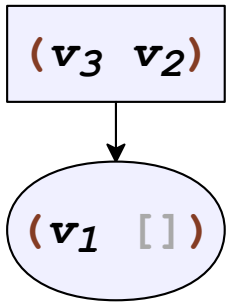

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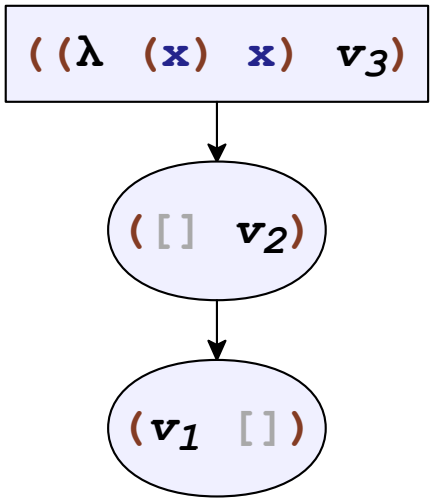
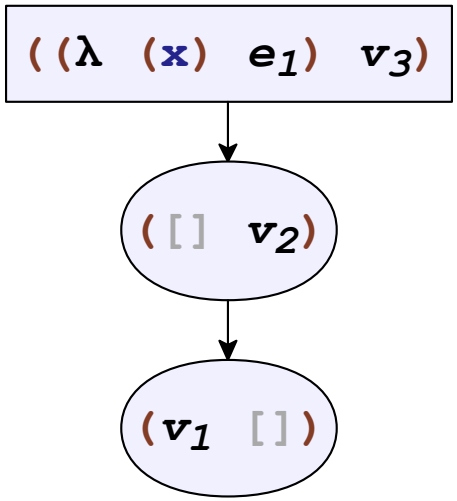
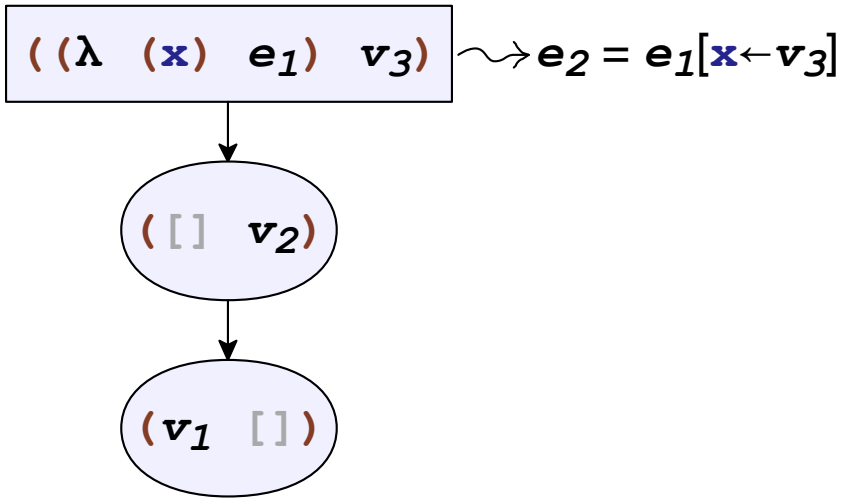


Tail Evaluation



Tail Evaluation



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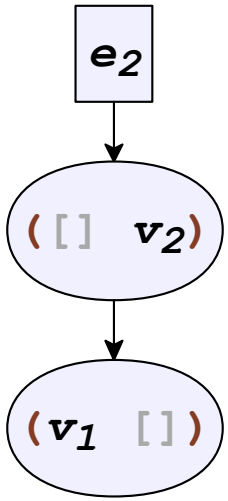
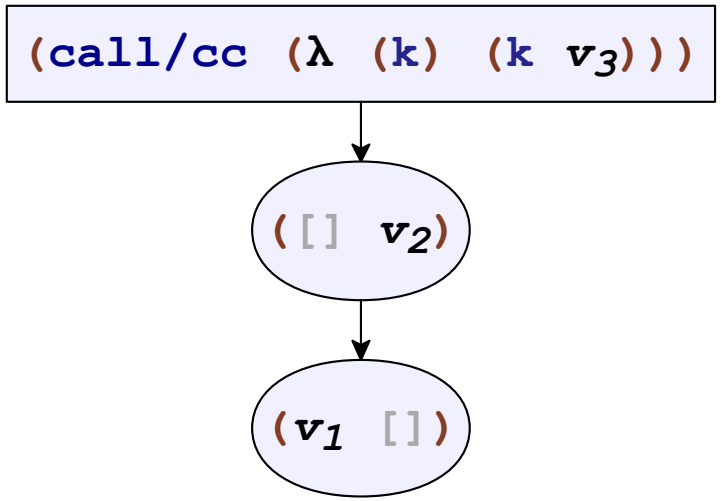


Continuations



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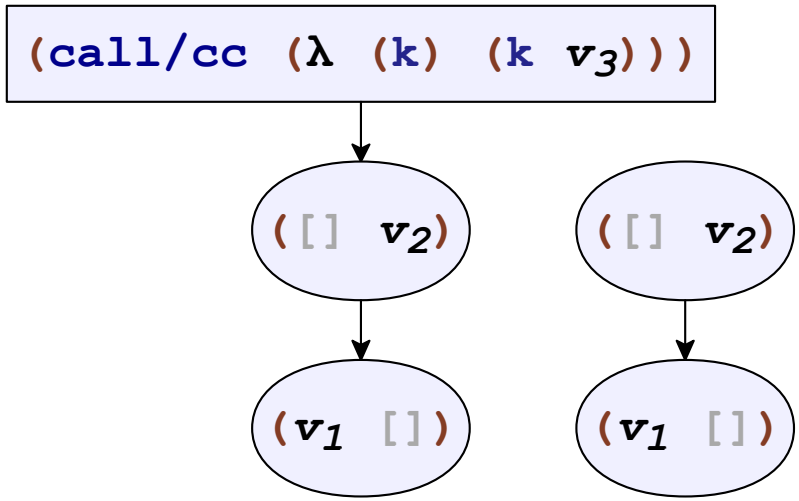

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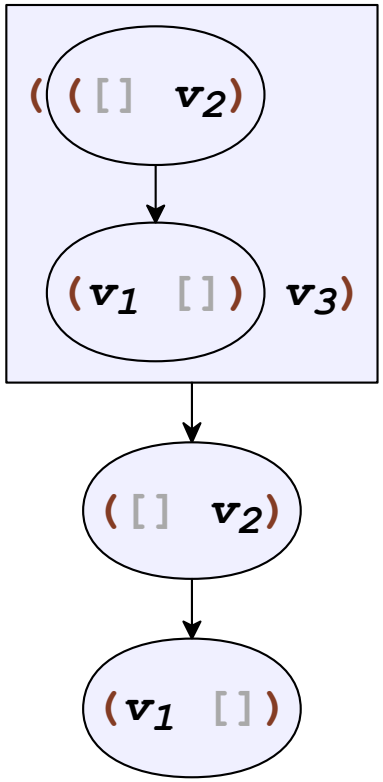
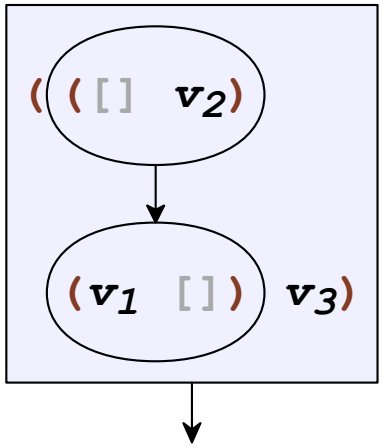
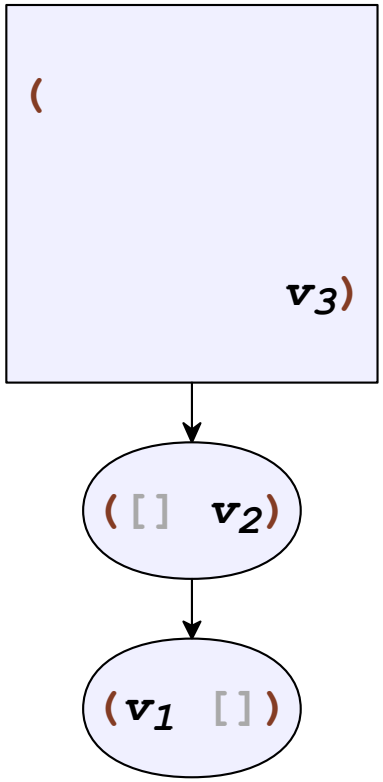


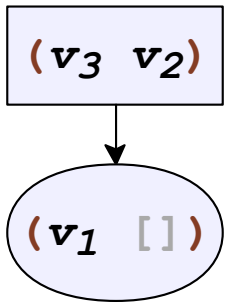
Continuations



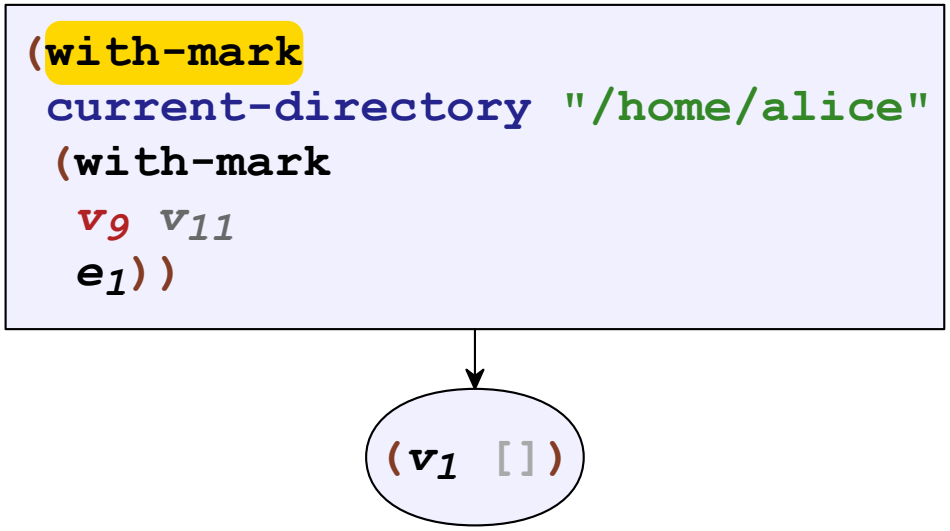
Continuations



Continuations



Continuation Marks



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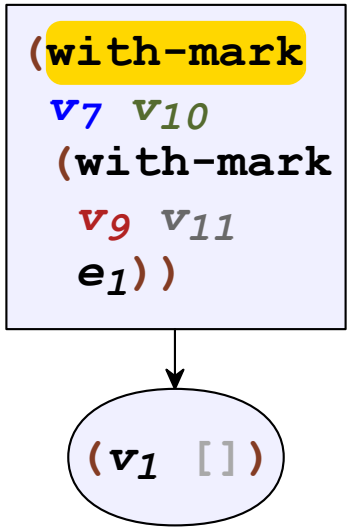

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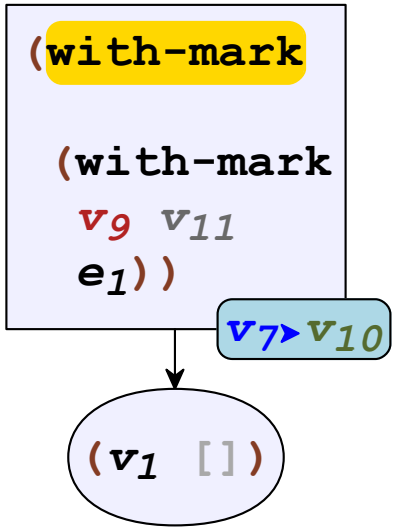

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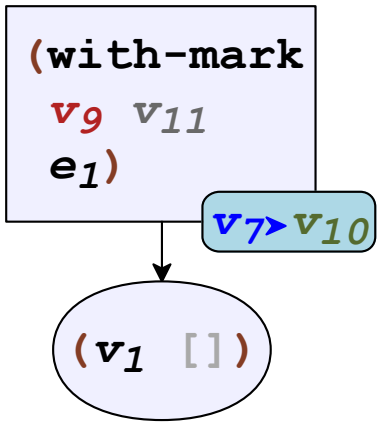

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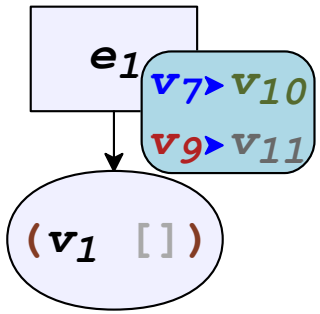

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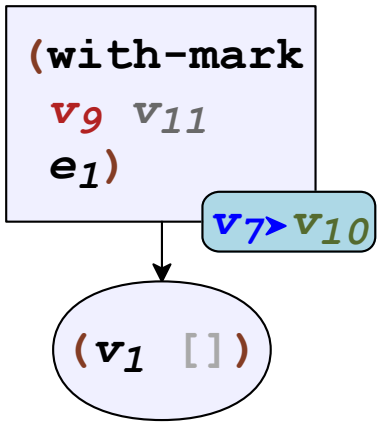

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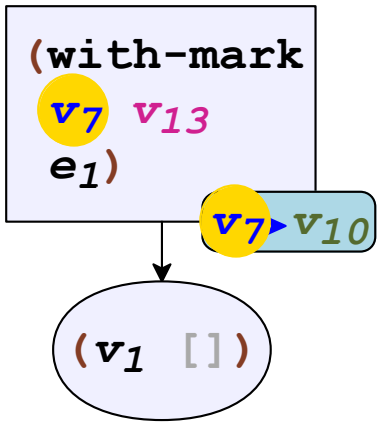

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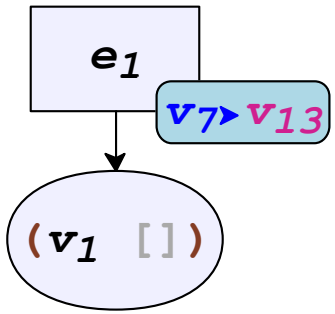

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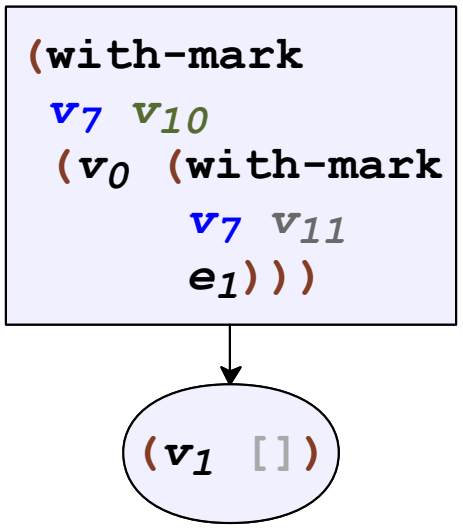

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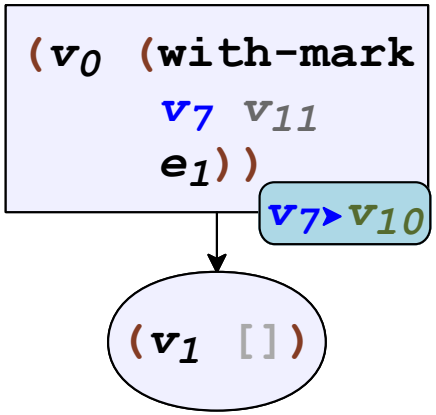

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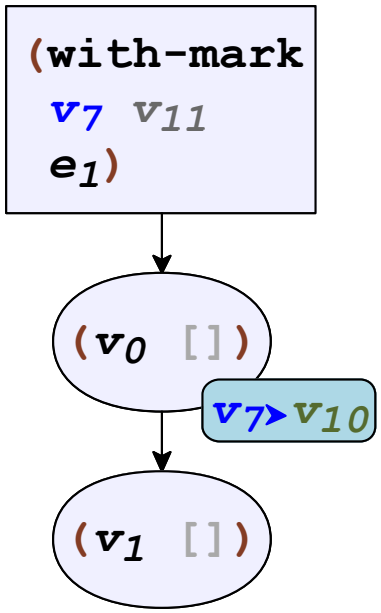

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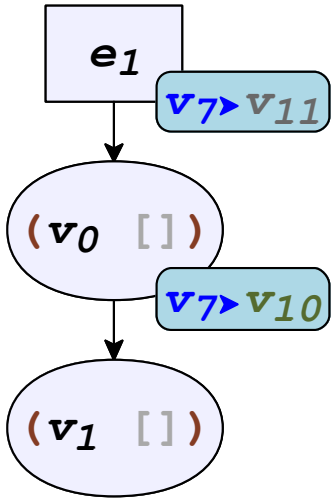

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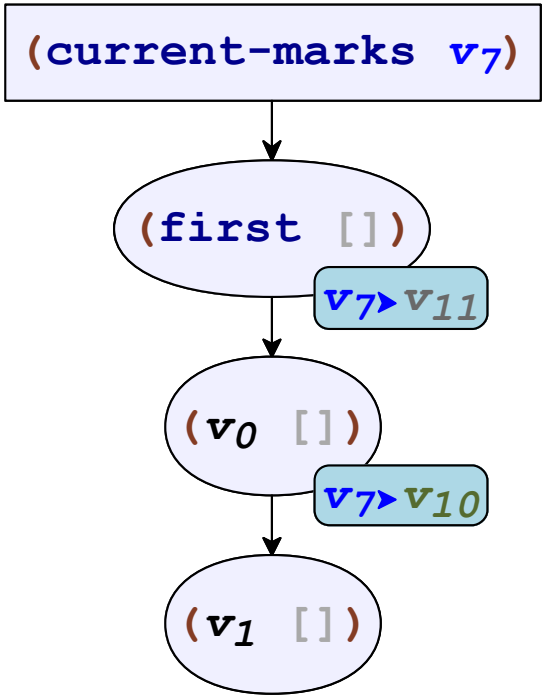

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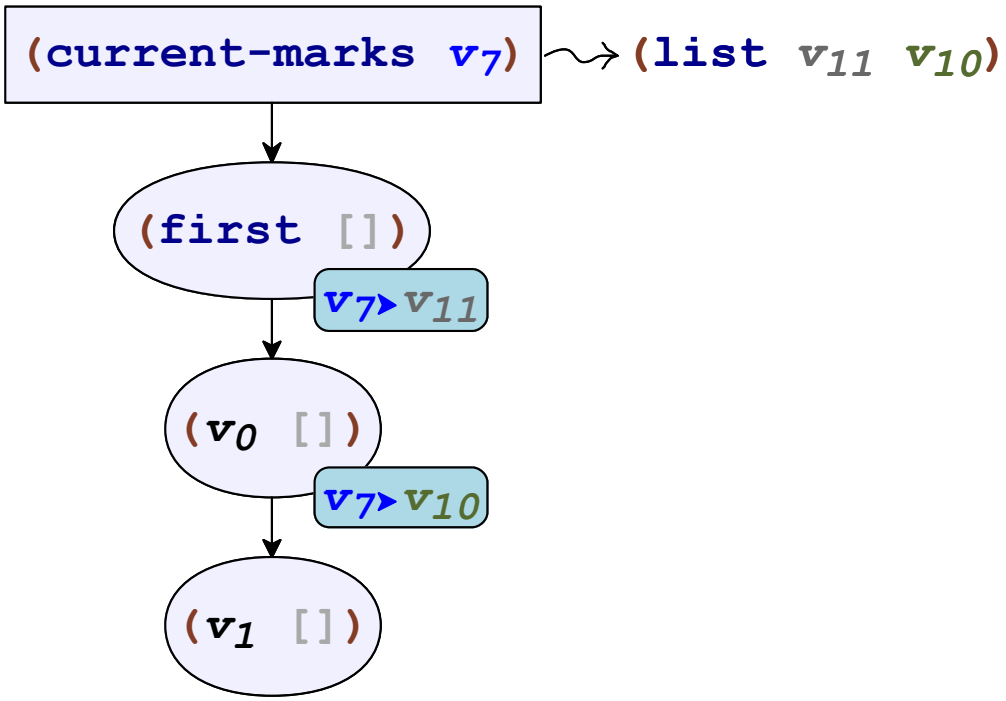

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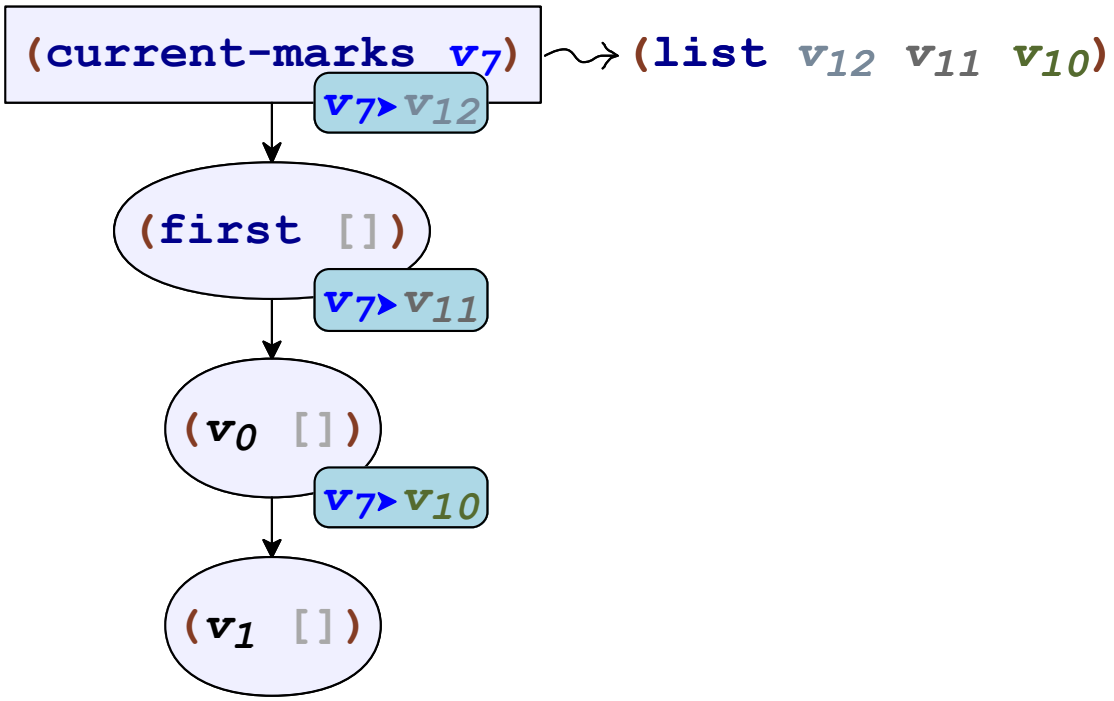
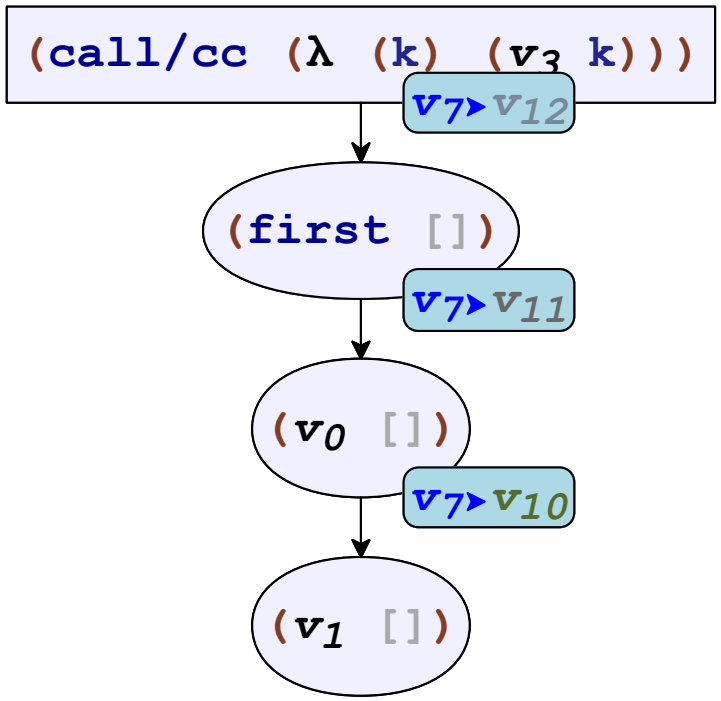


Capturing Marks



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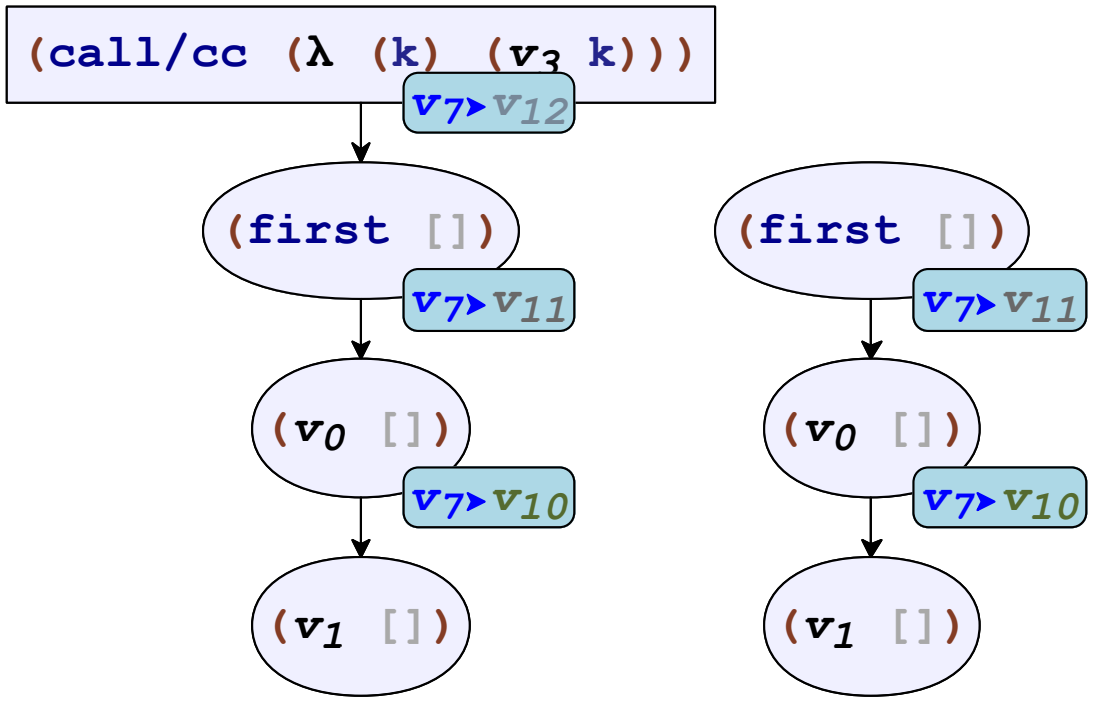
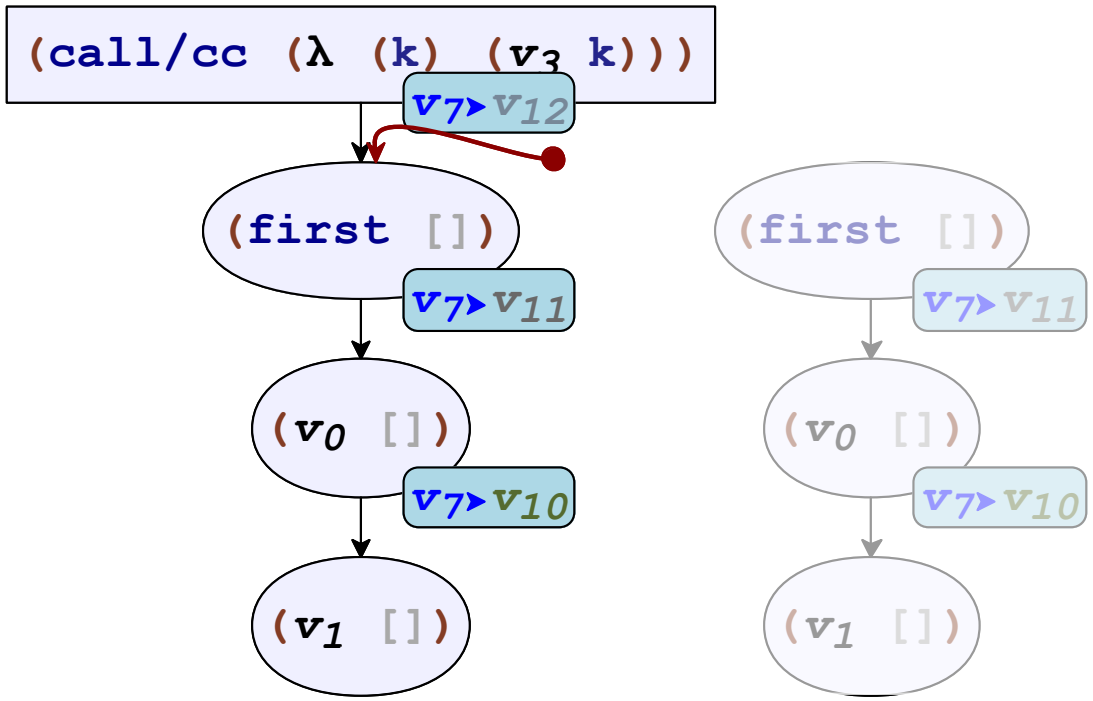
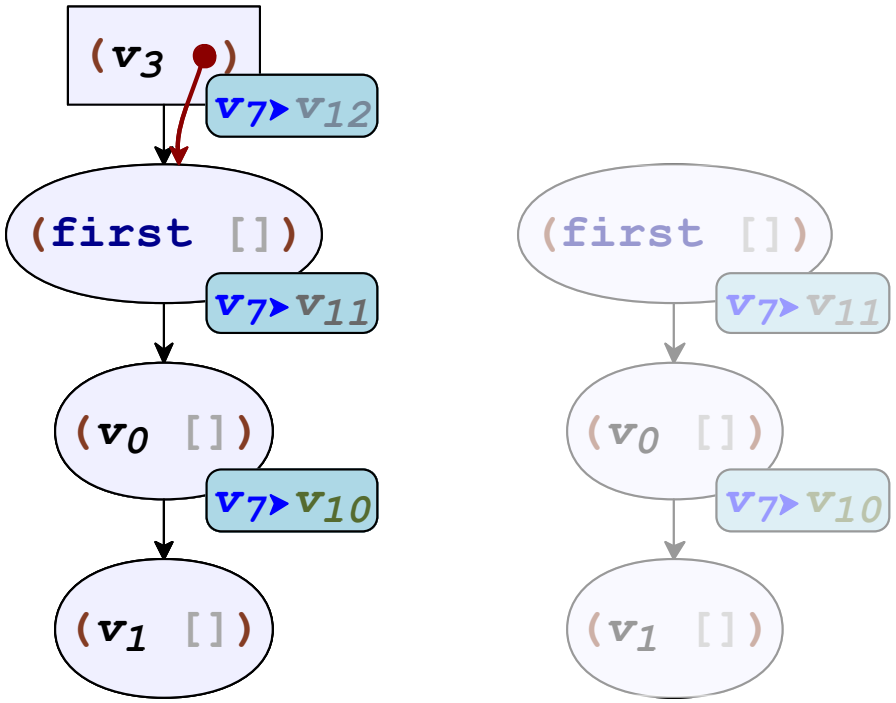


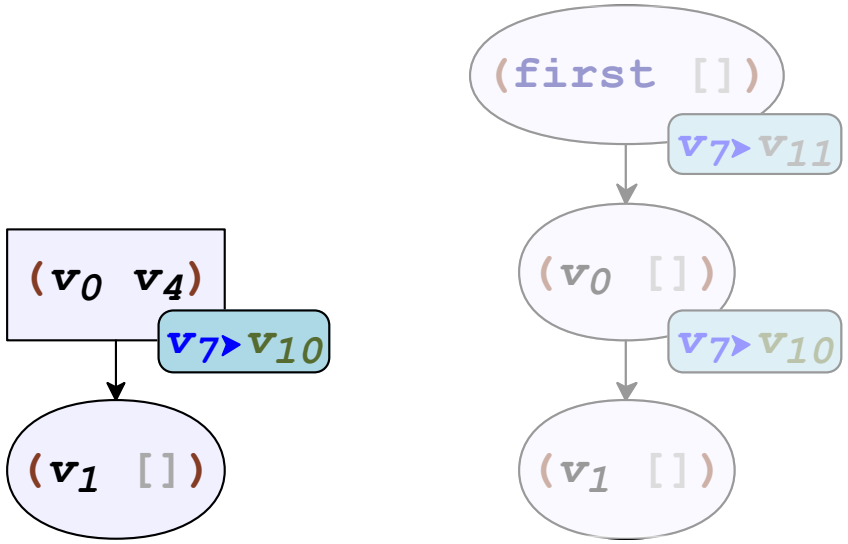
Heap-Allocated Frames



Heap-Allocated Frames



Heap-Allocated Frames



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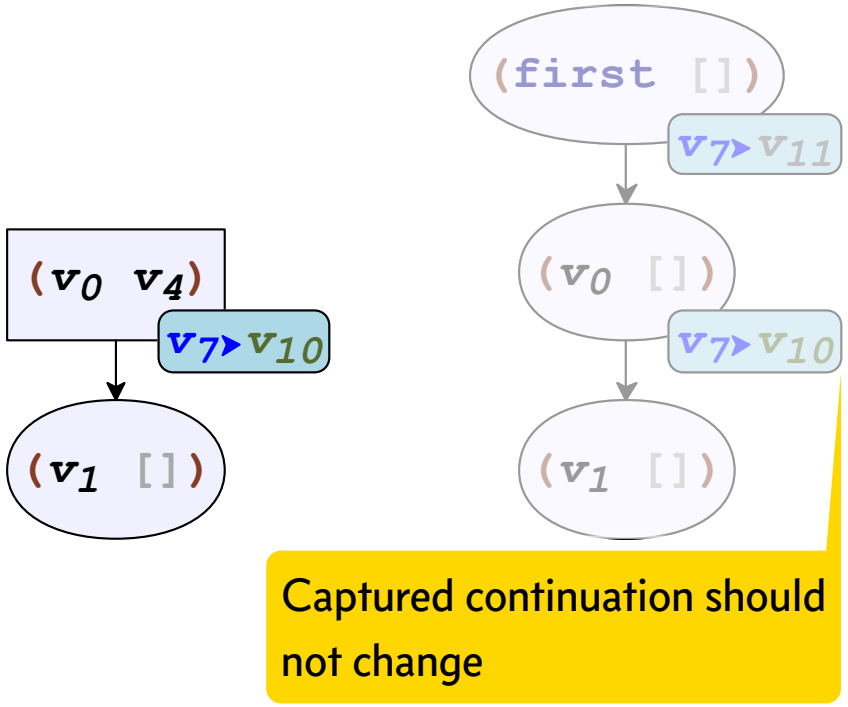

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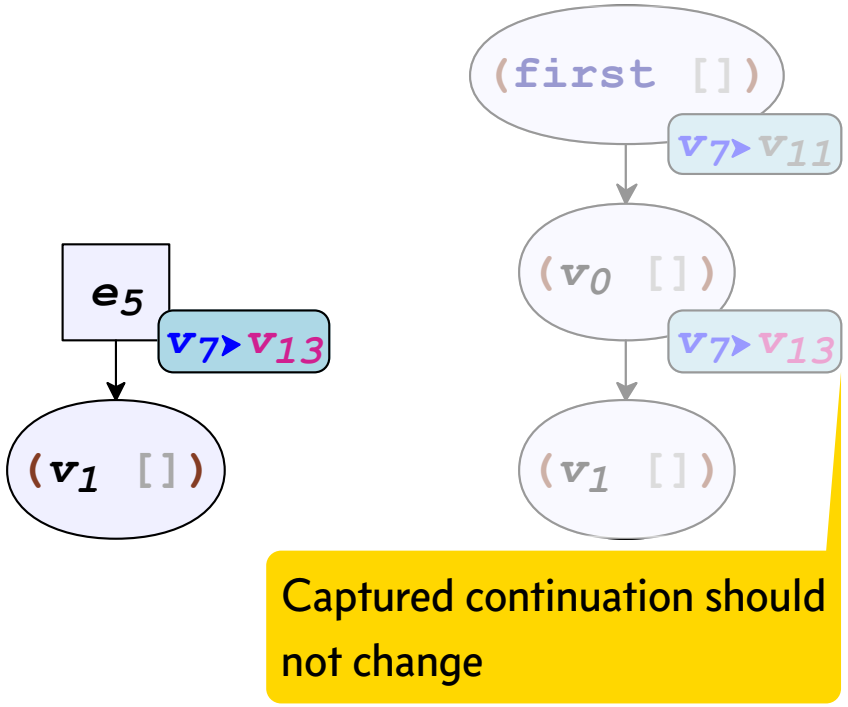
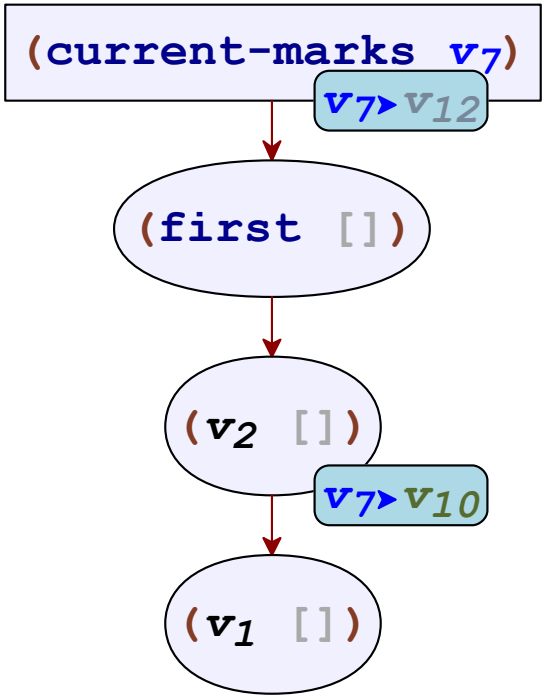
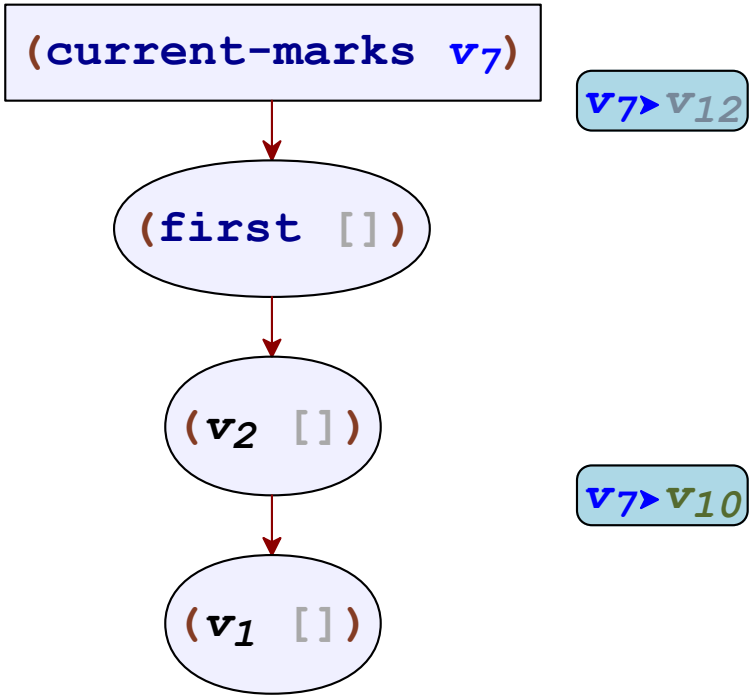


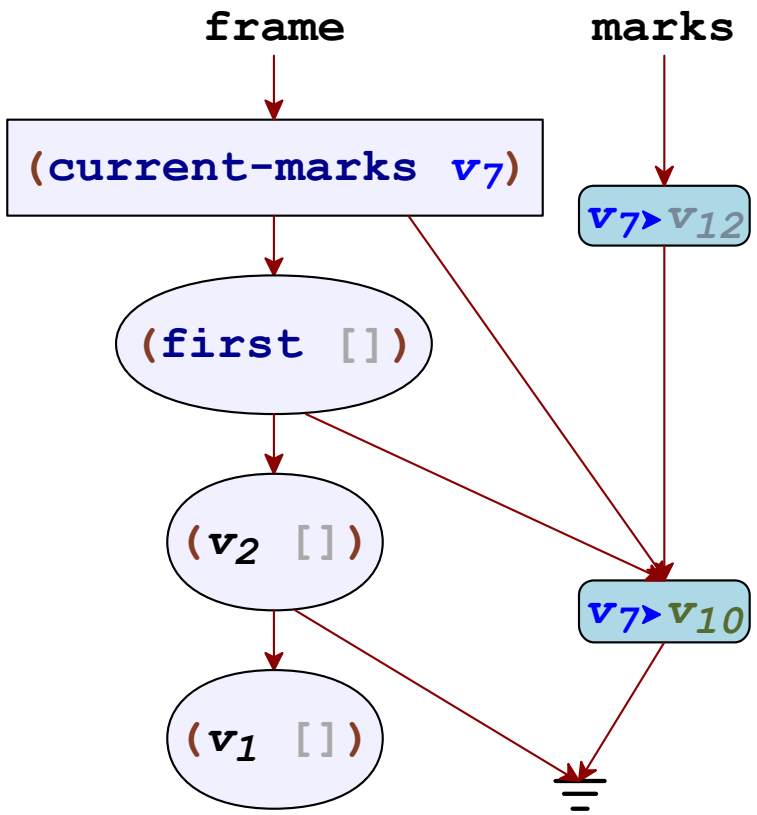
Functional Heap-Allocated Frames



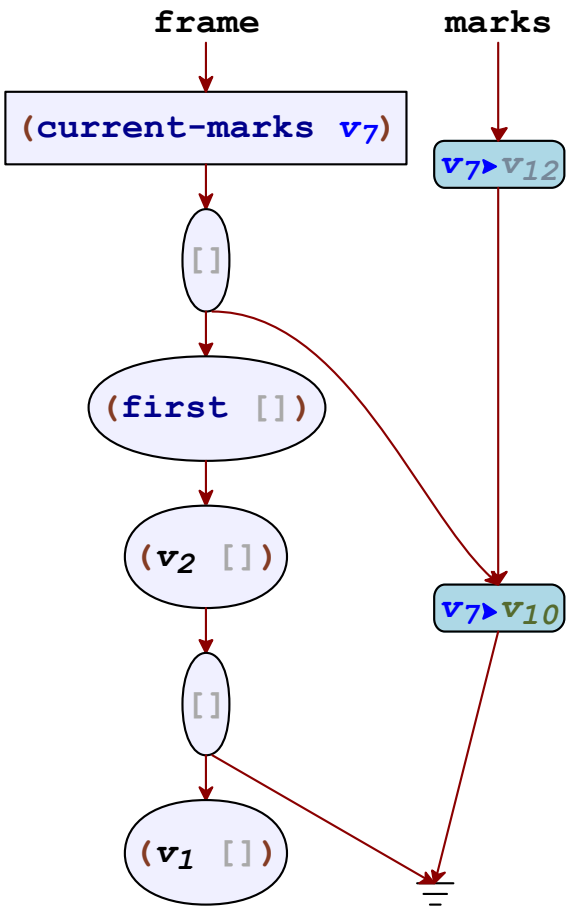
Functional Heap-Allocated Frames



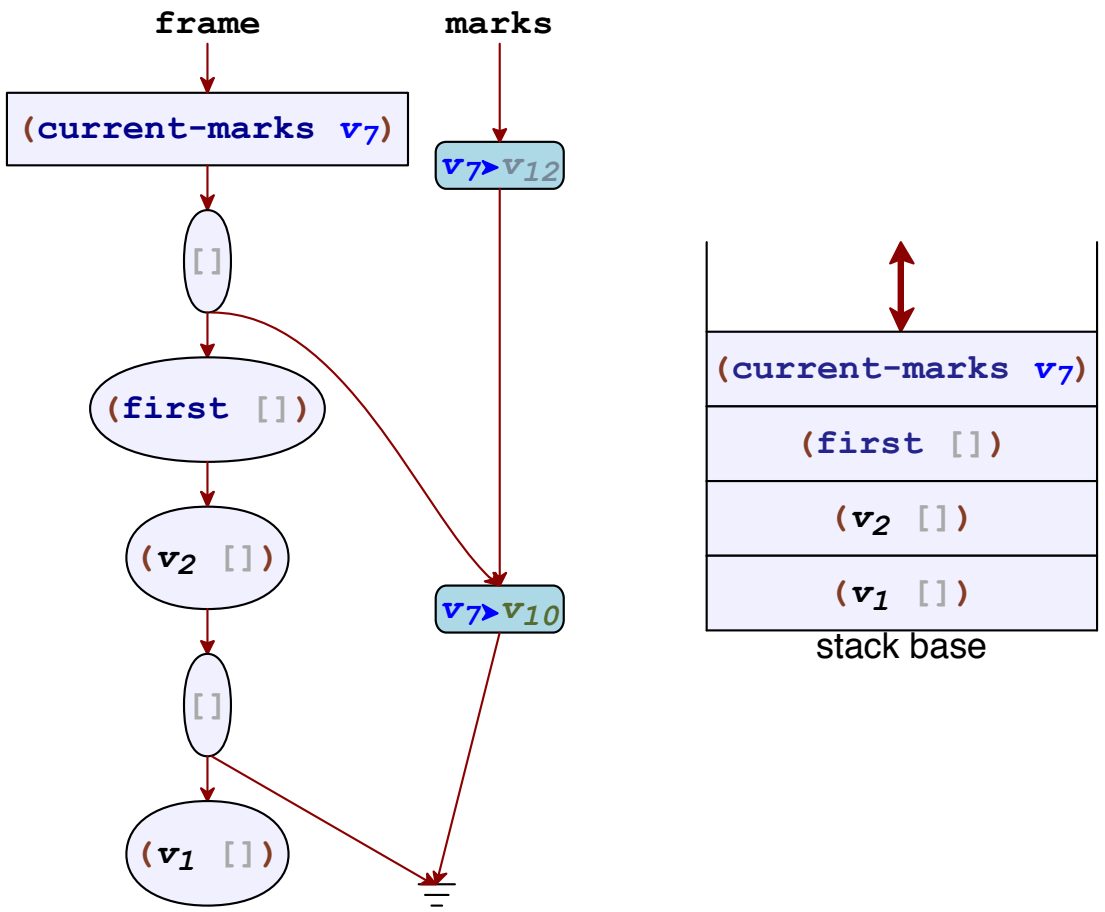
Functional Heap-Allocated Frames



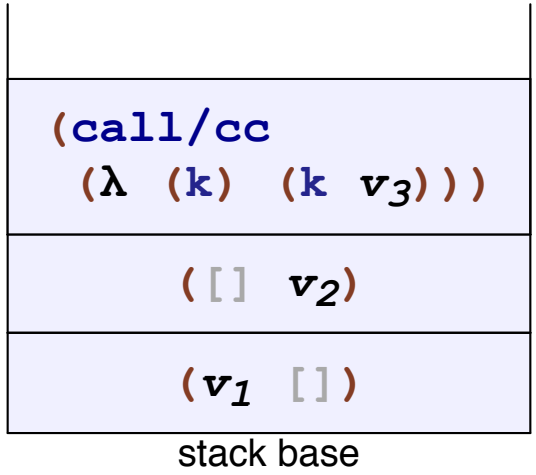
Functional Heap-Allocated Frames



Heap versus Stack

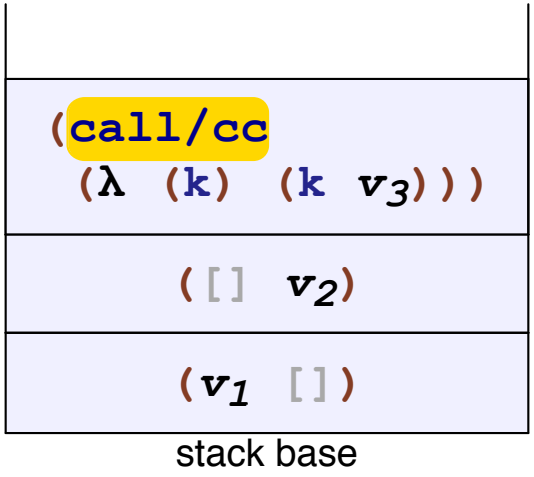


Stack-Allocated Frames

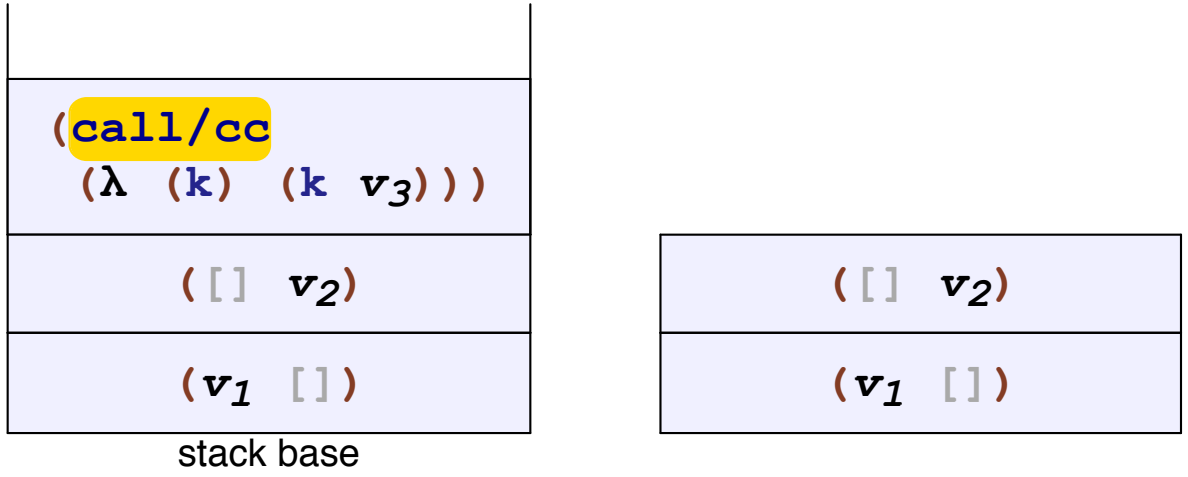


"Representing Control in the Presence of First-Class Continuations"
PLDI'90 Heib, Dybvig, and Bruggeman

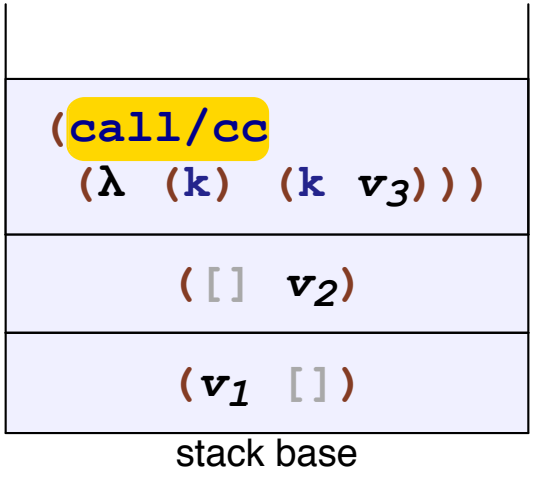
Capturing Stack-Based Continuations



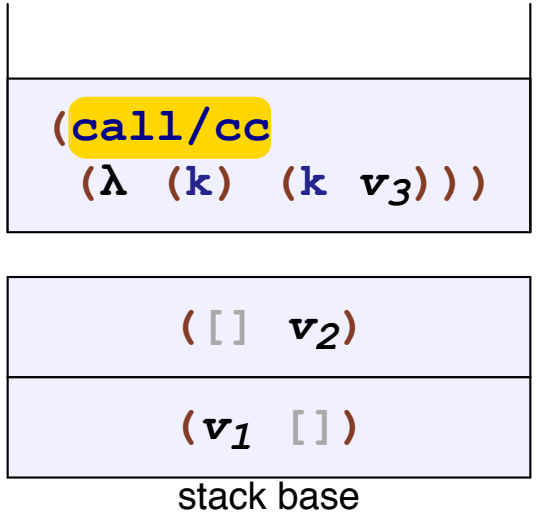
Capturing Stack-Based Continuations



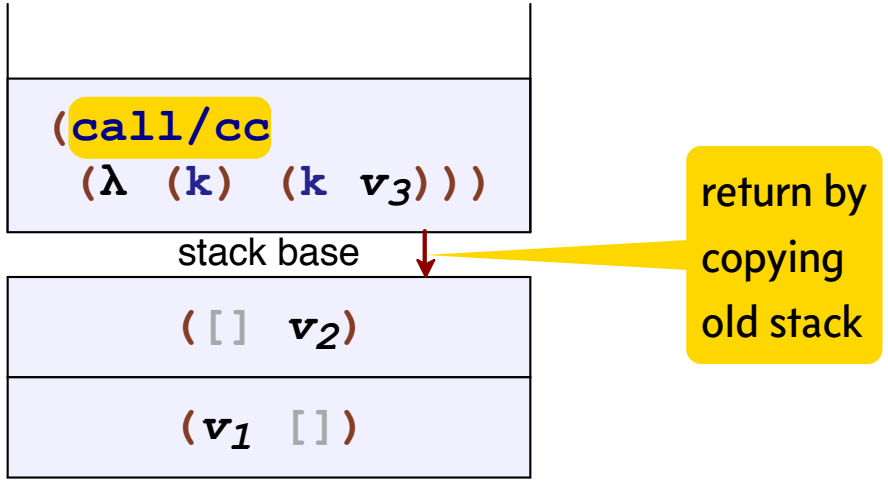
Capturing Stack-Based Continuations



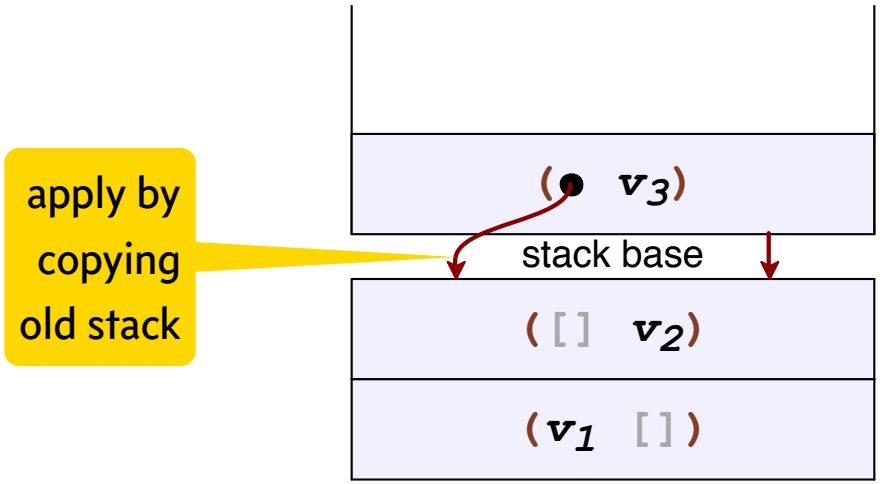
Capturing Stack-Based Continuations



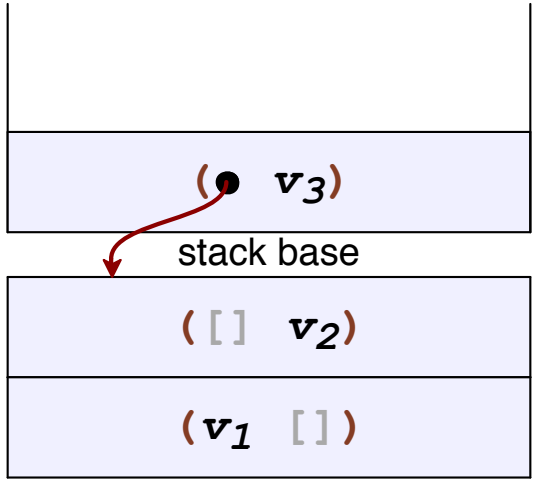
Capturing Stack-Based Continuations



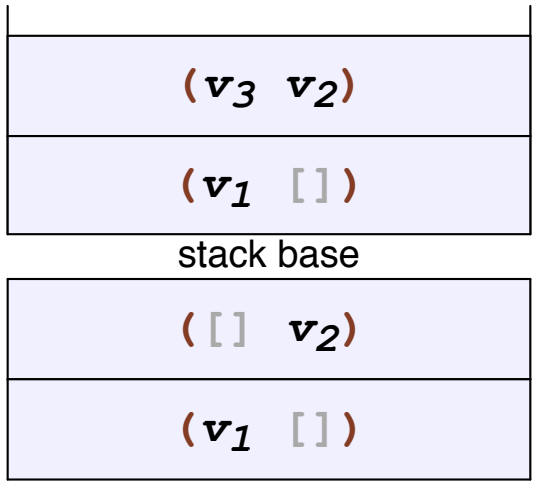
Capturing Stack-Based Continuations



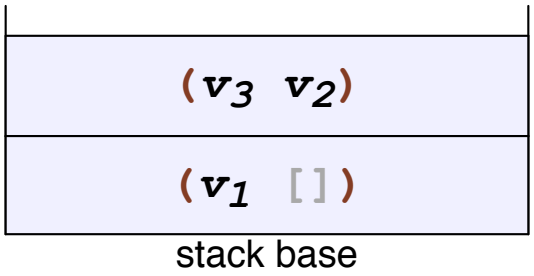
Applying Stack-Based Continuations



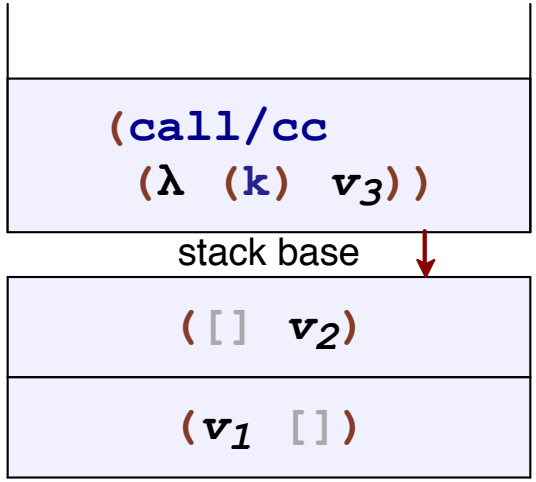
Applying Stack-Based Continuations



Applying Stack-Based Continuations



Returning After Capture



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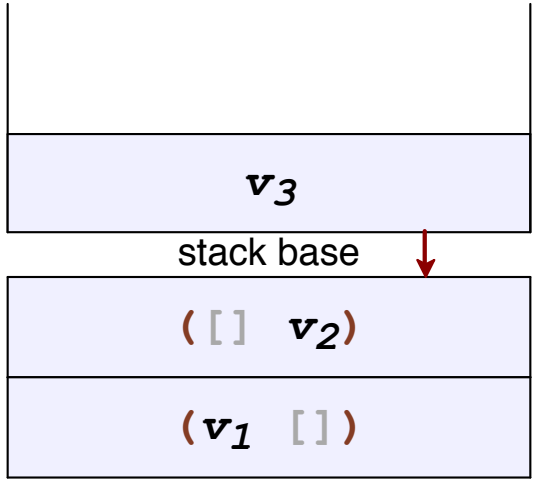

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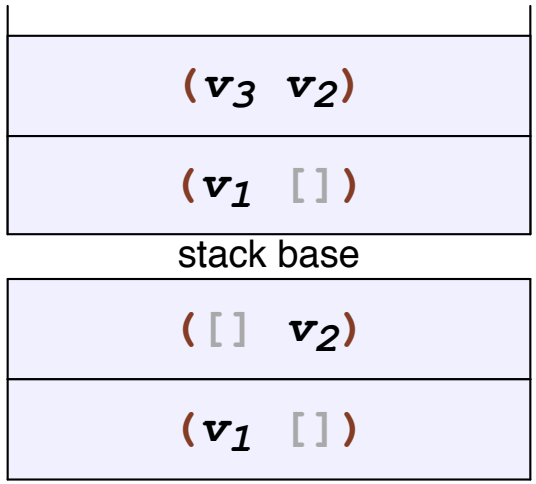
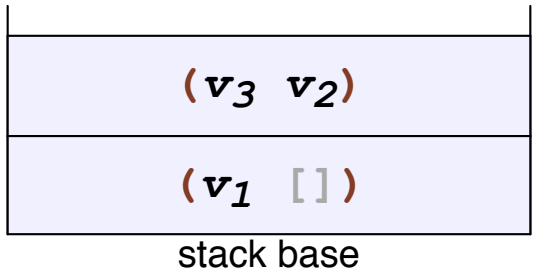
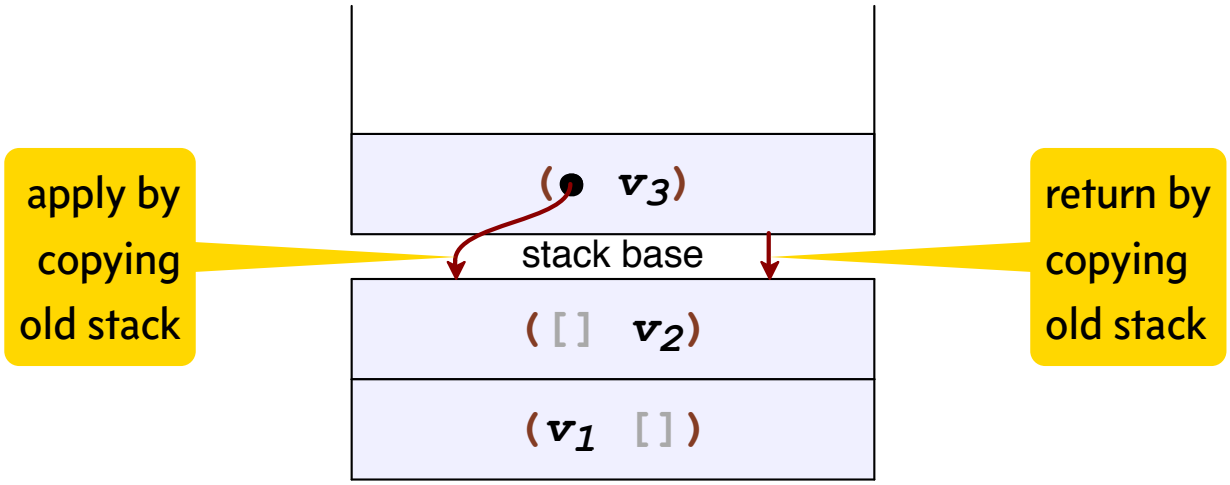


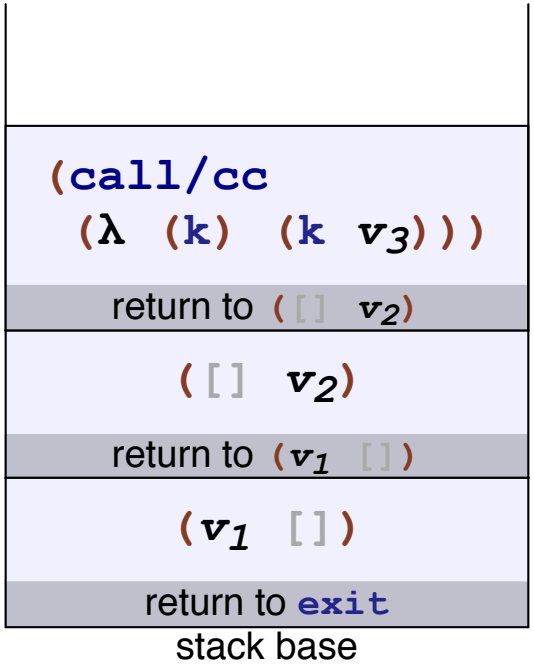
Returning After Capture



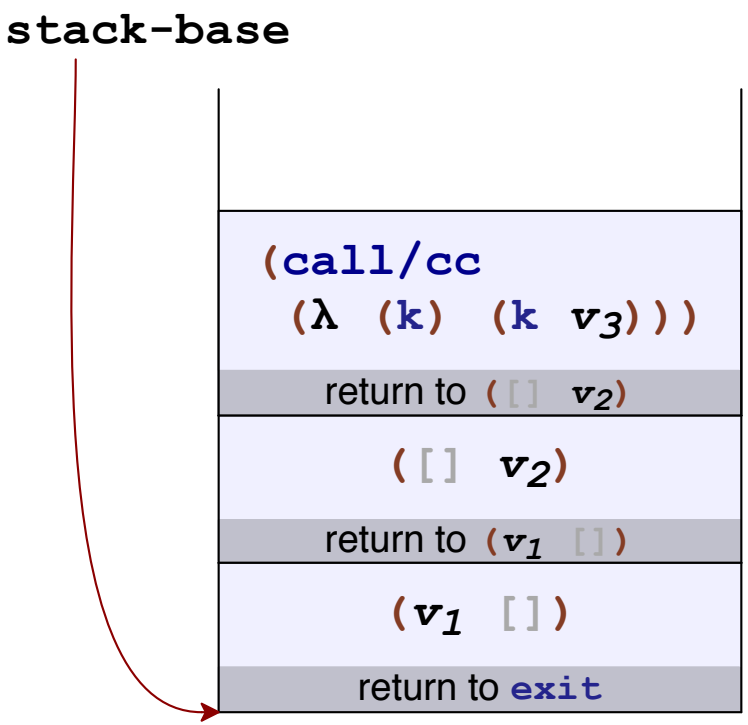
Two Kinds of Continuation Pointers



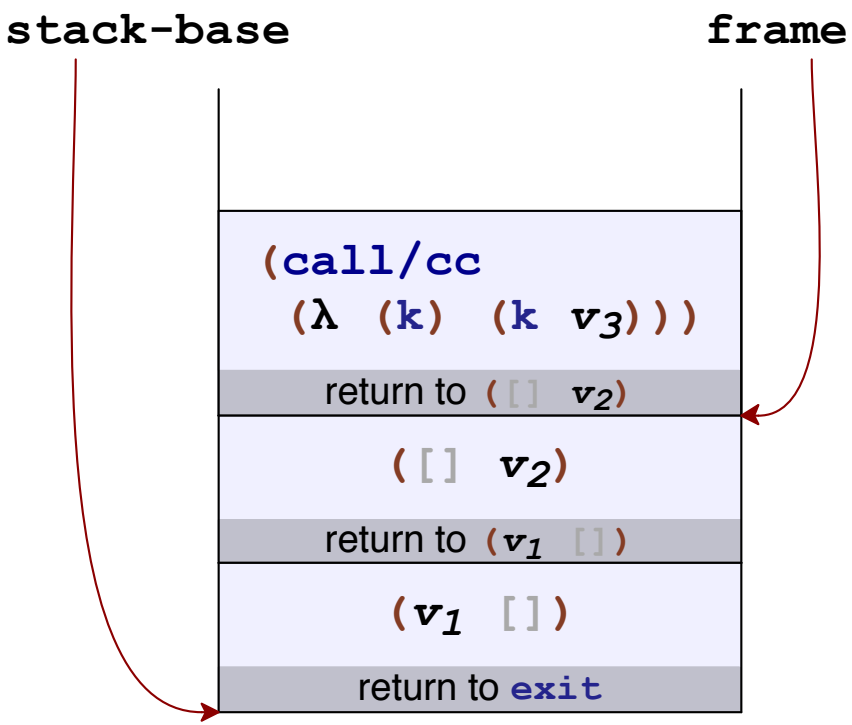
Returns in Stack Frames



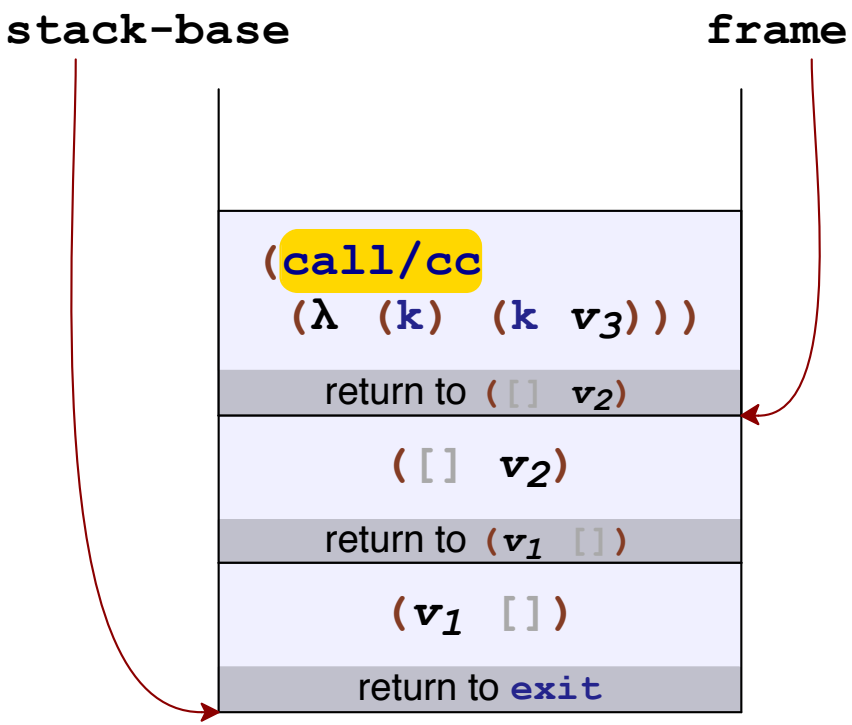
Returns in Stack Frames



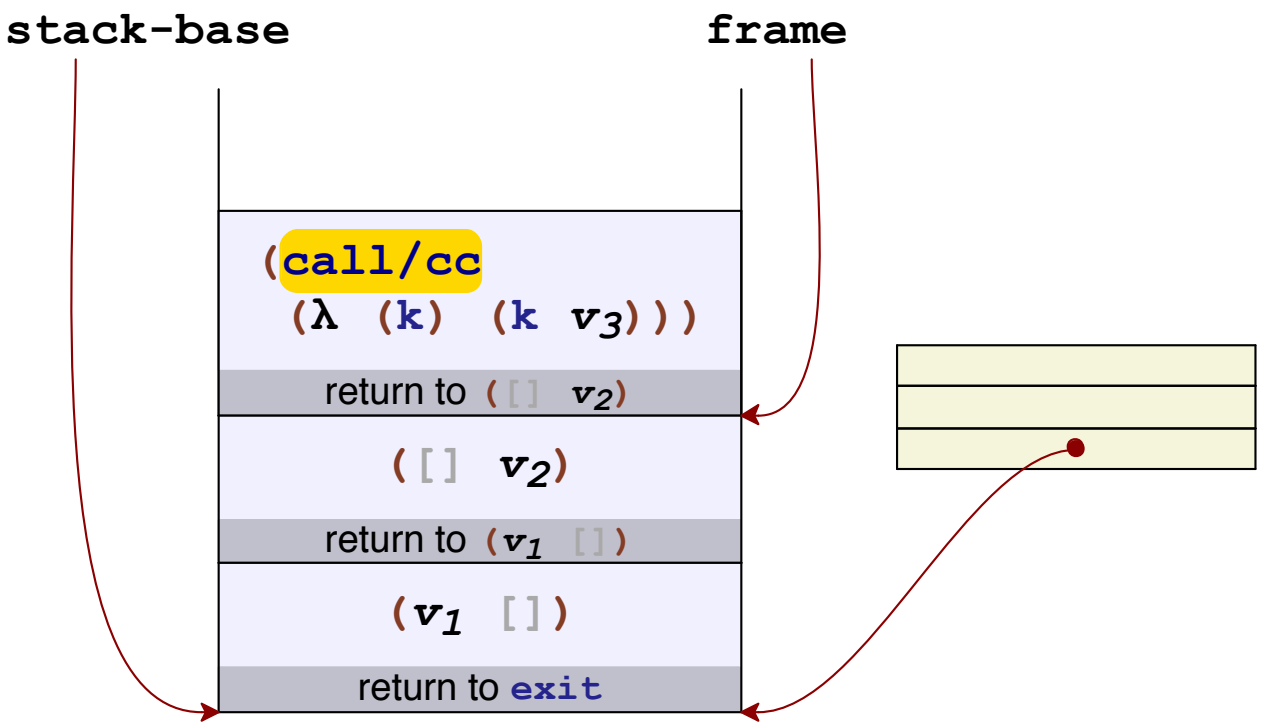
Returns in Stack Frames



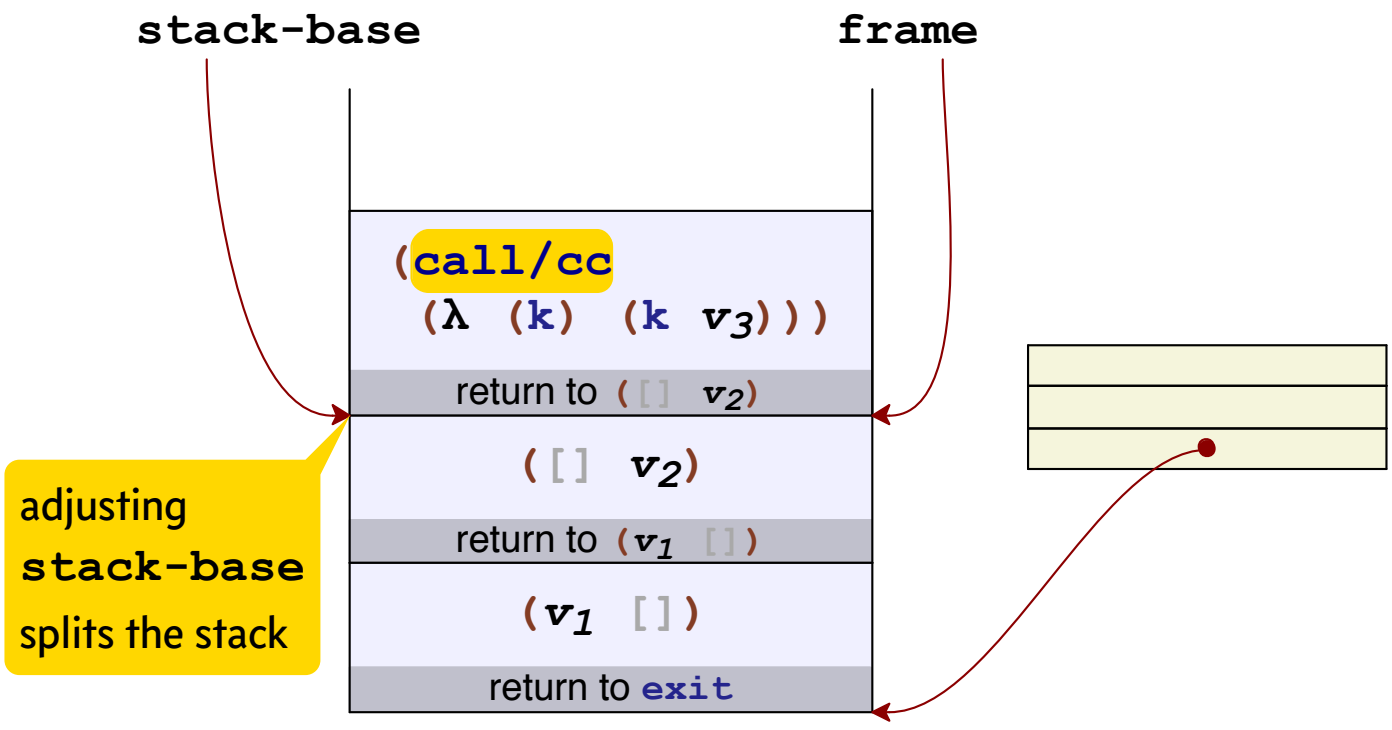
Capturing Stack-Based Continuations



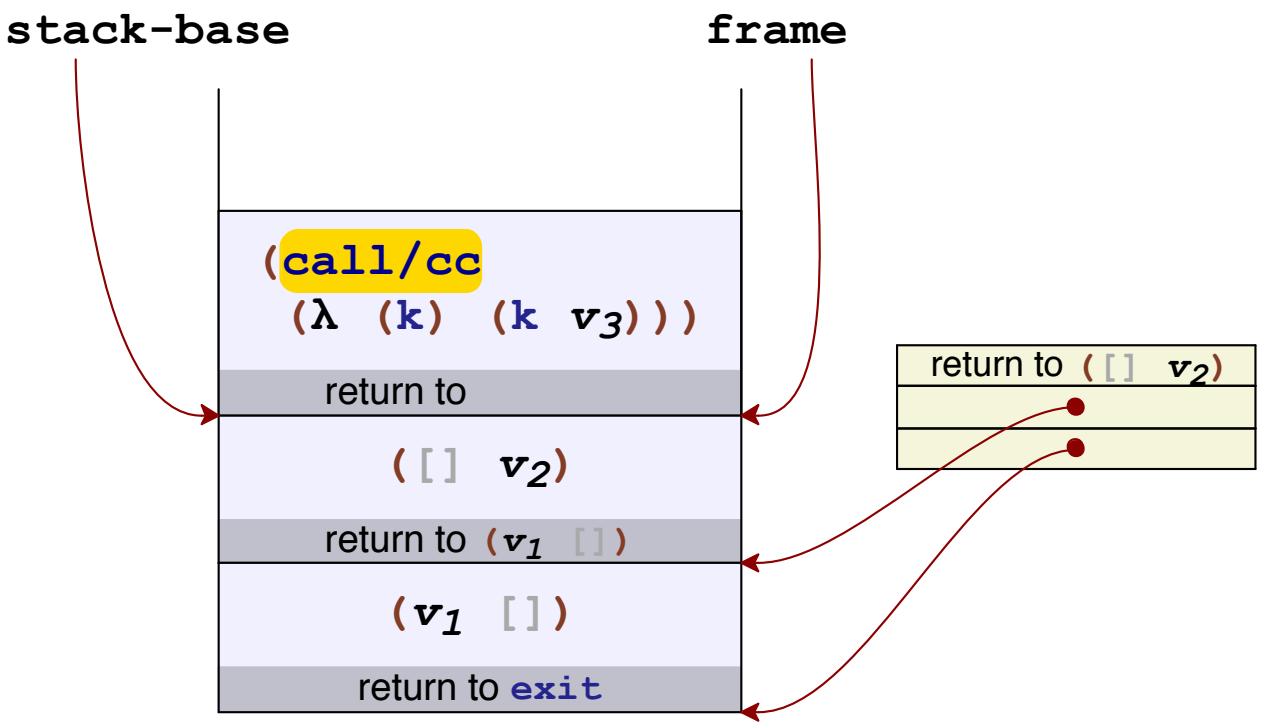
Capturing Stack-Based Continuations



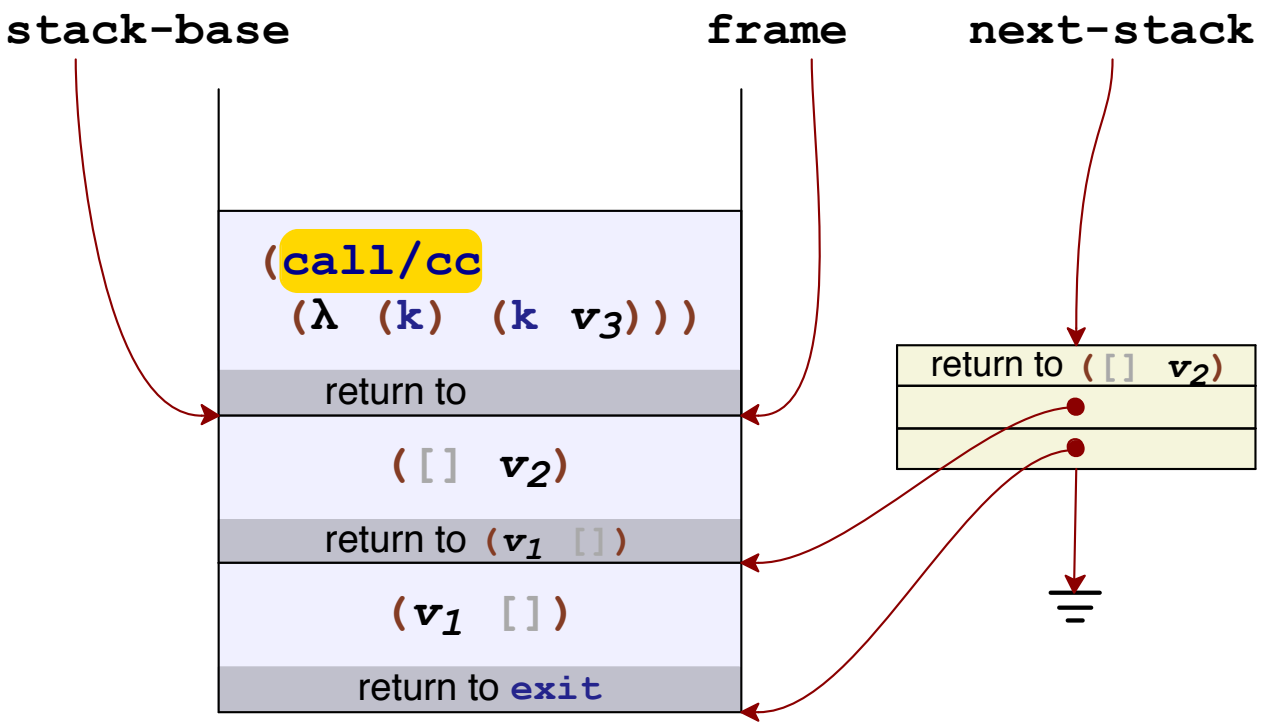
Capturing Stack-Based Continuations



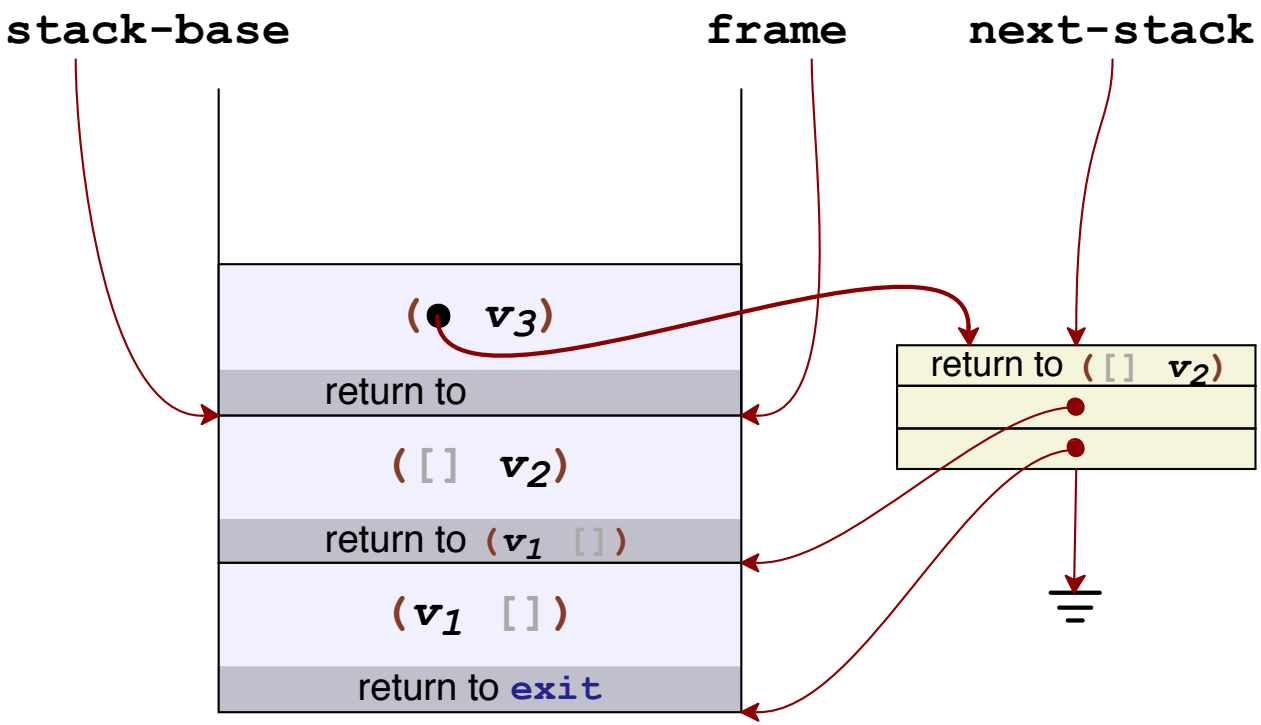
Capturing Stack-Based Continuations



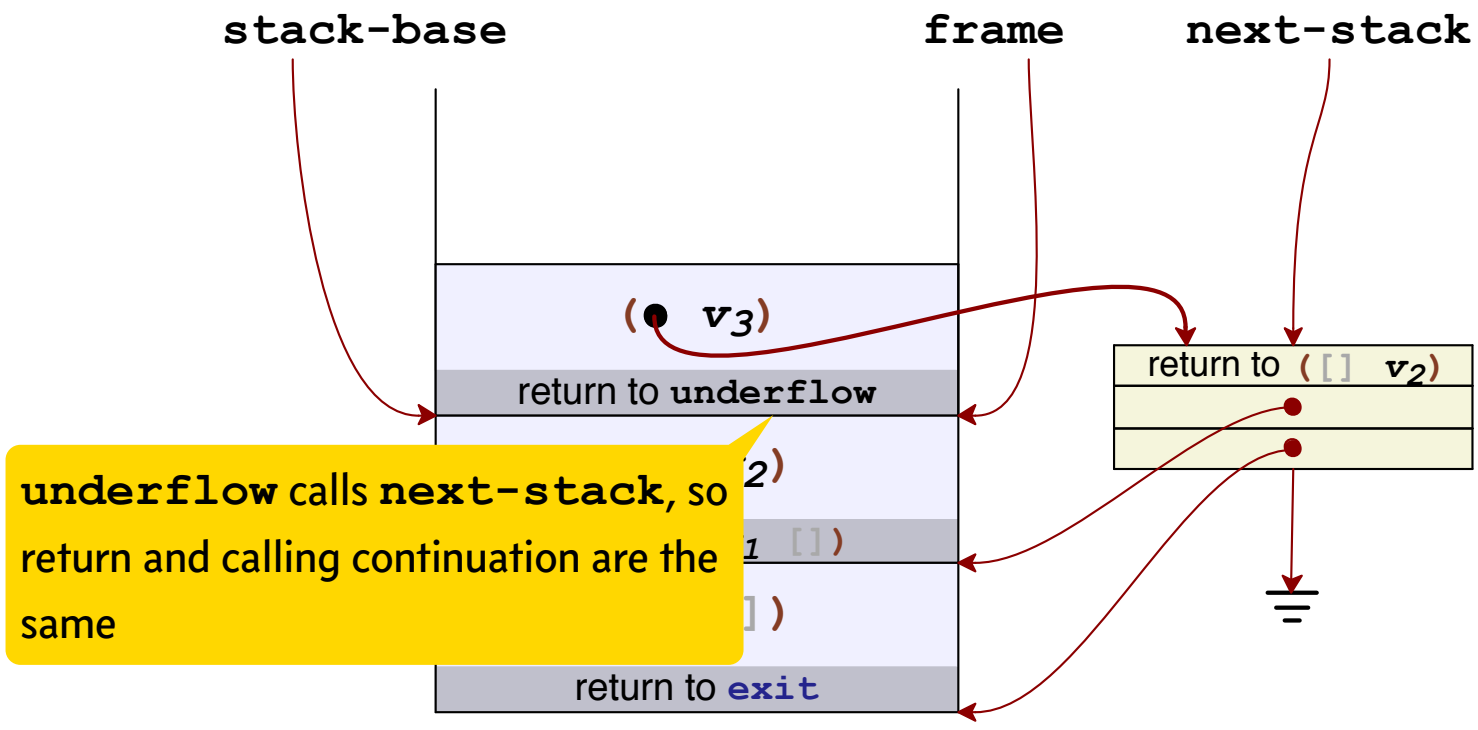
Capturing Stack-Based Continuations



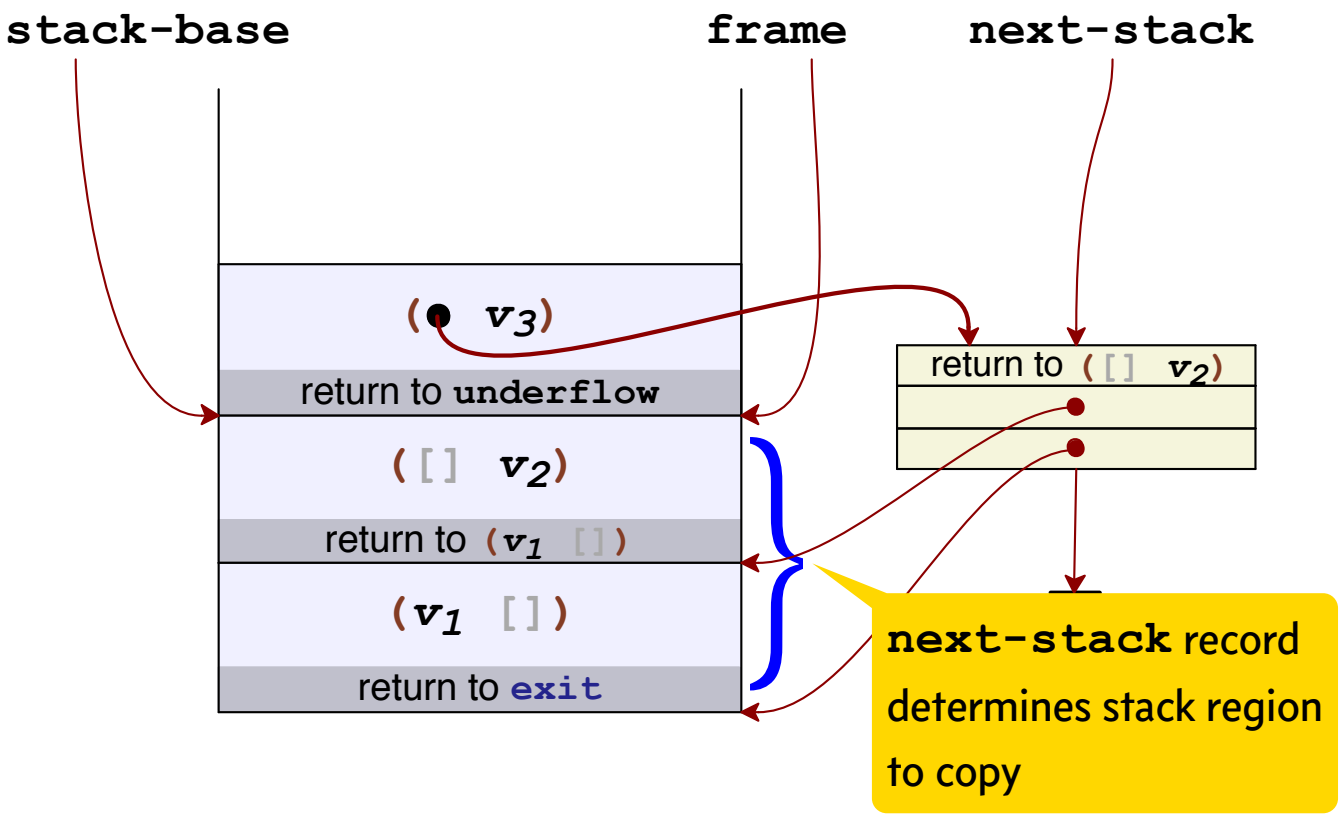
Capturing Stack-Based Continuations



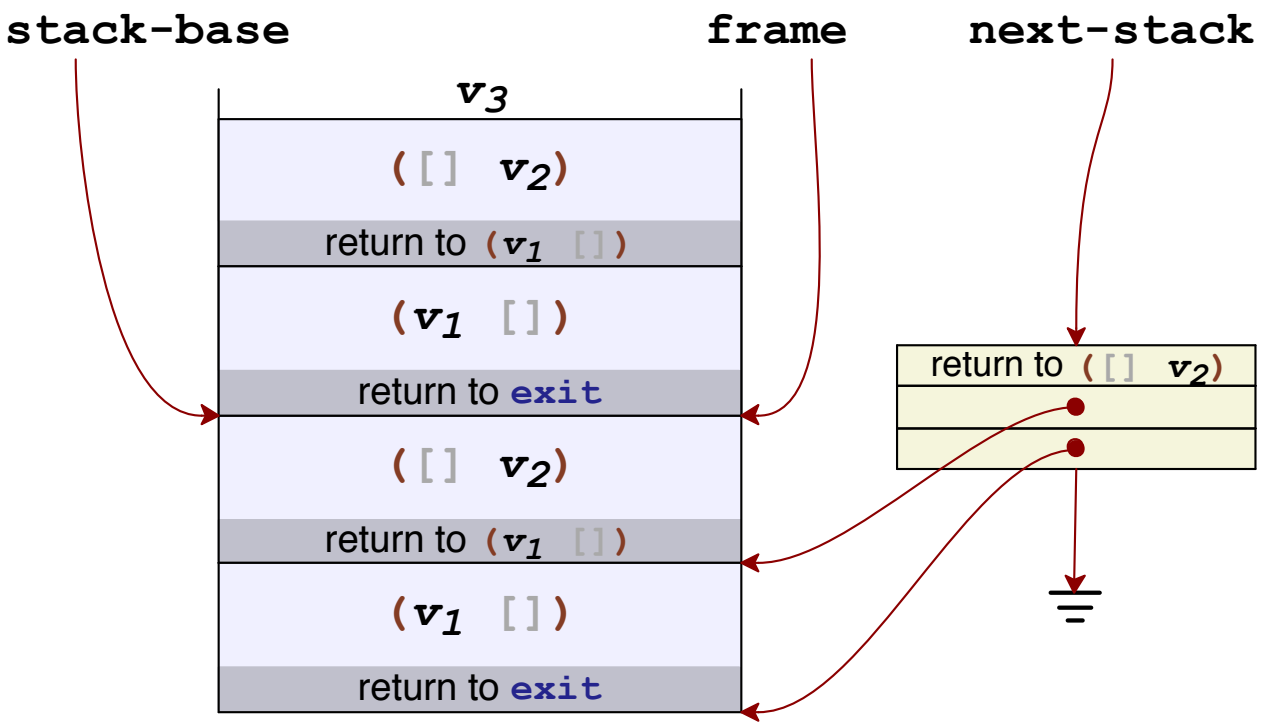
Capturing Stack-Based Continuations



Applying Stack-Based Continuations



Applying Stack-Based Continuations



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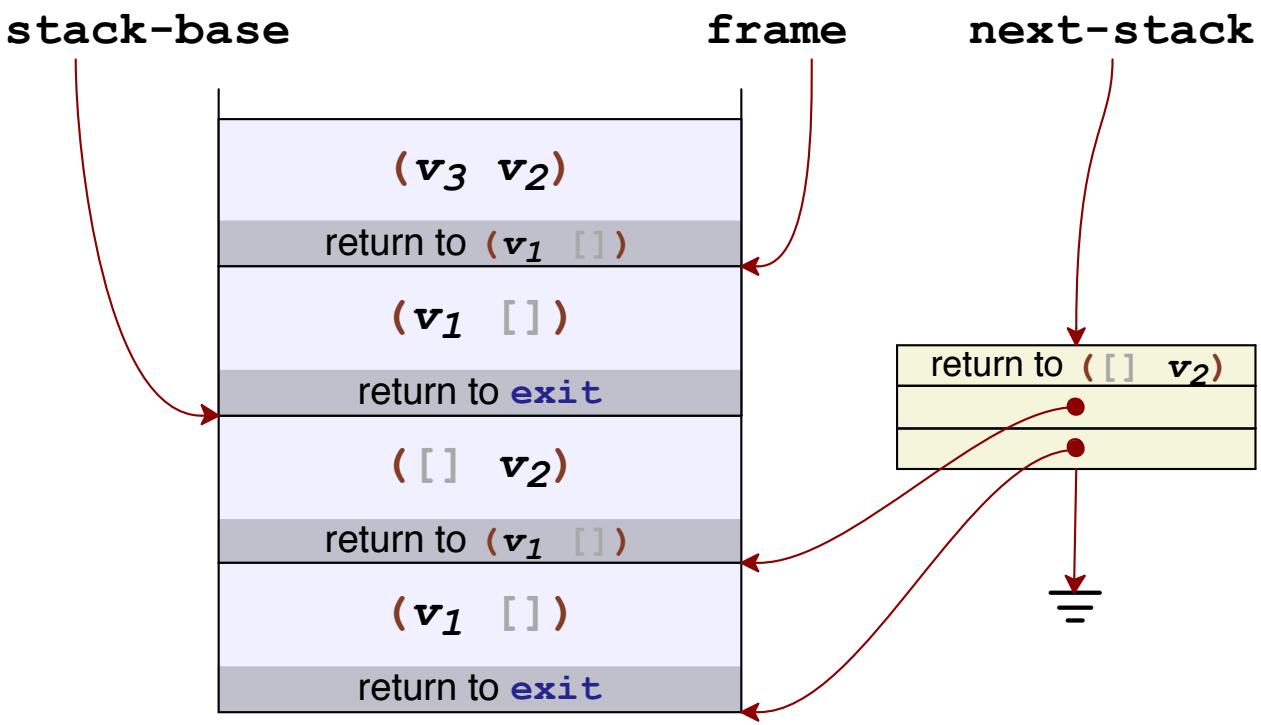
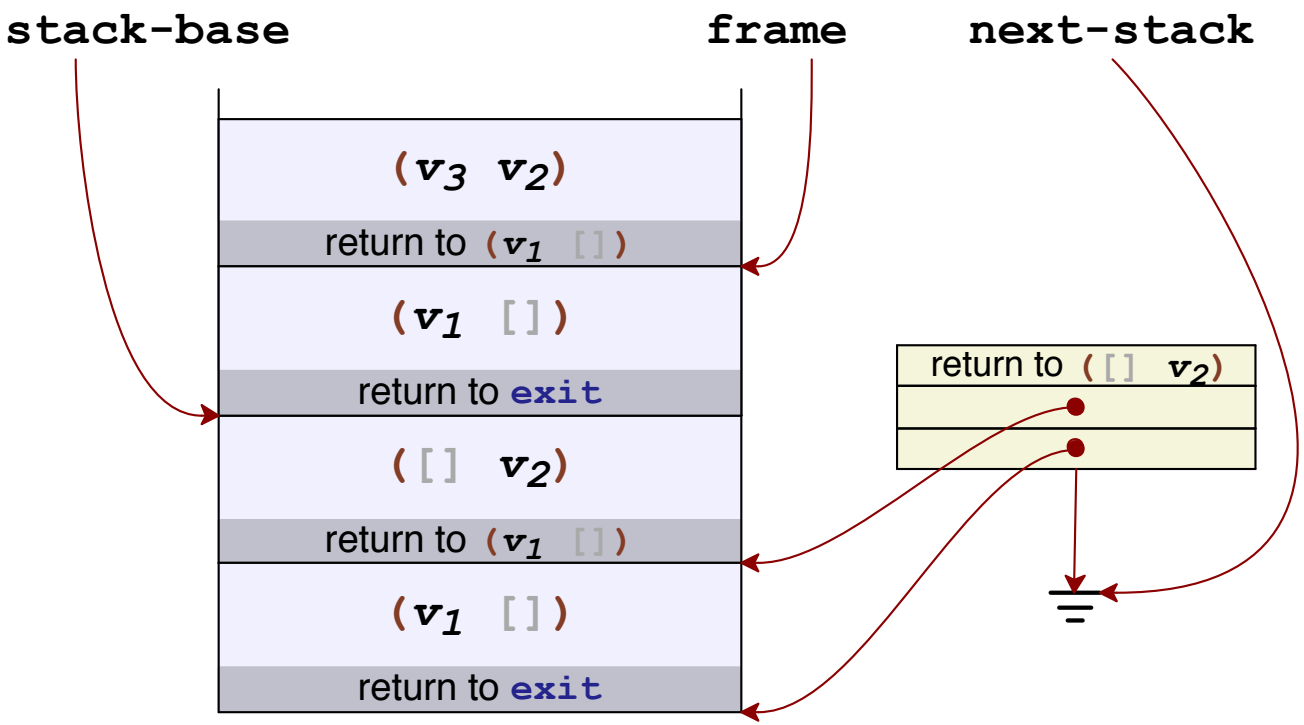
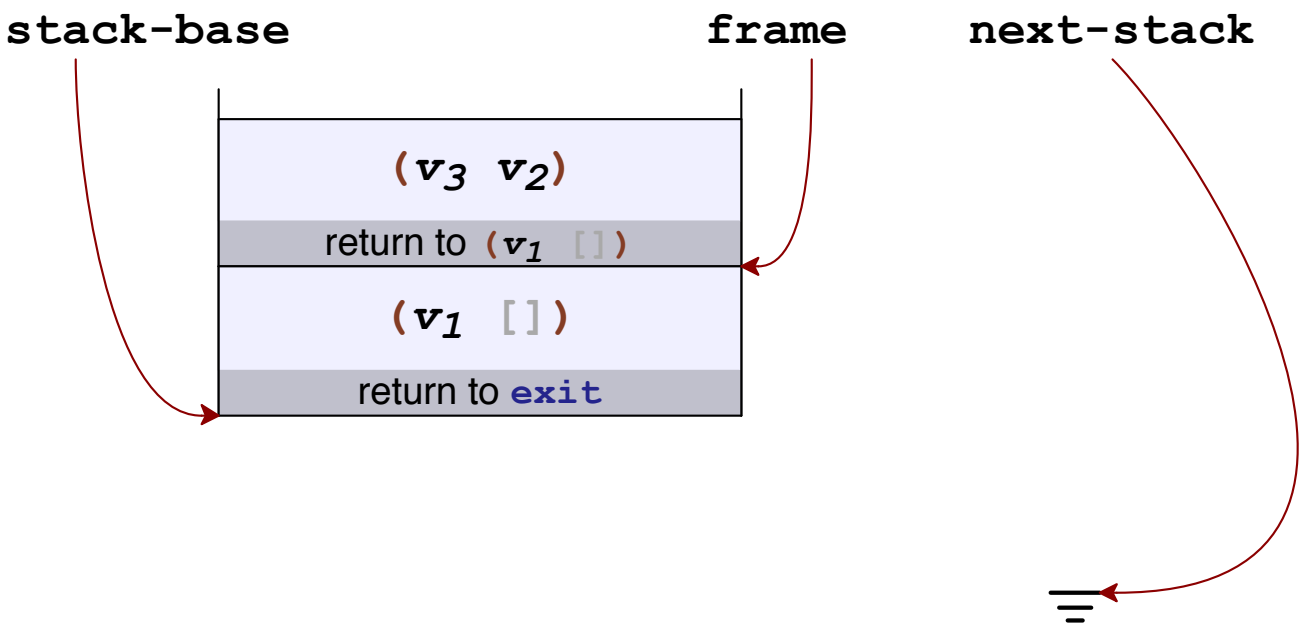


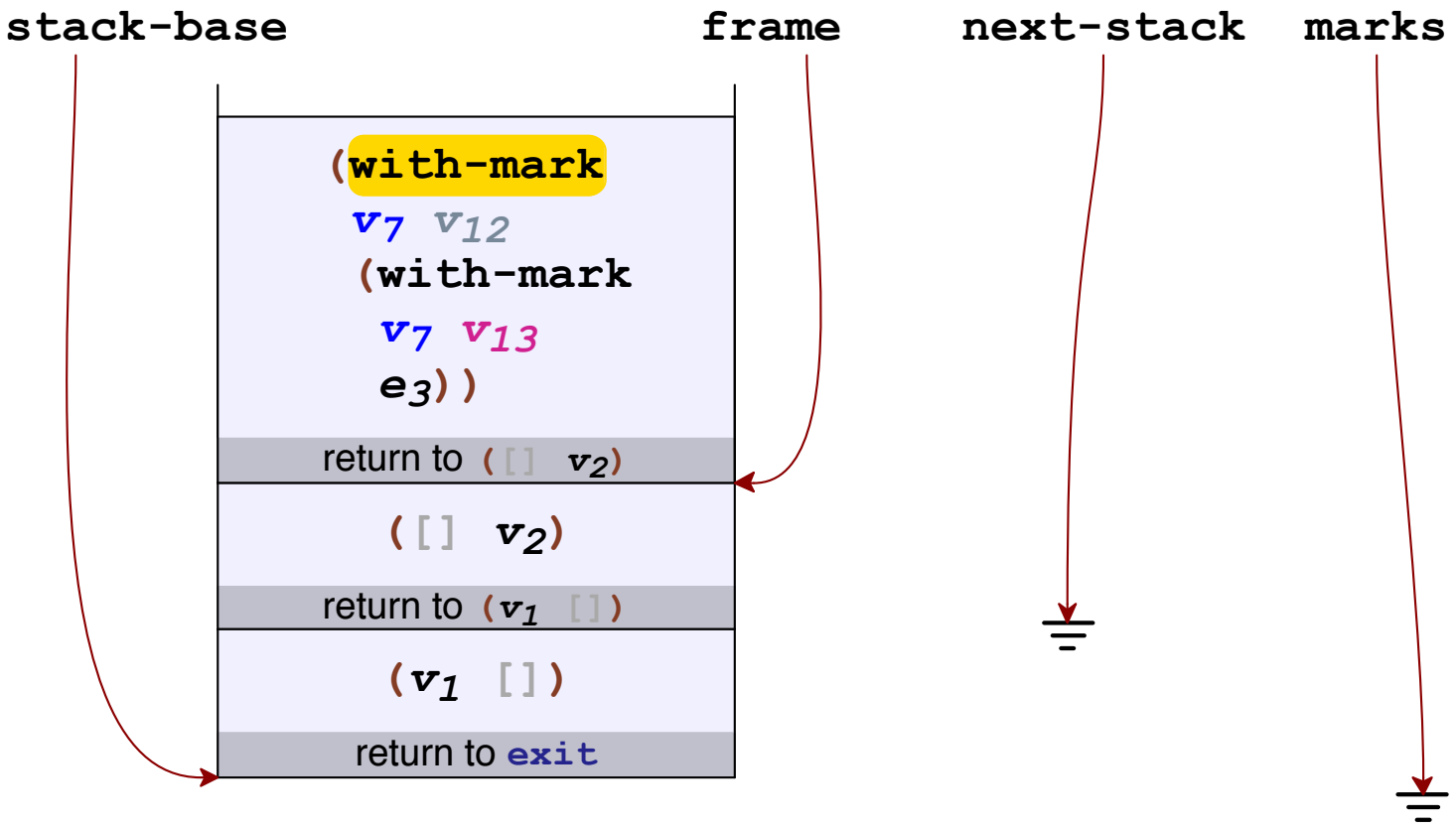
Applying Stack-Based Continuations



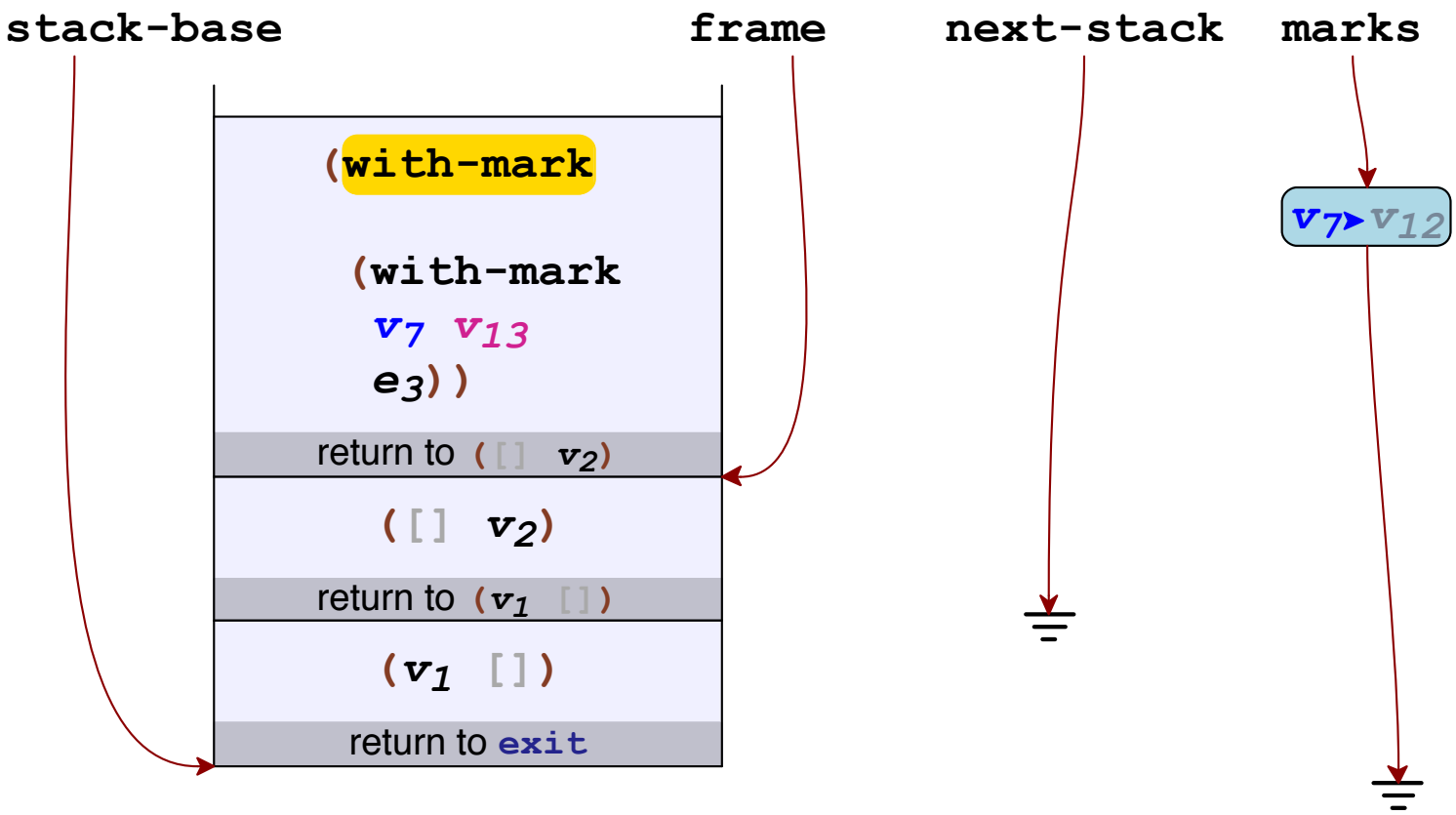
Applying Stack-Based Continuations



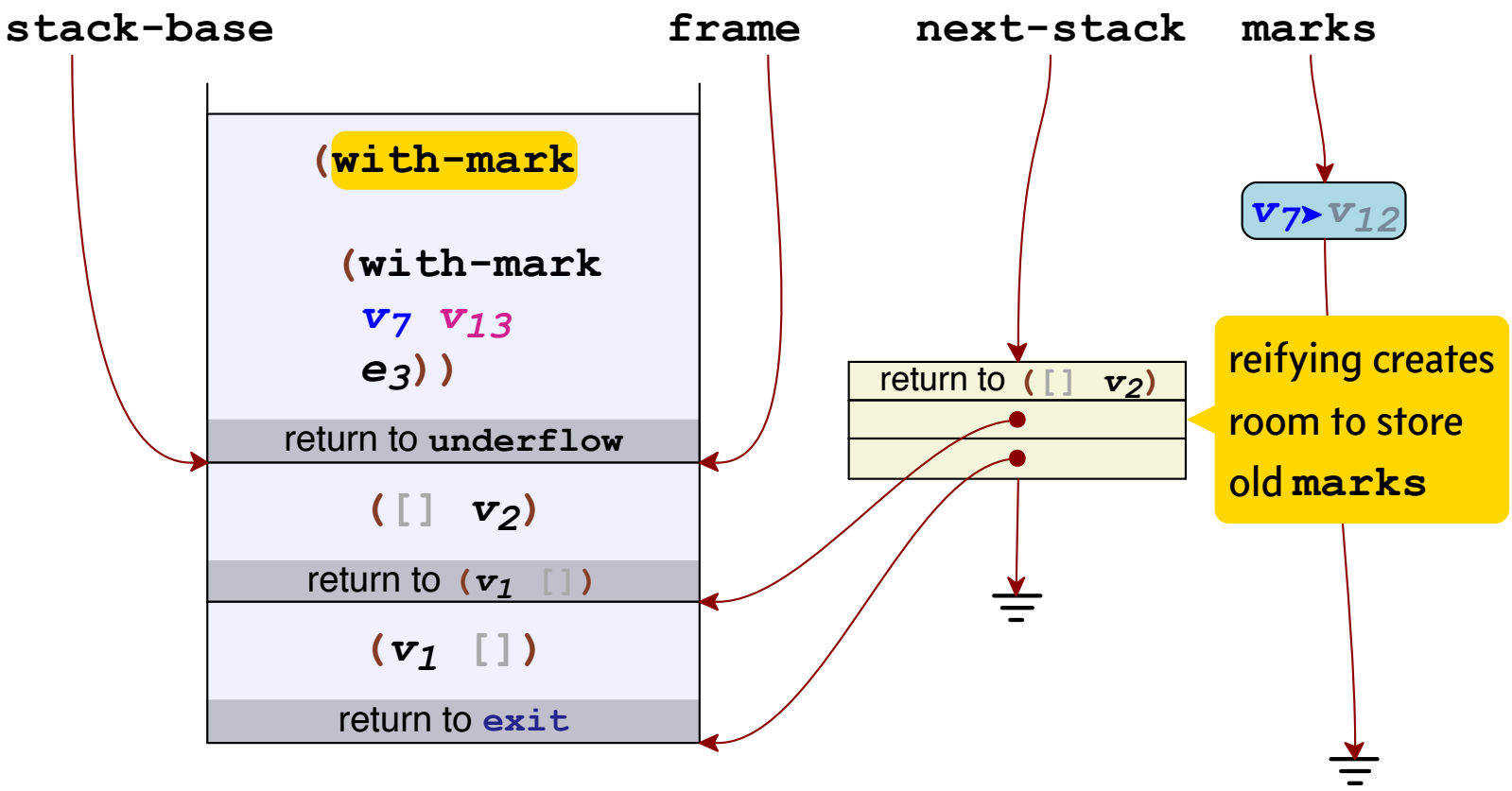
new! Setting Continuation Marks



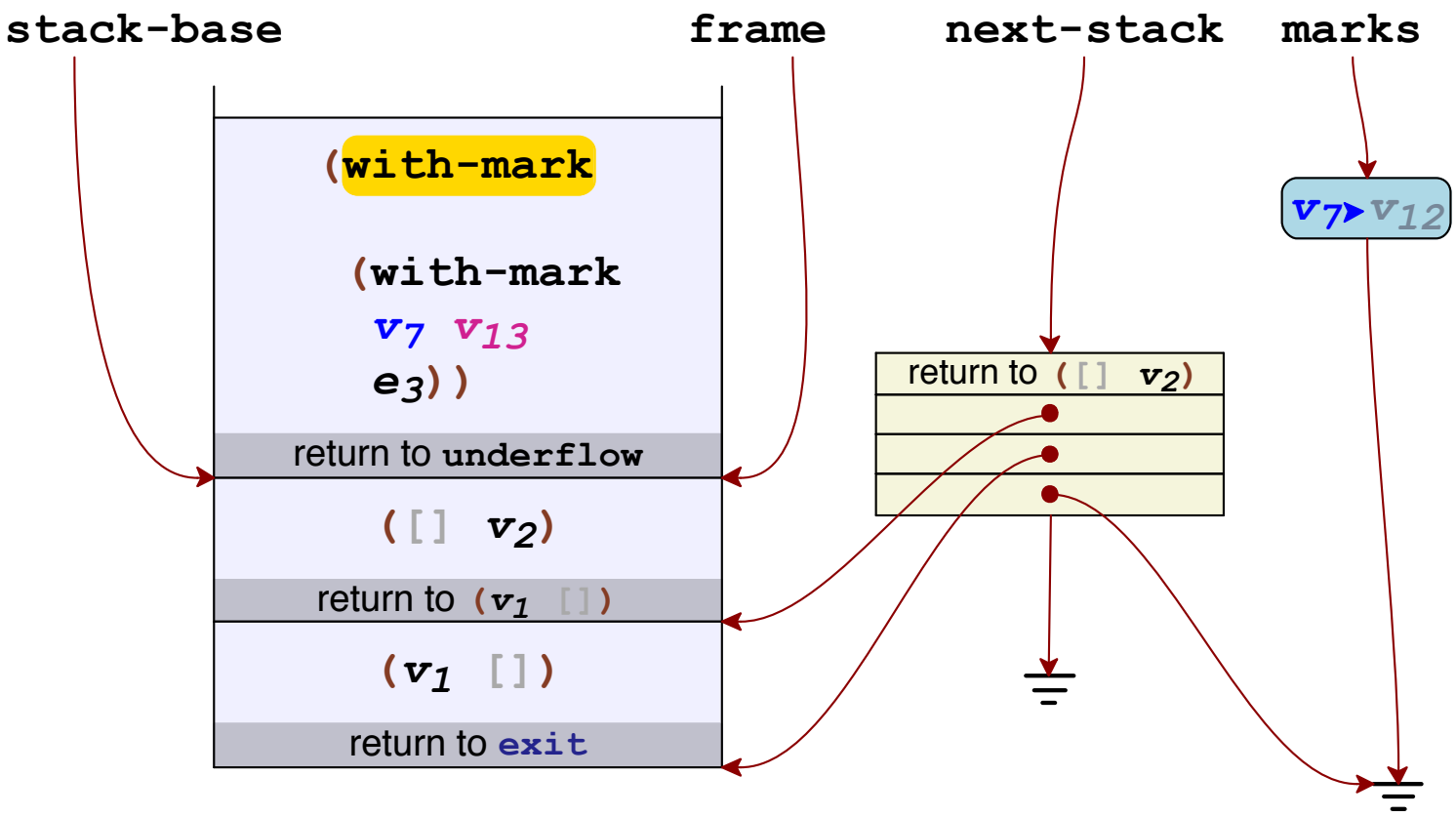
Setting Continuation Marks



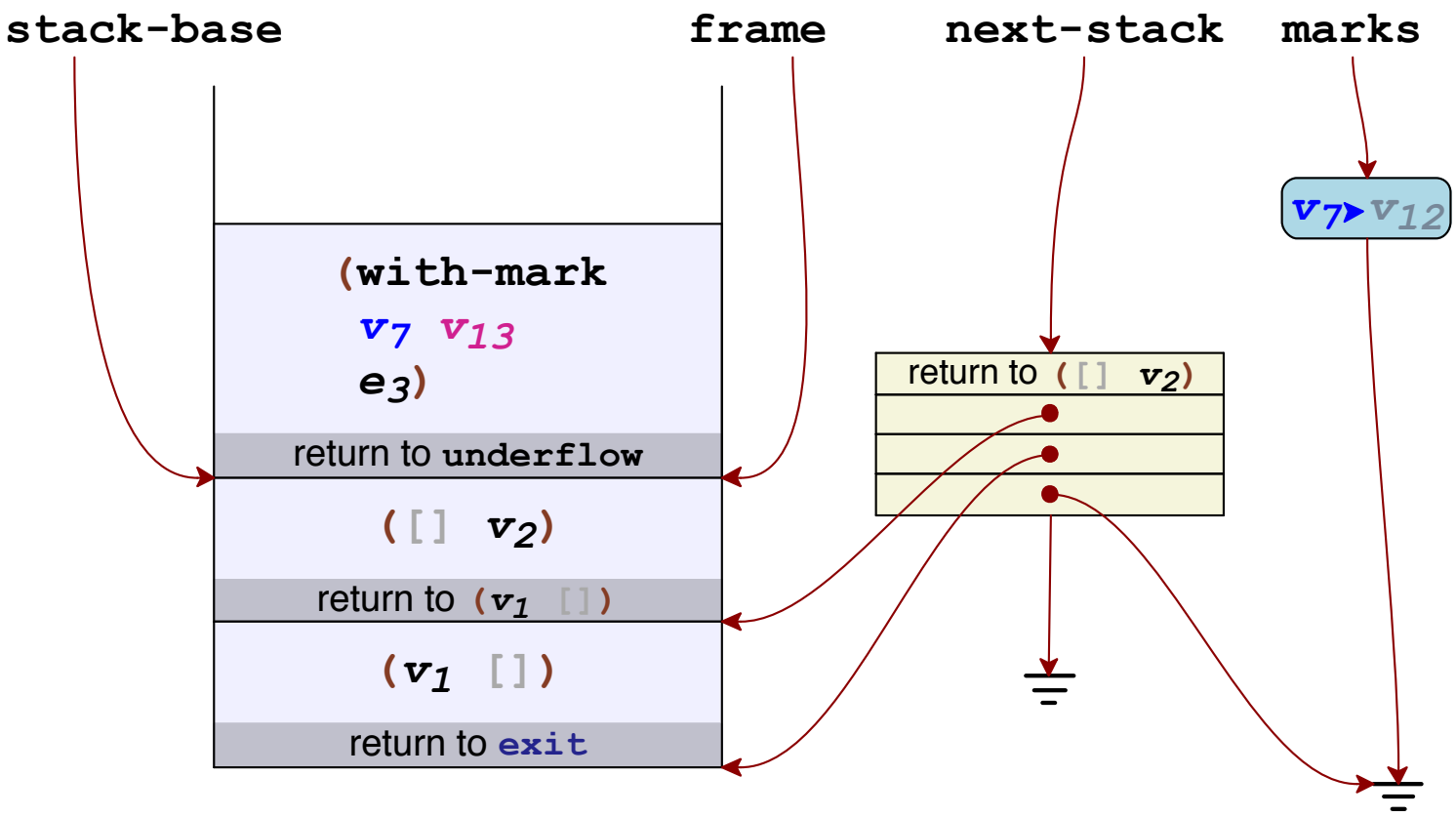
Setting Continuation Marks



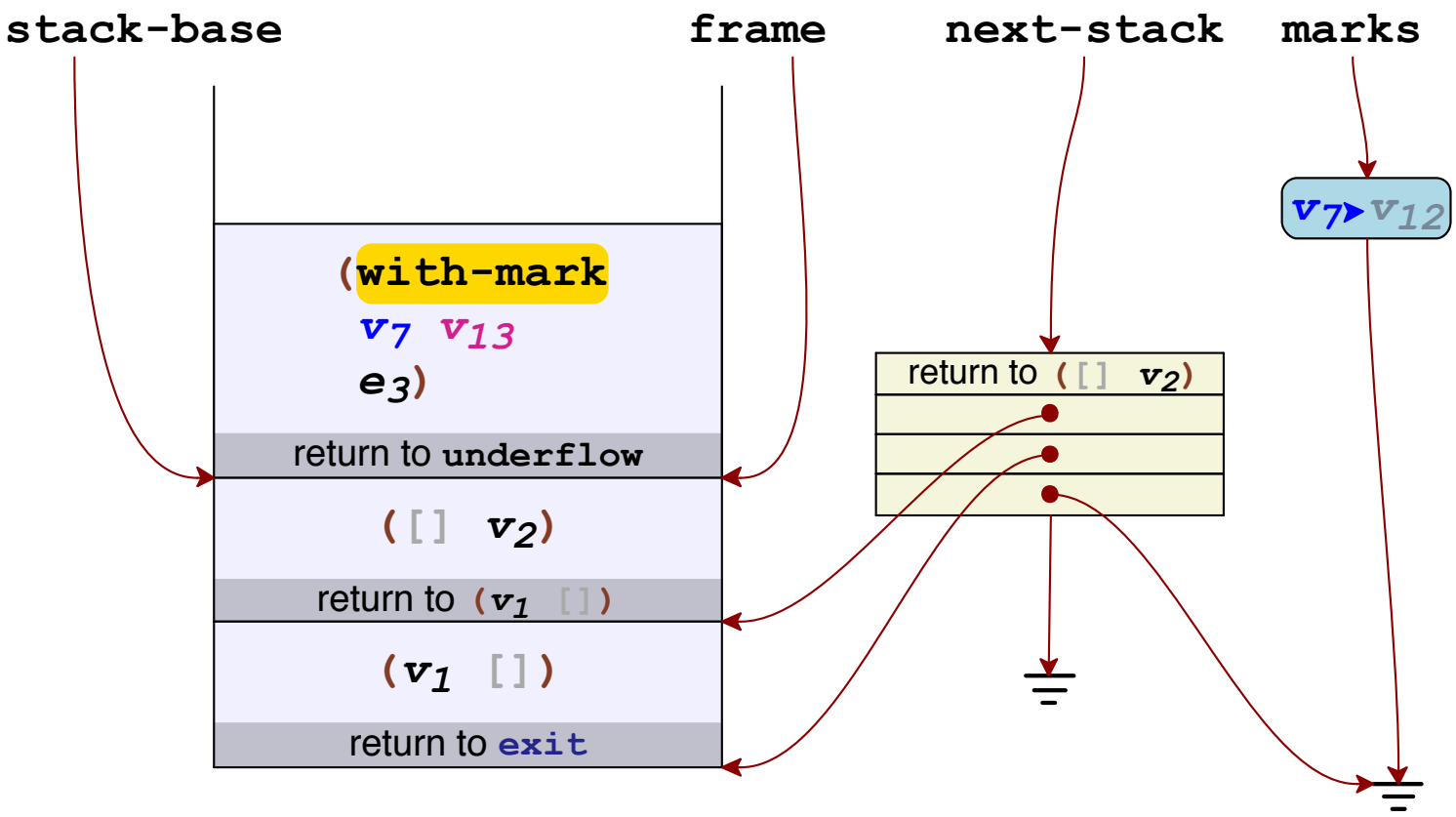
Setting Continuation Marks



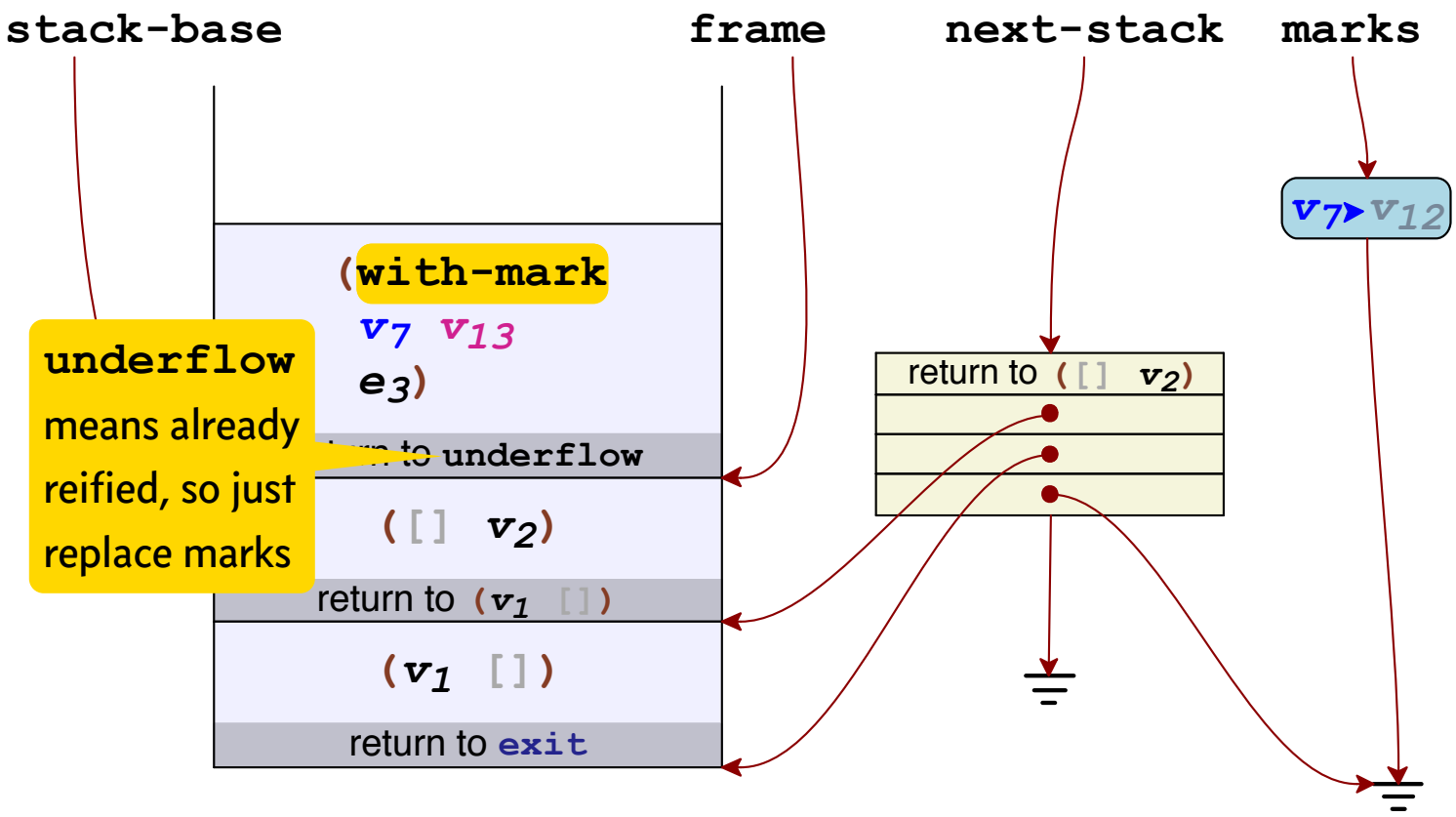
Setting Continuation Marks



Setting Continuation Marks



Setting Continuation Marks



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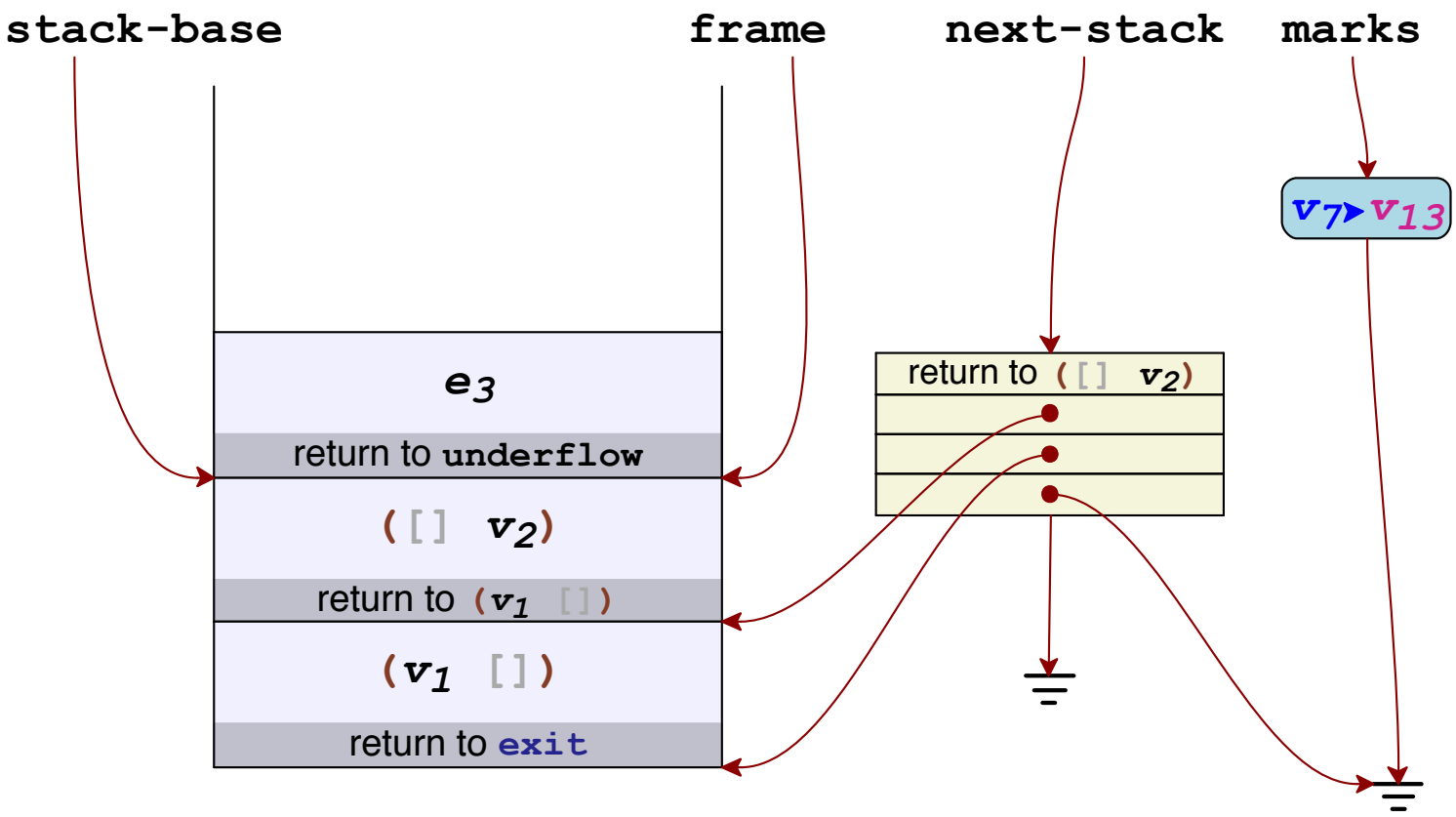
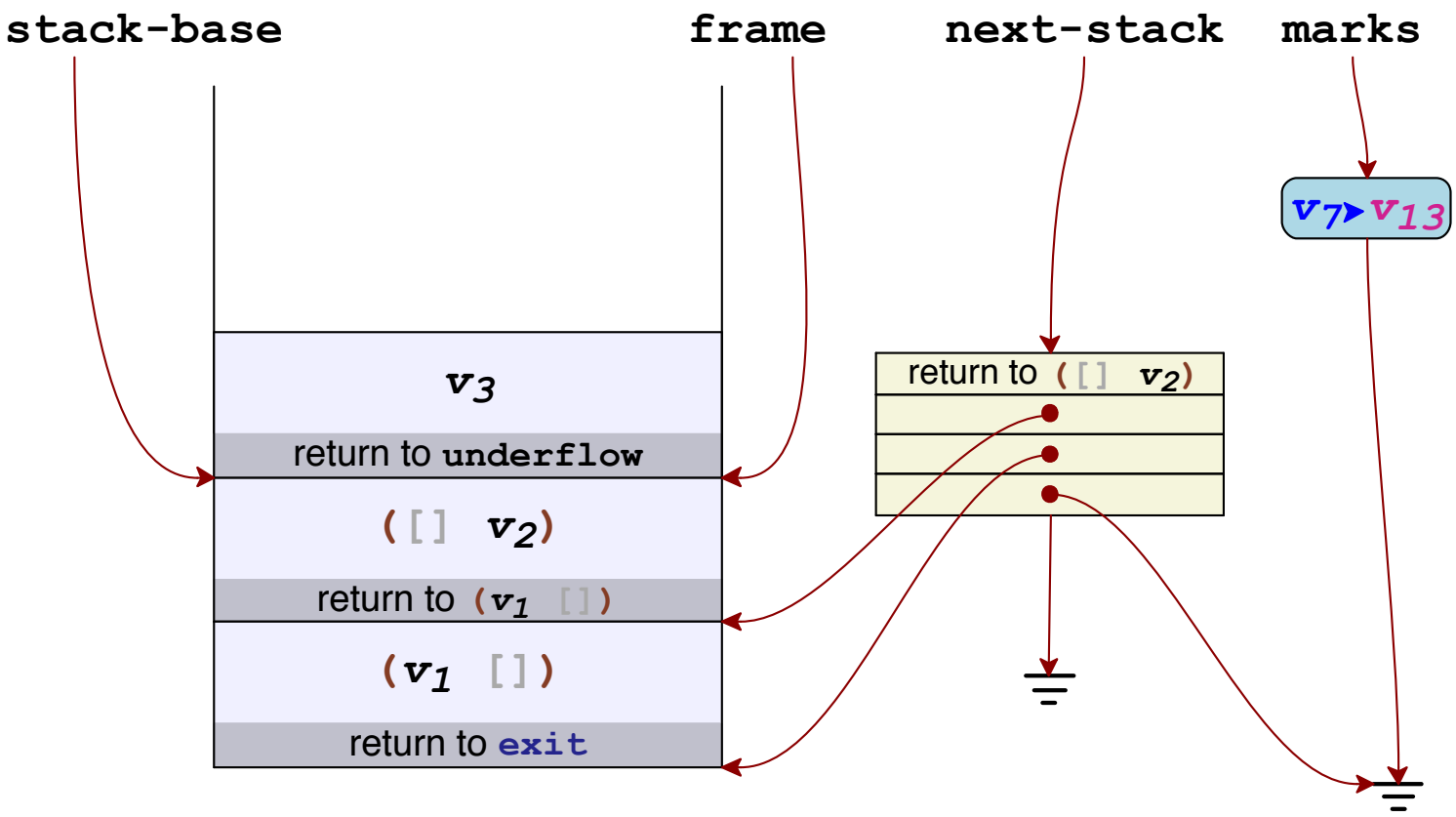
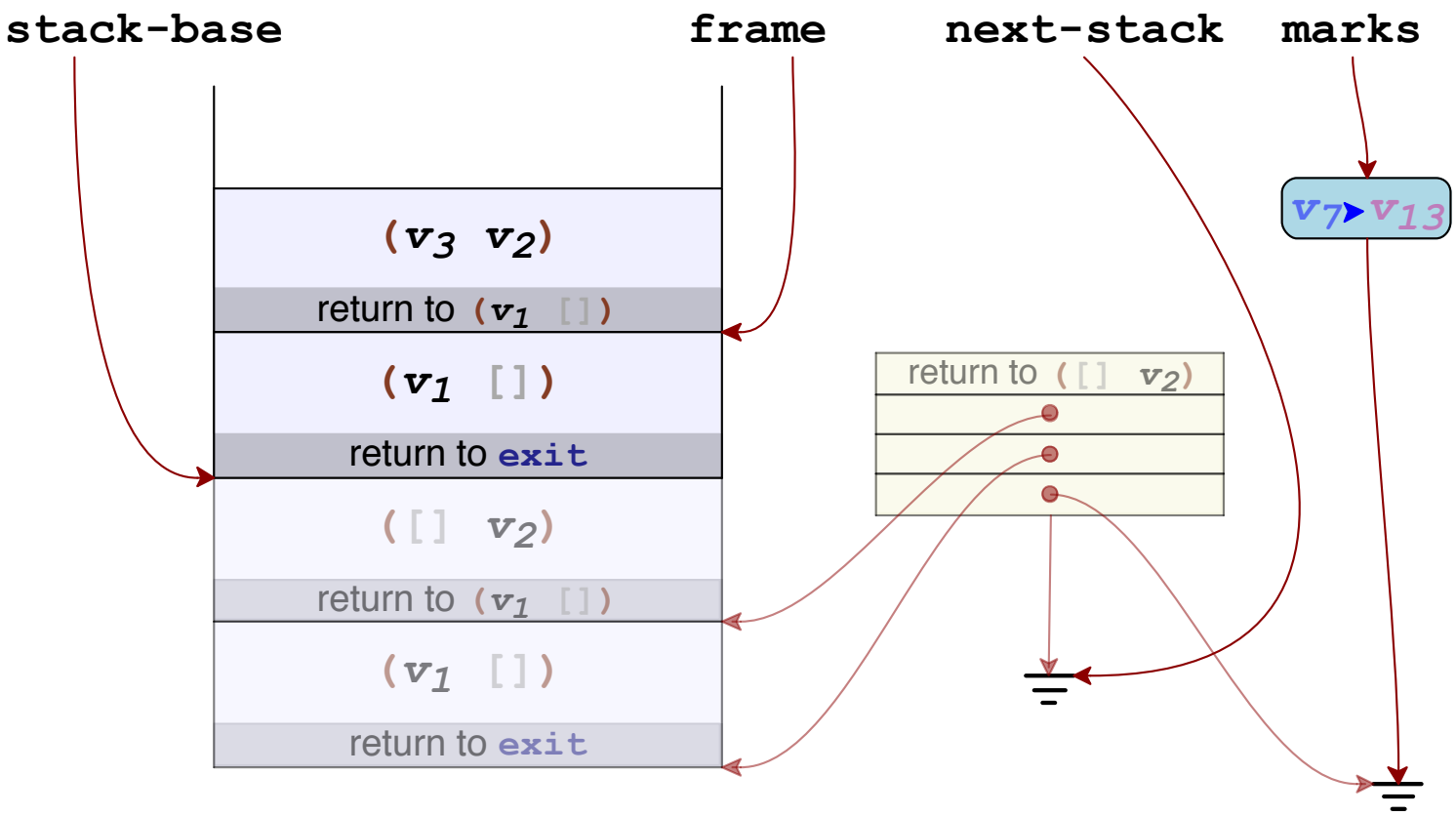


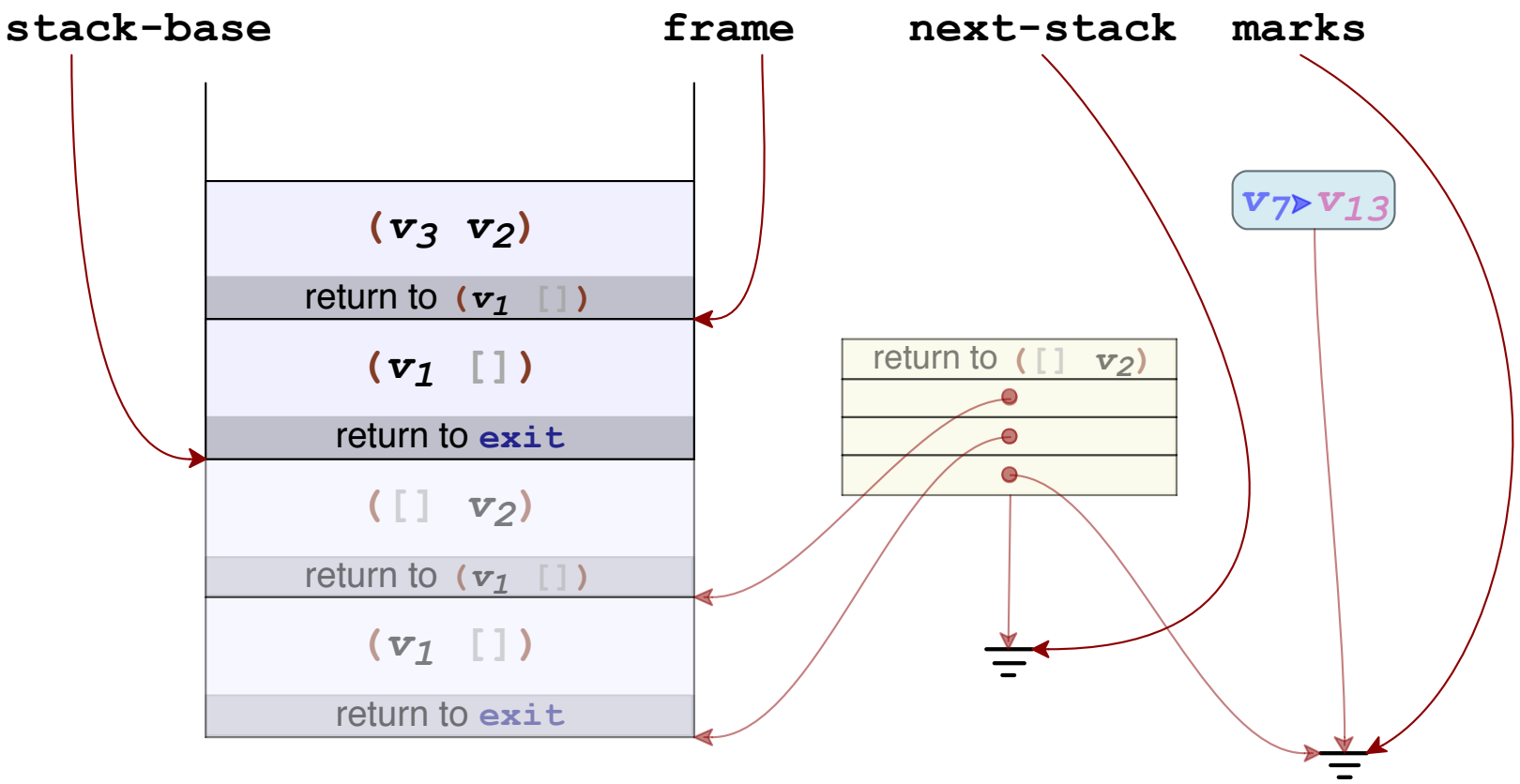
Setting Continuation Marks



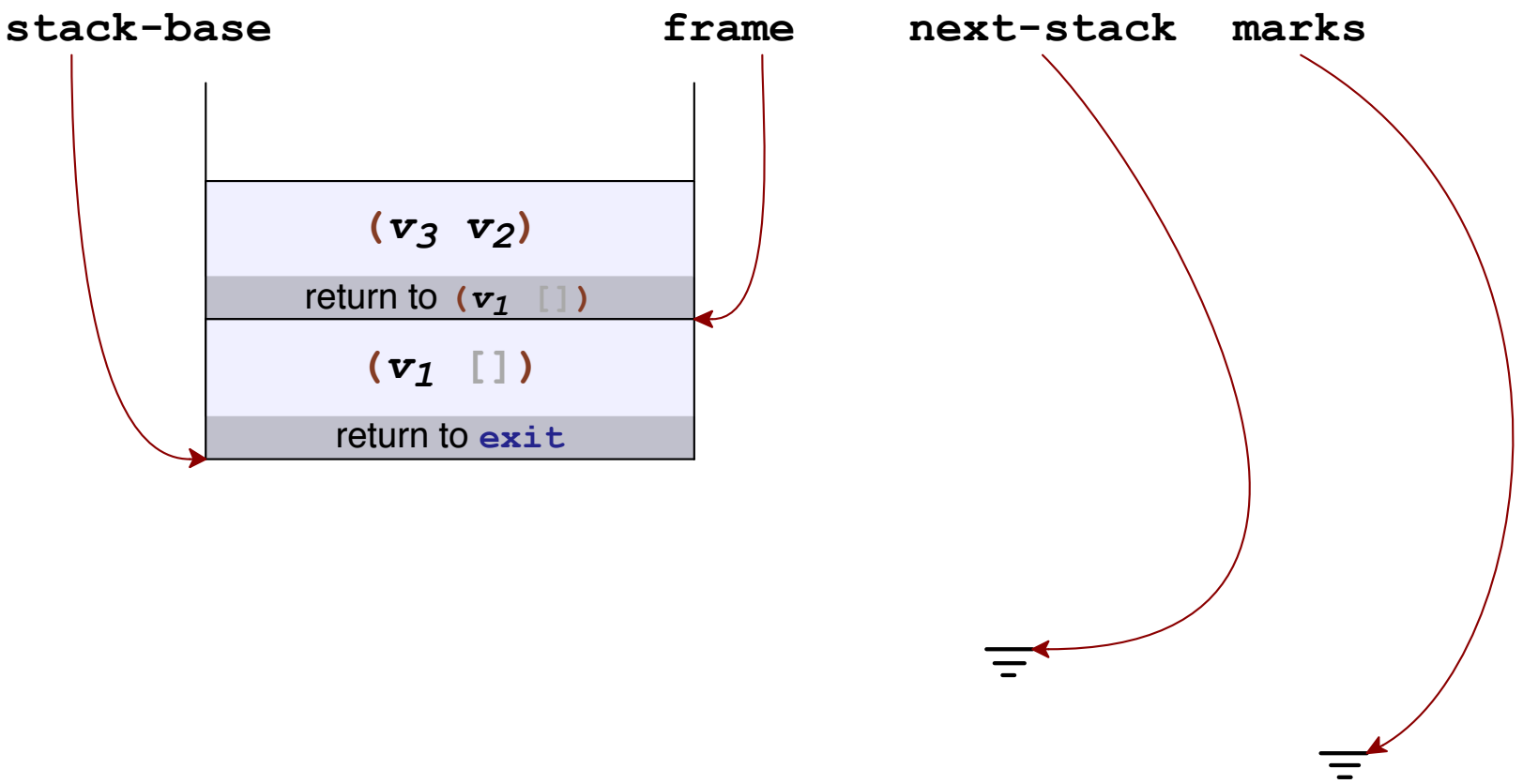
Removing Continuation Marks



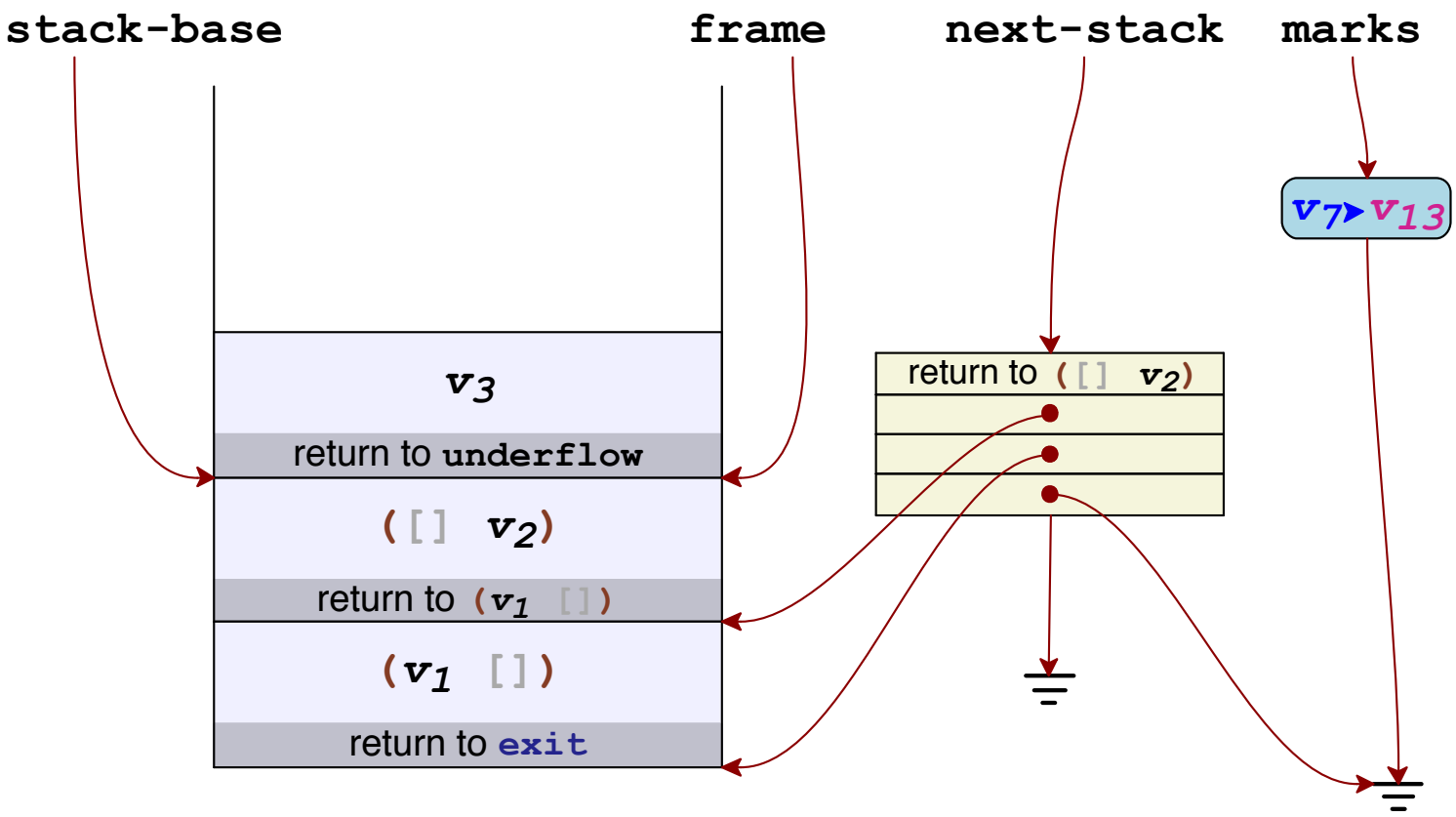
Removing Continuation Marks



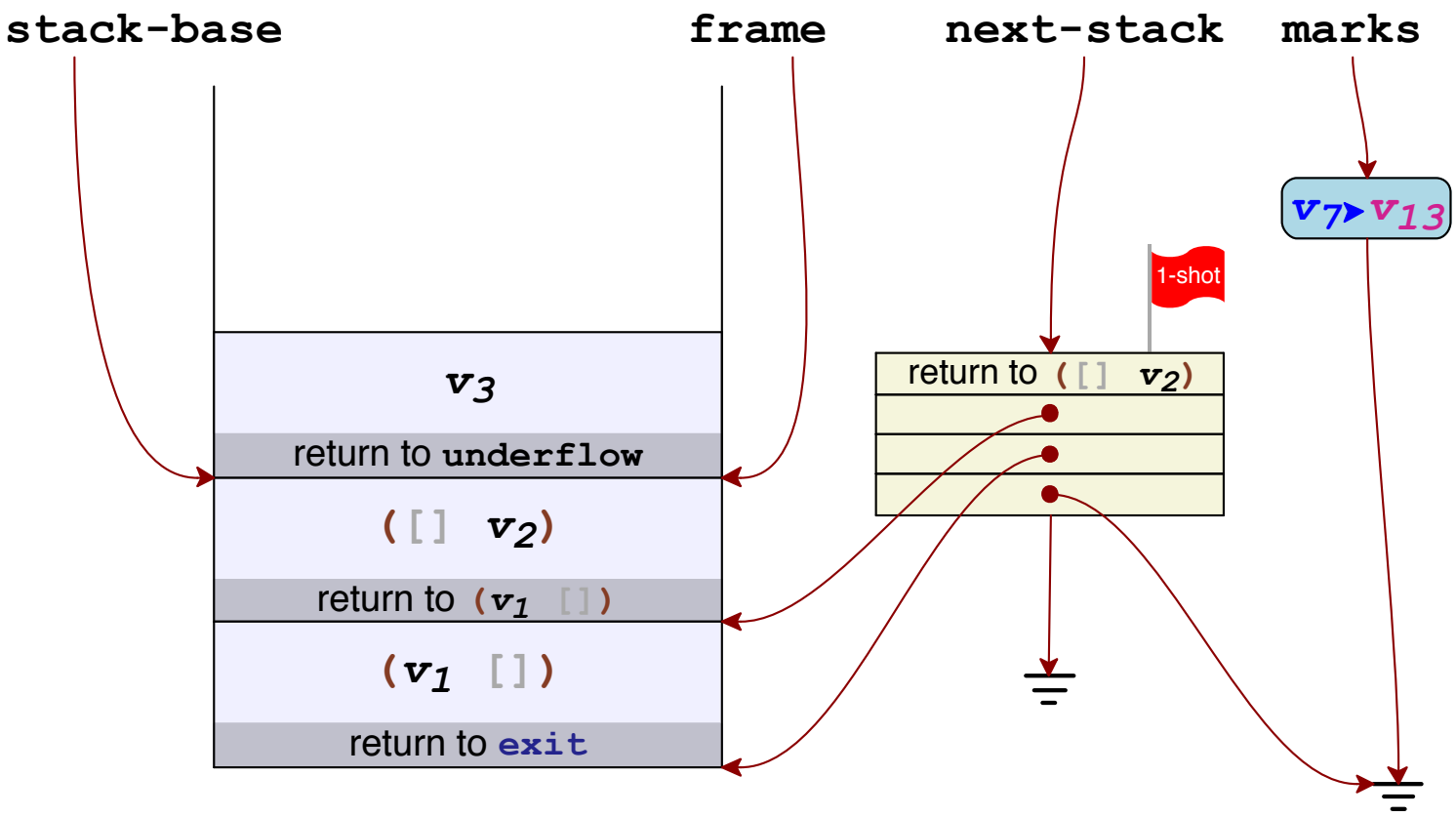
Removing Continuation Marks



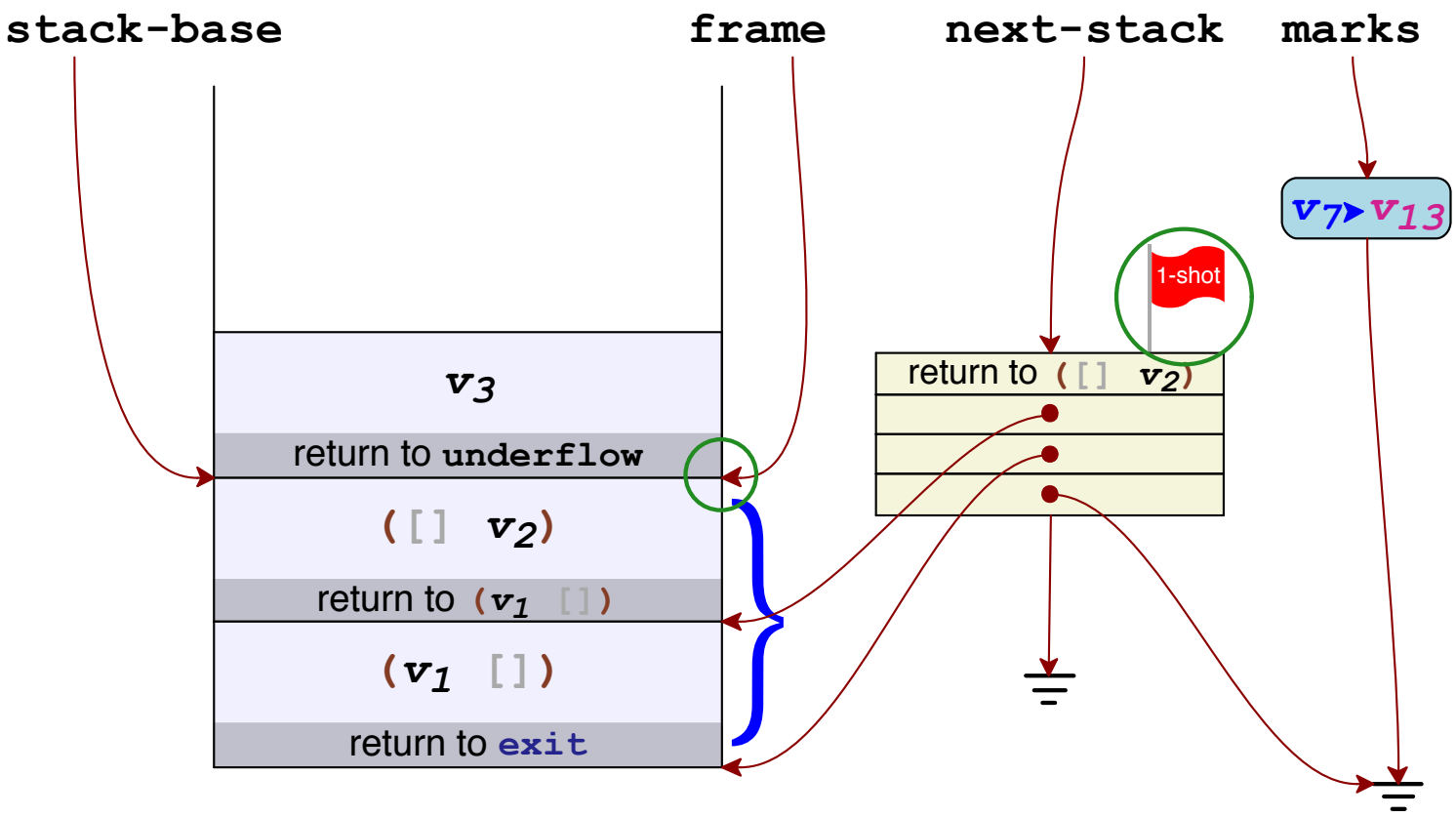
Optimistic One-Shot Continuations



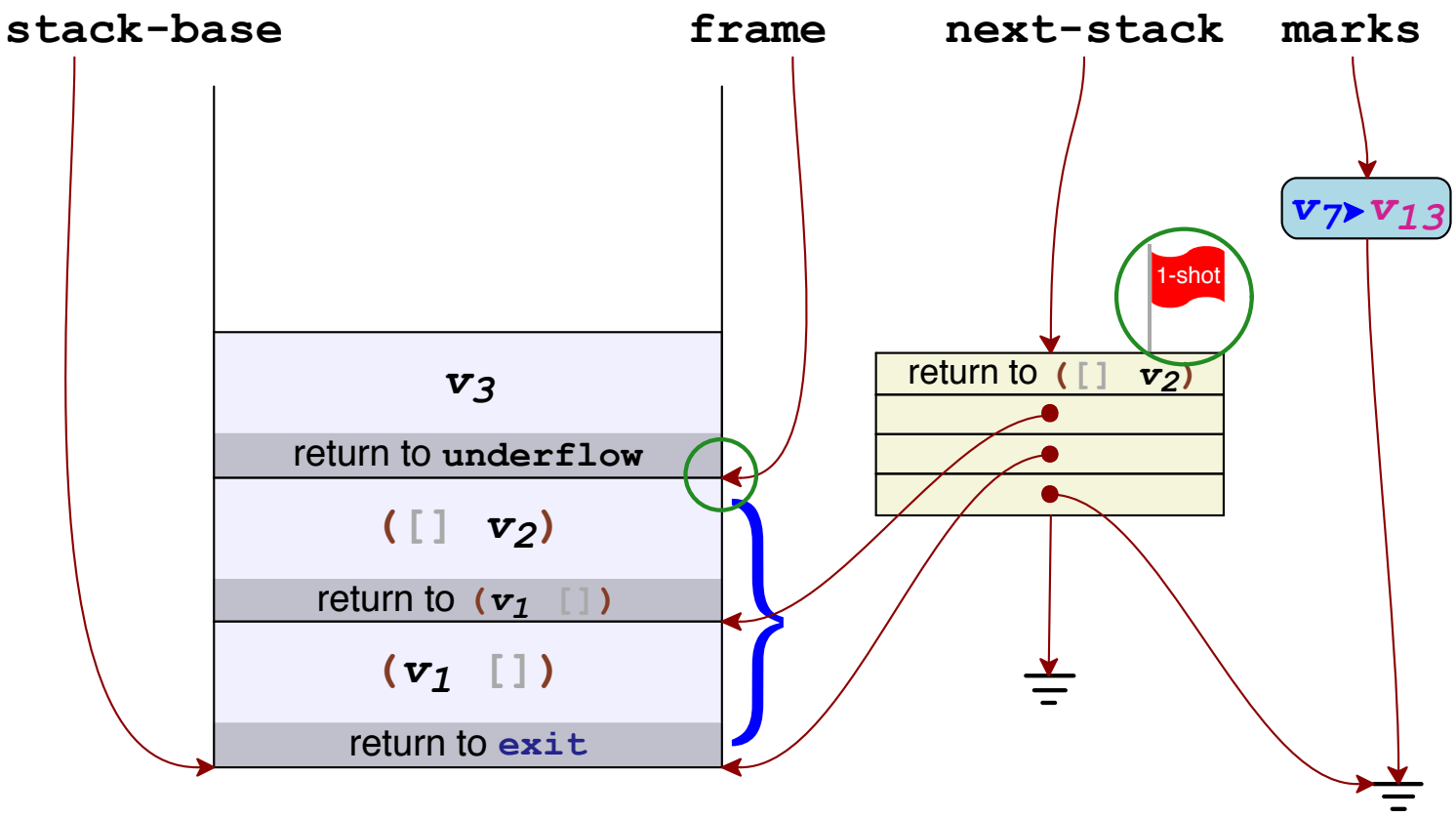
Optimistic One-Shot Continuations



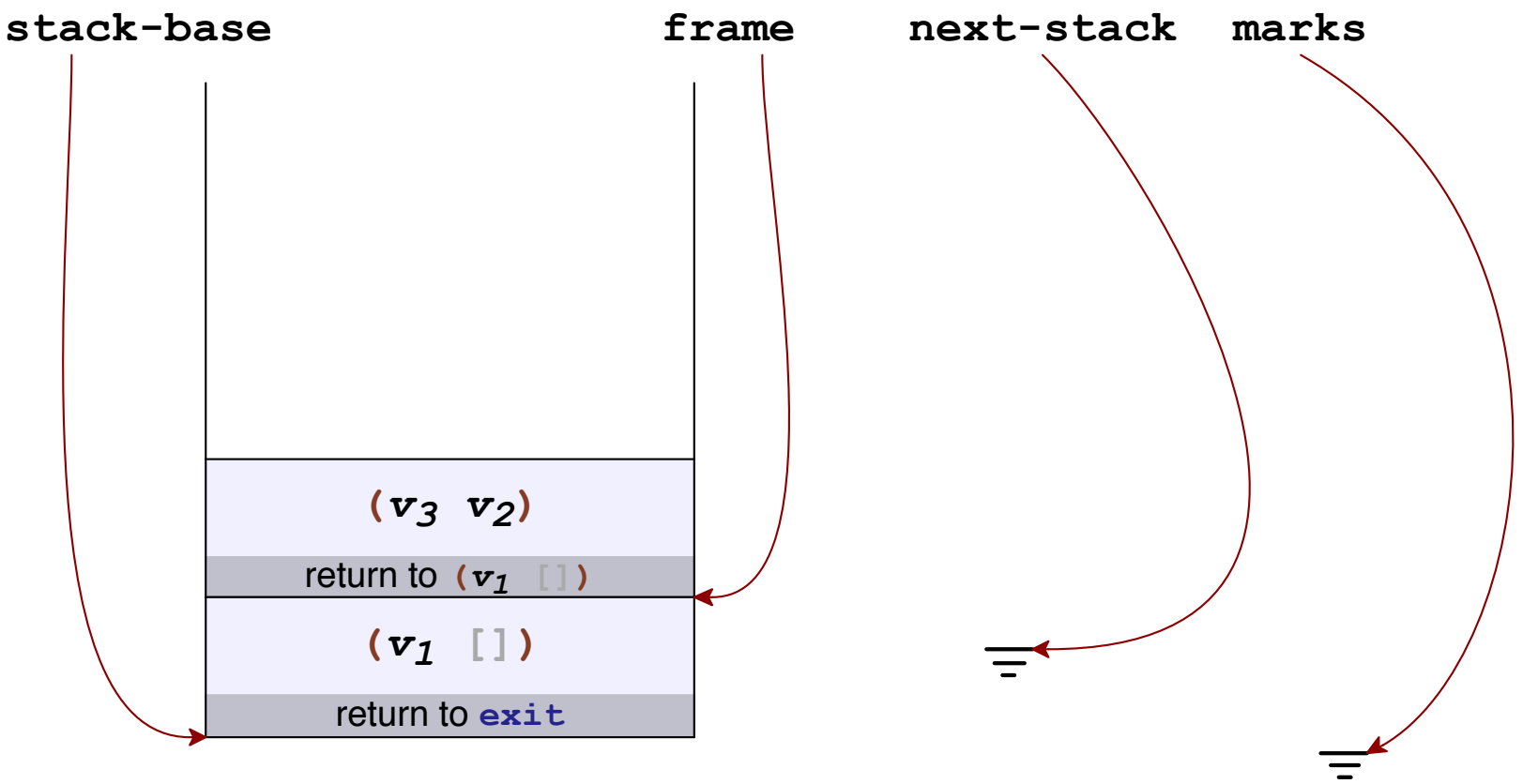
Optimistic One-Shot Continuations



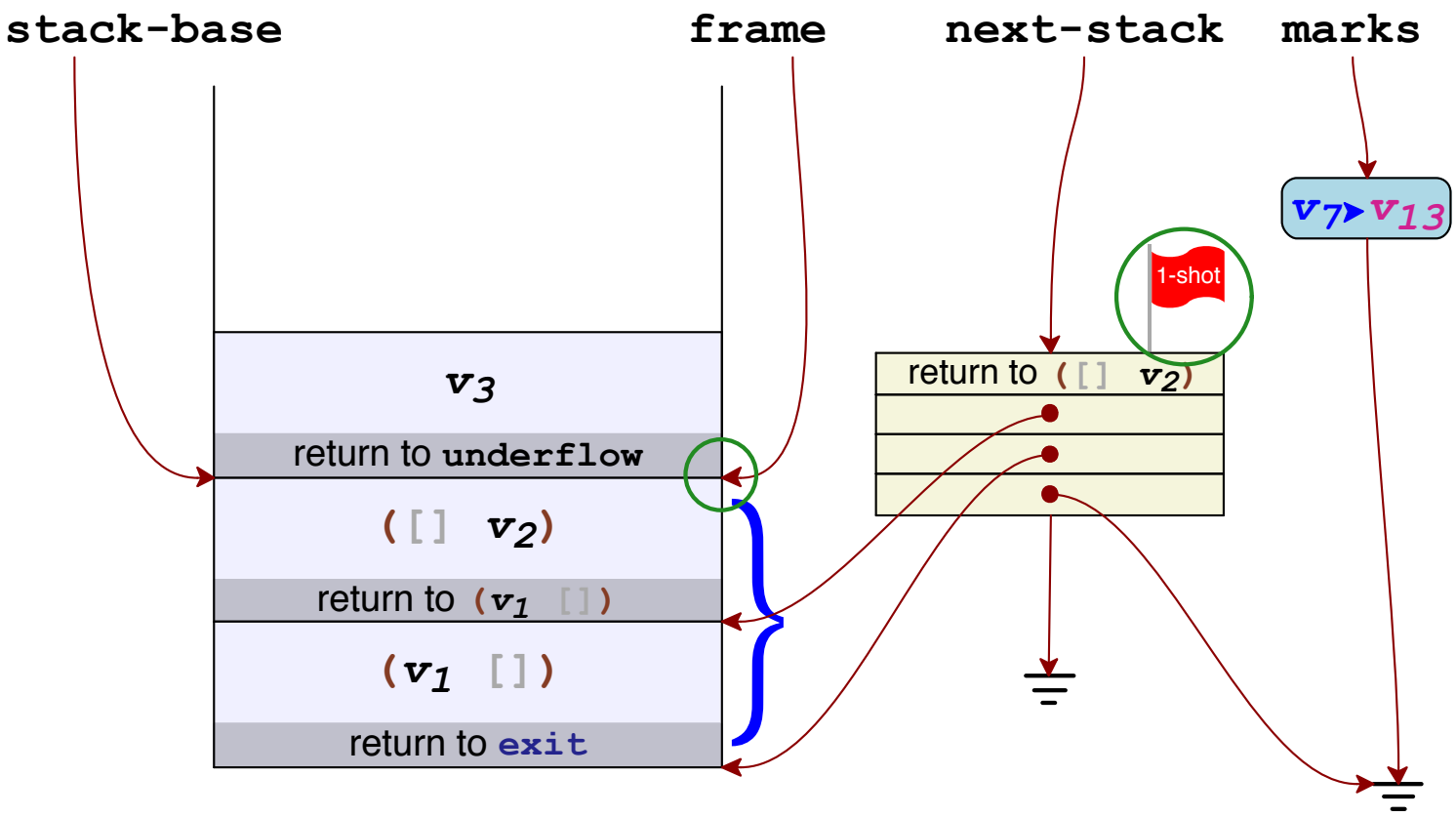
Optimistic One-Shot Continuations



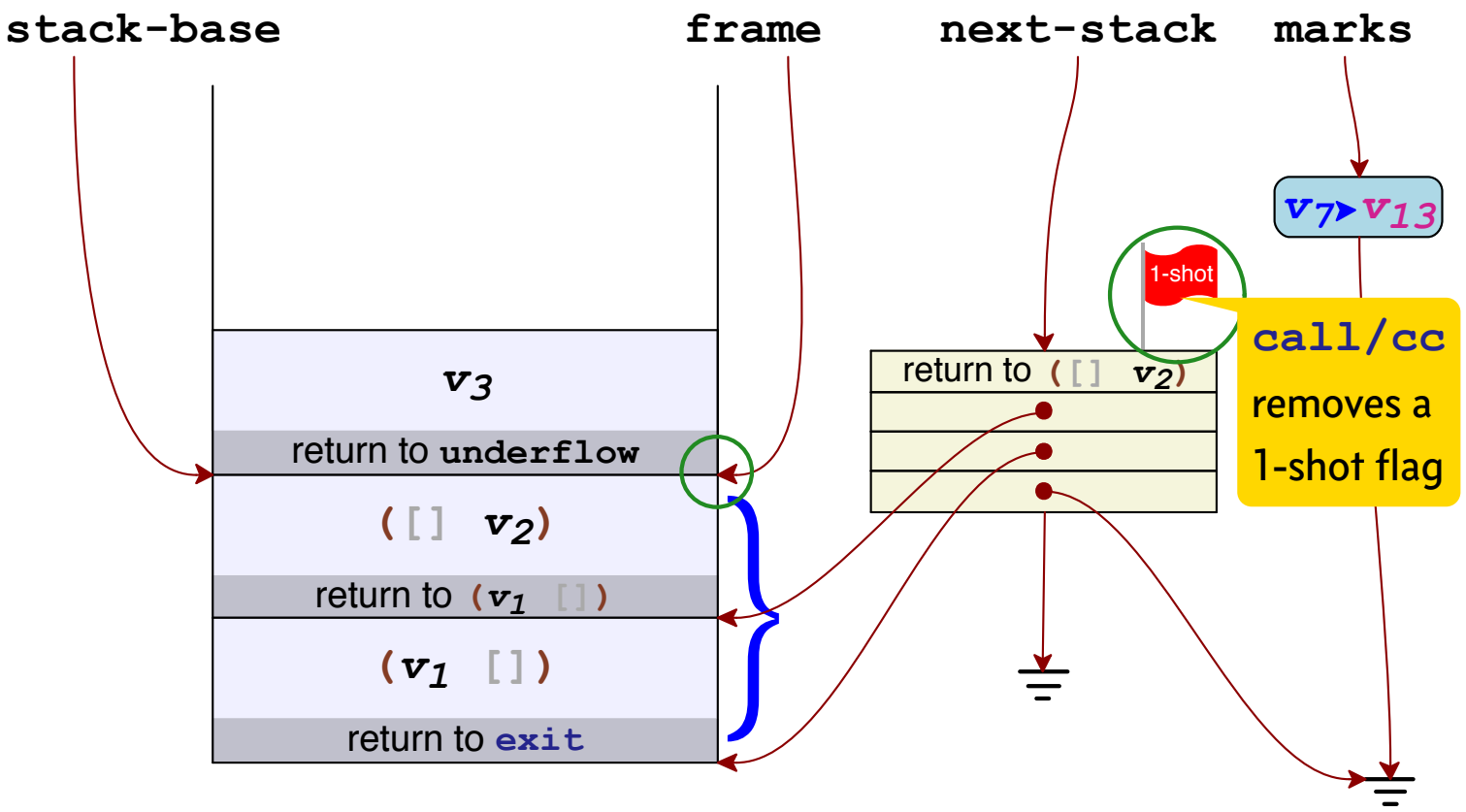
Optimistic One-Shot Continuations



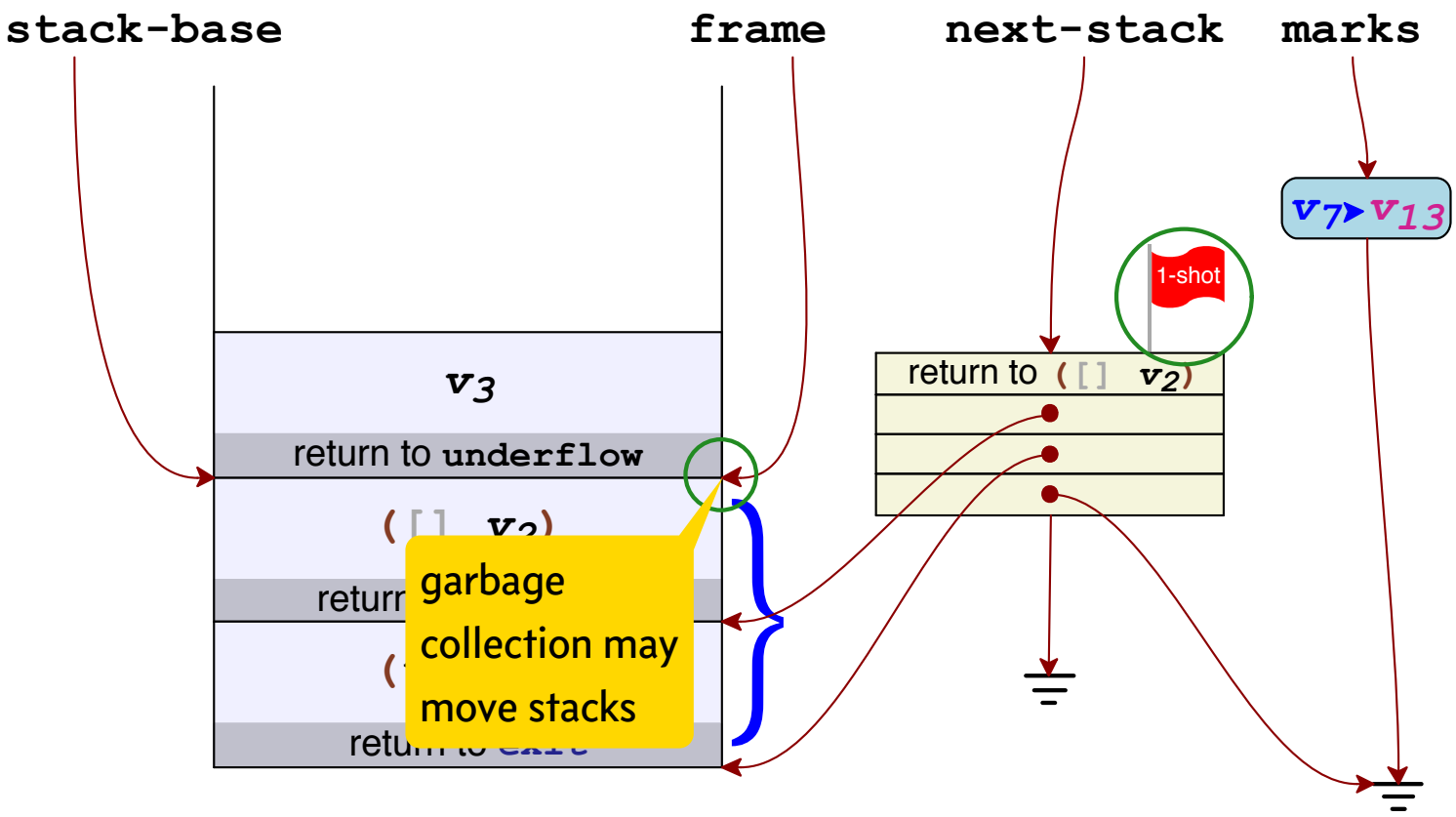
Optimistic One-Shot Continuations



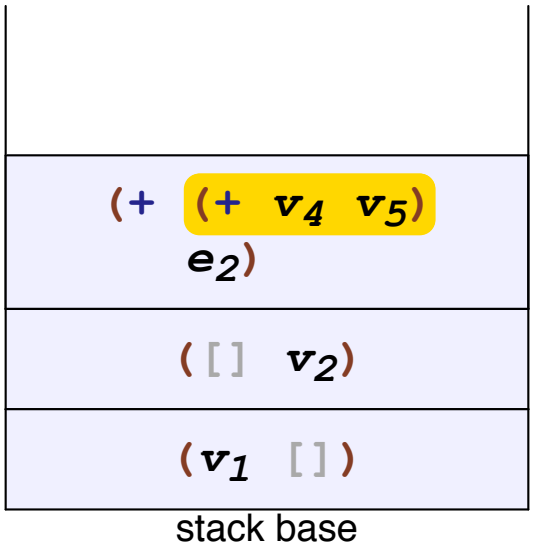
Optimistic One-Shot Continuations



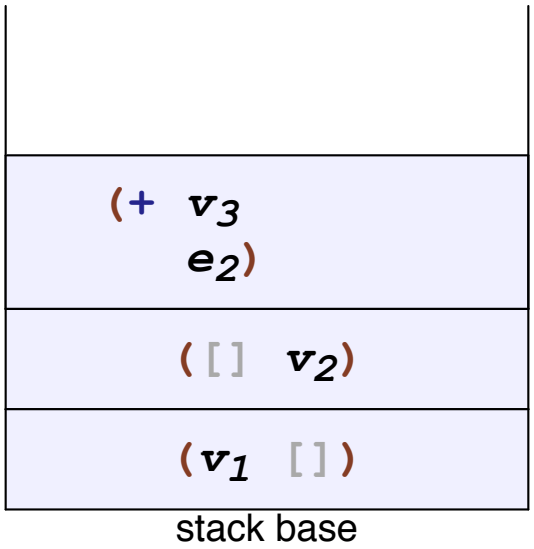
Optimistic One-Shot Continuations



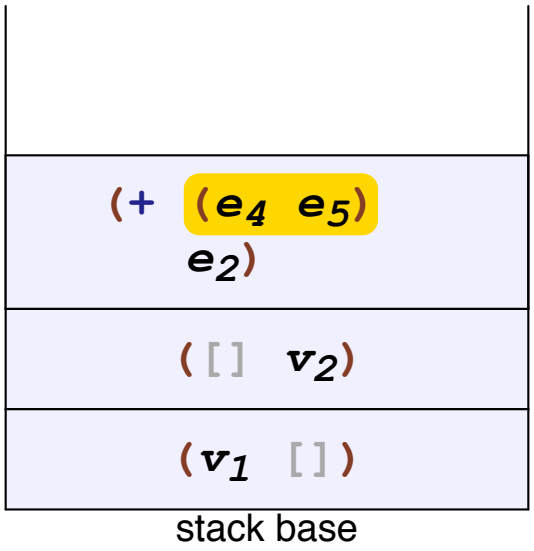
Optimization for Primitives: Don't Create Frame



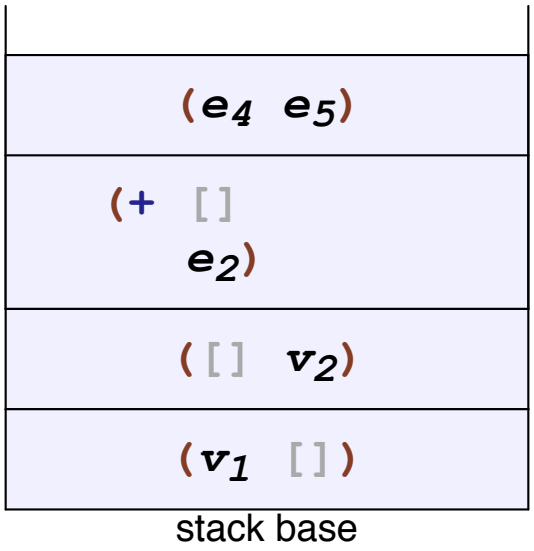
Optimization for Primitives: Don't Create Frame



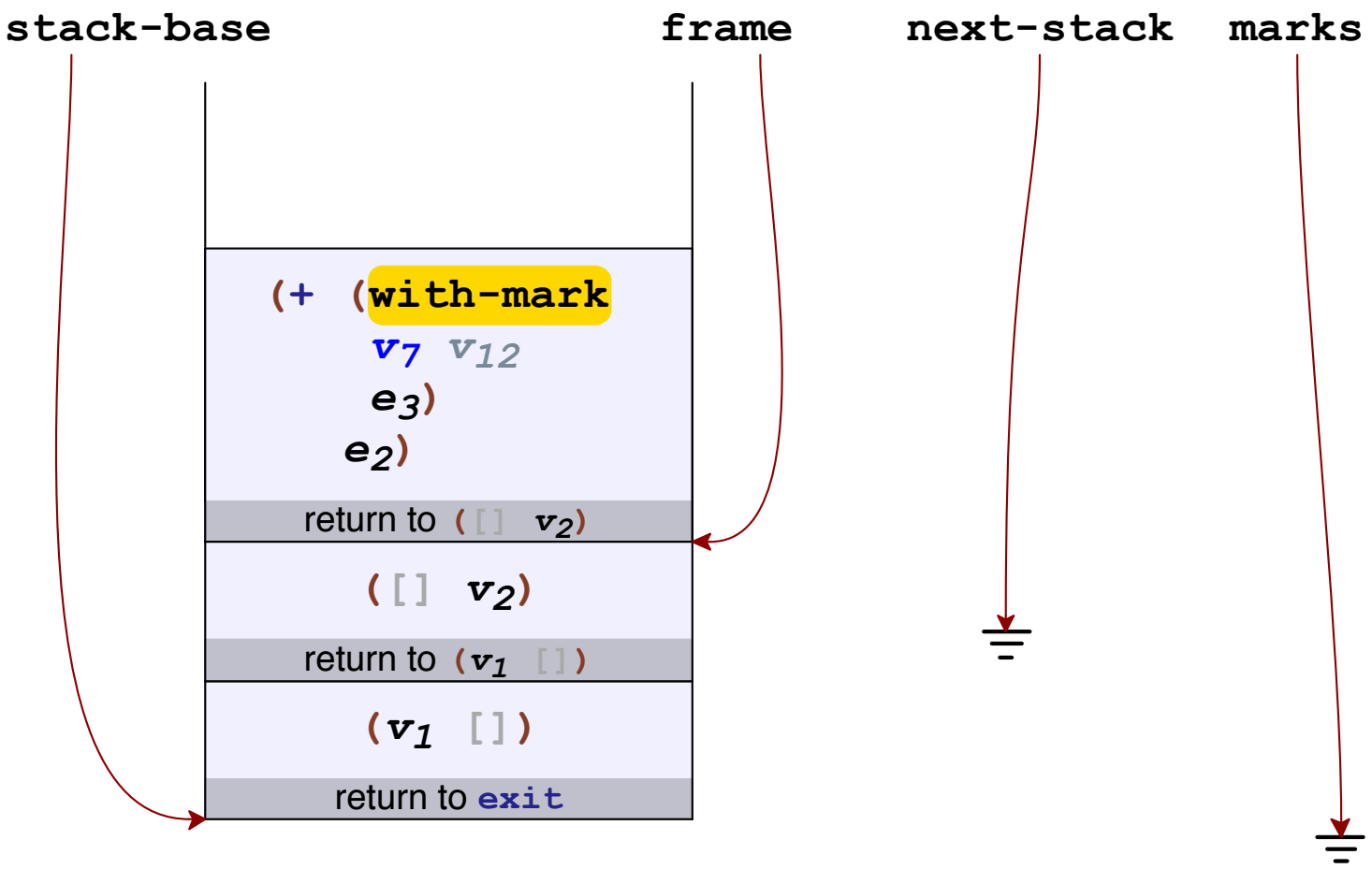
Create Frame for Nested Call



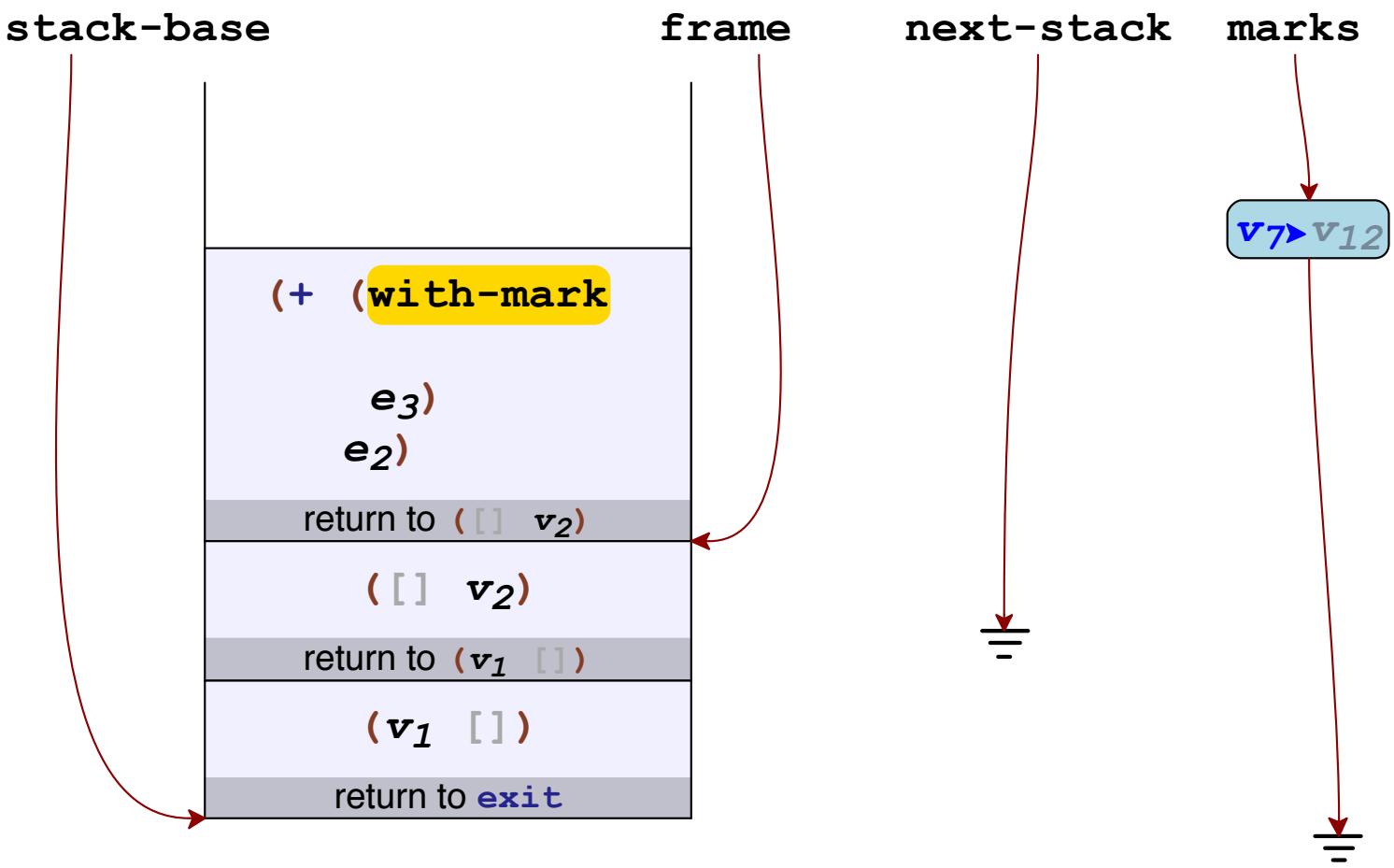
Create Frame for Nested Call



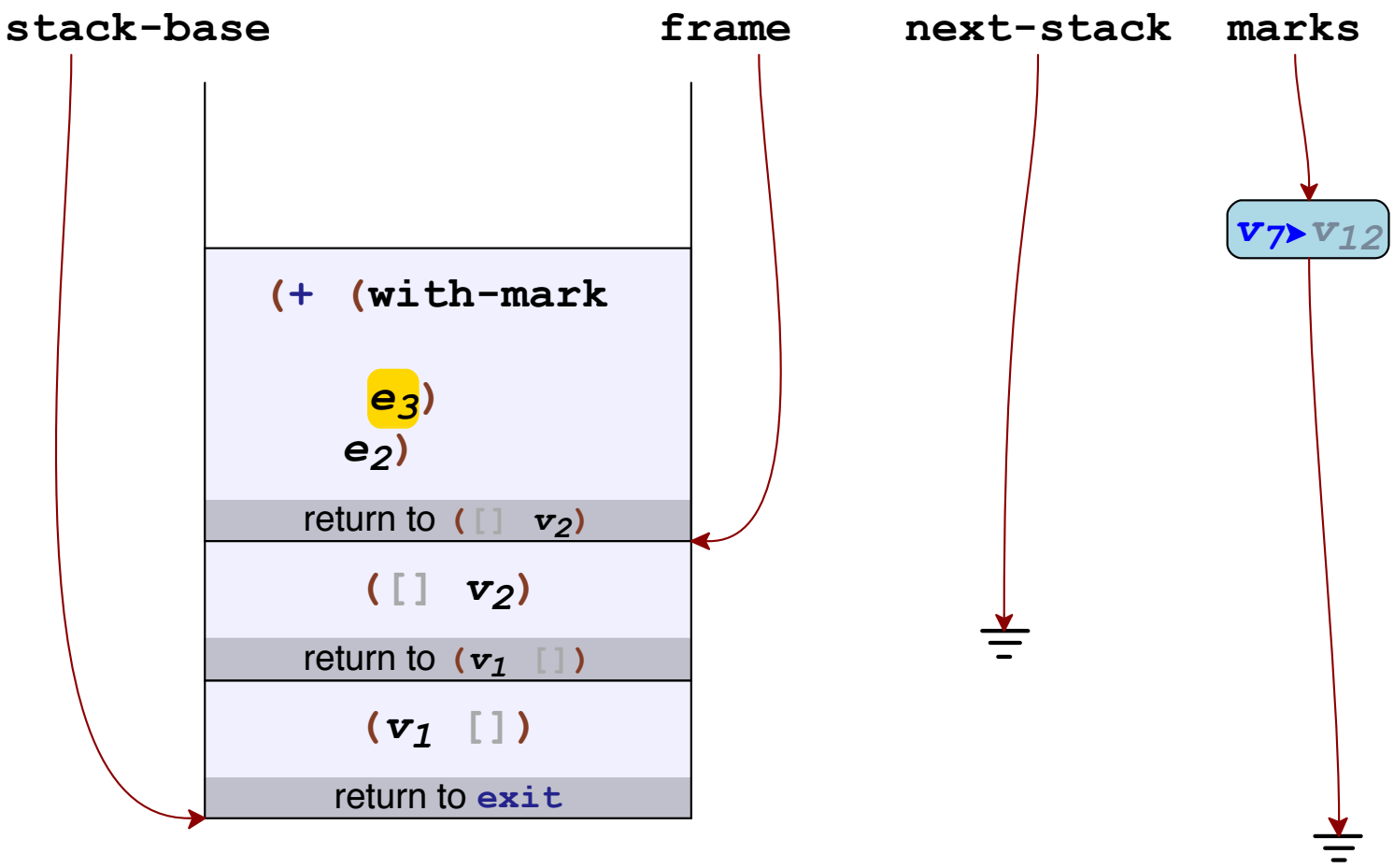
Optimzation for Non-Tail Marking



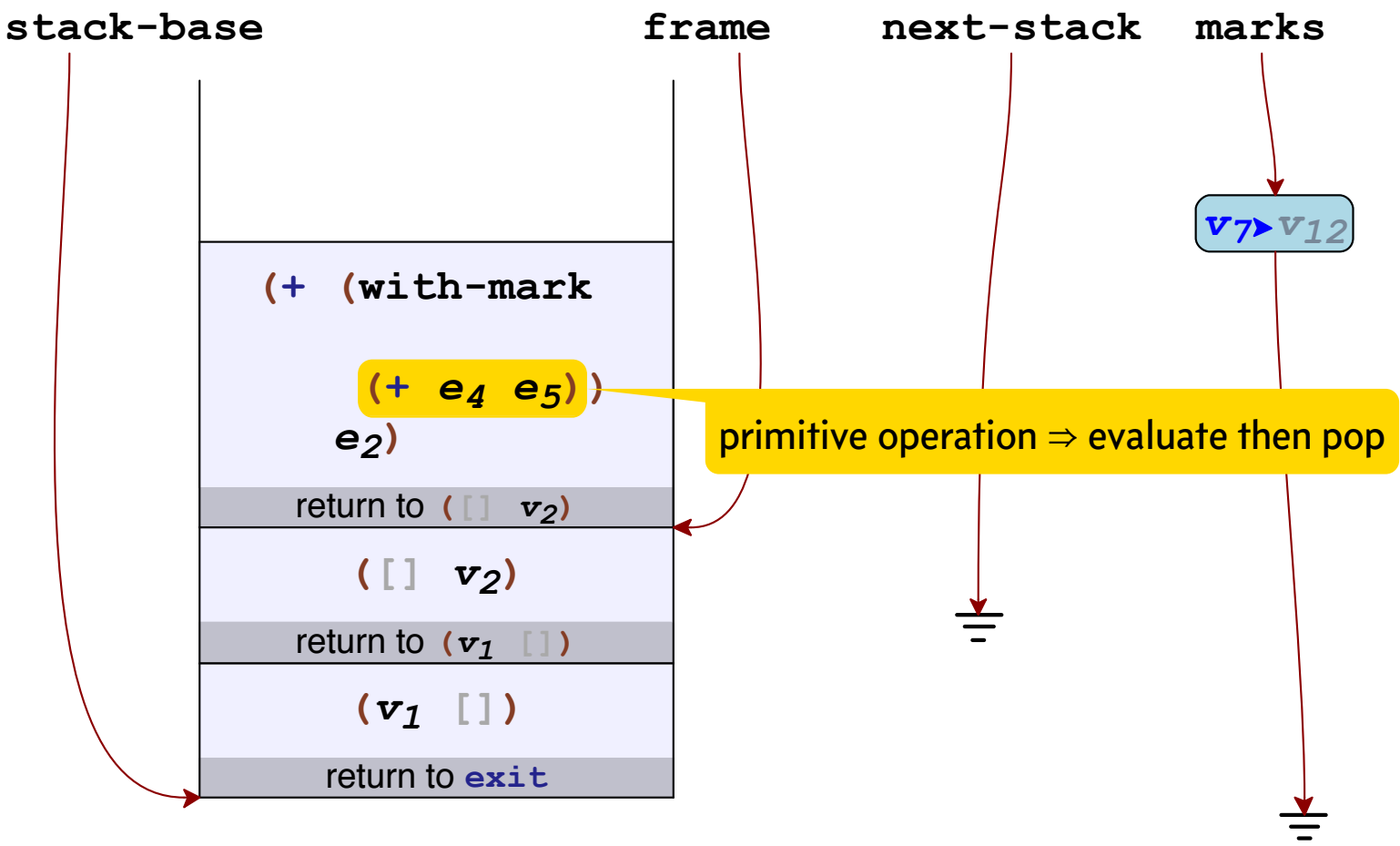
Optimzation for Non-Tail Marking



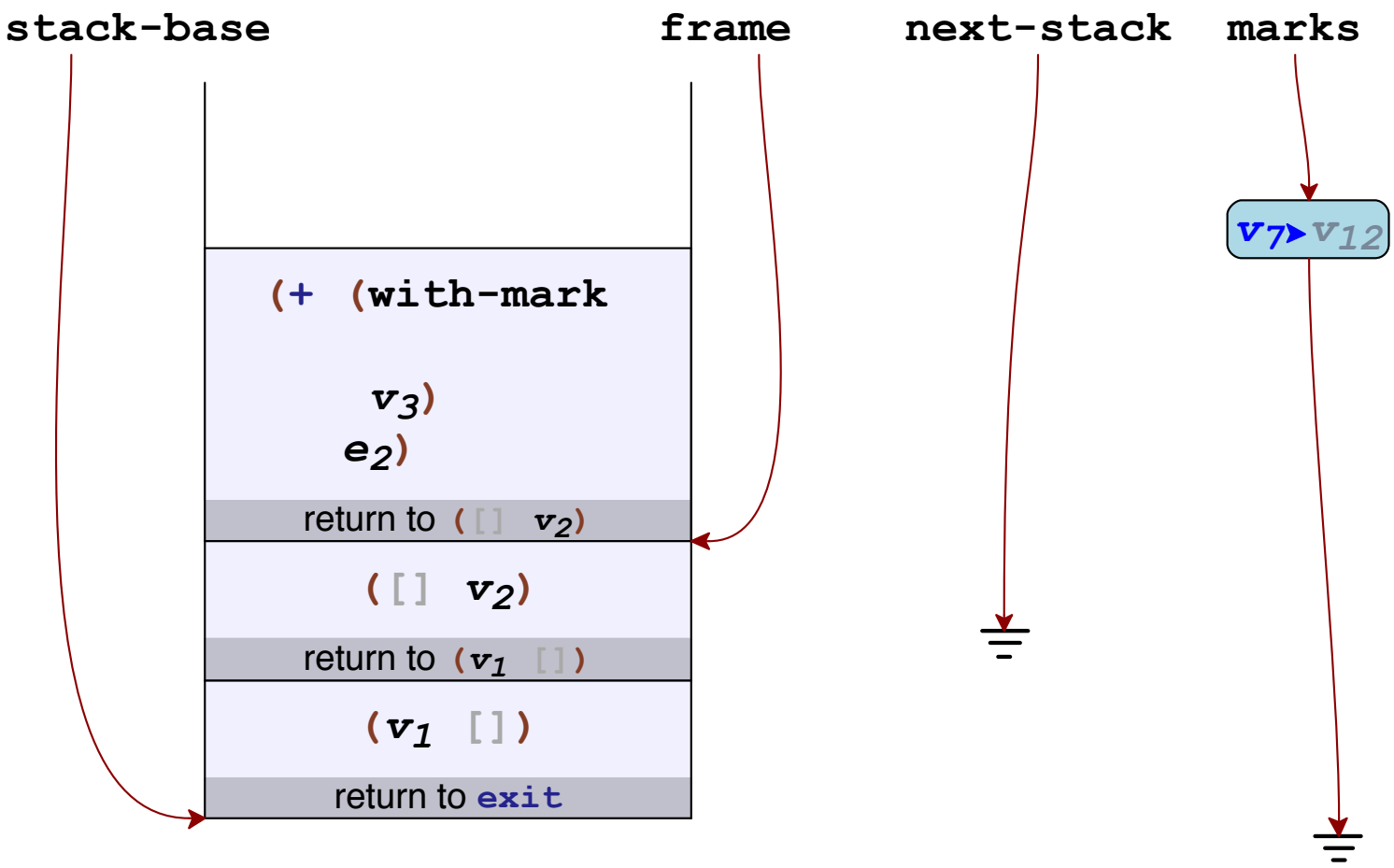
Optimzation for Non-Tail Marking



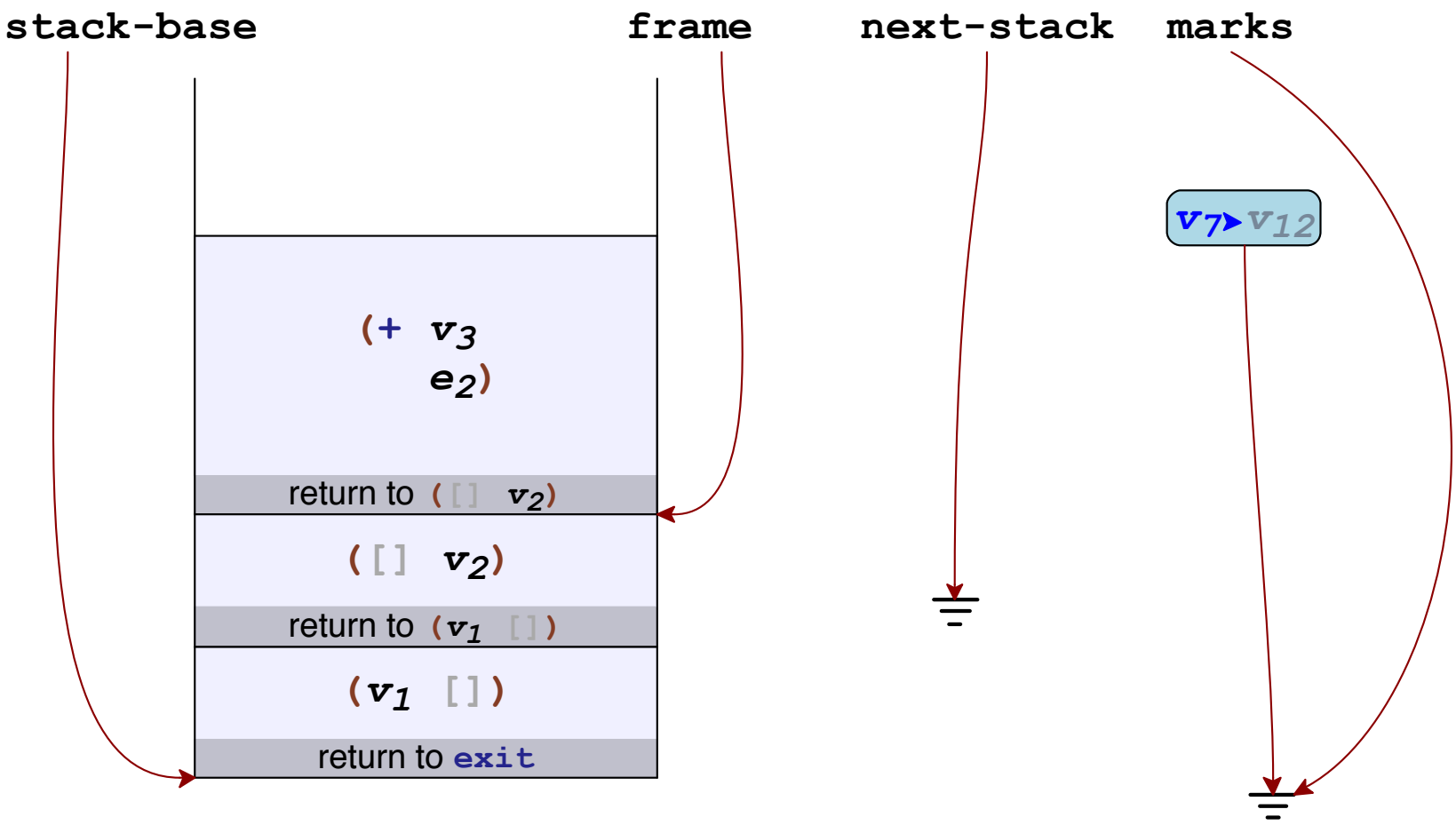
Non-Tail Marking with Primitive Operation



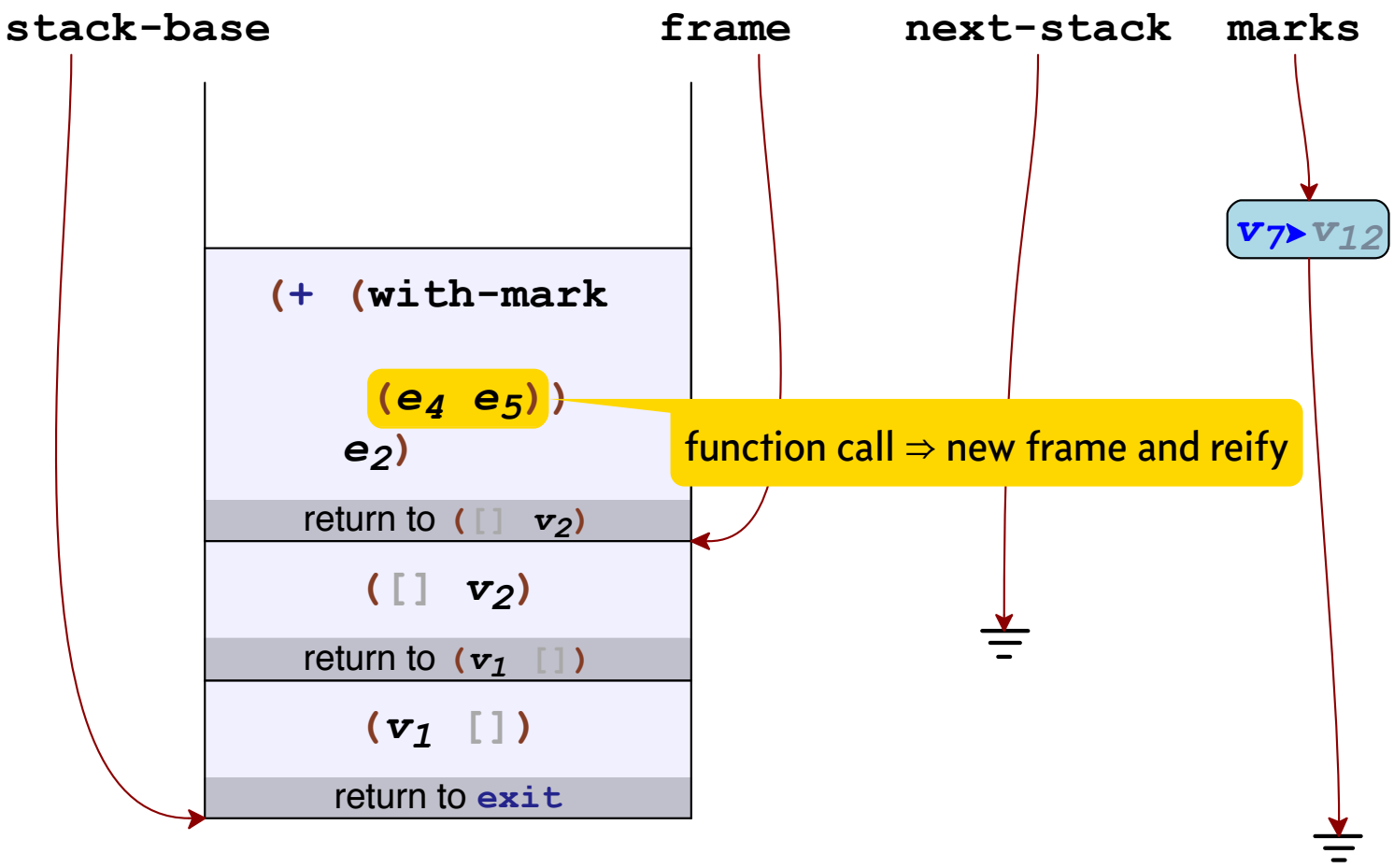
Non-Tail Marking with Primitive Operation



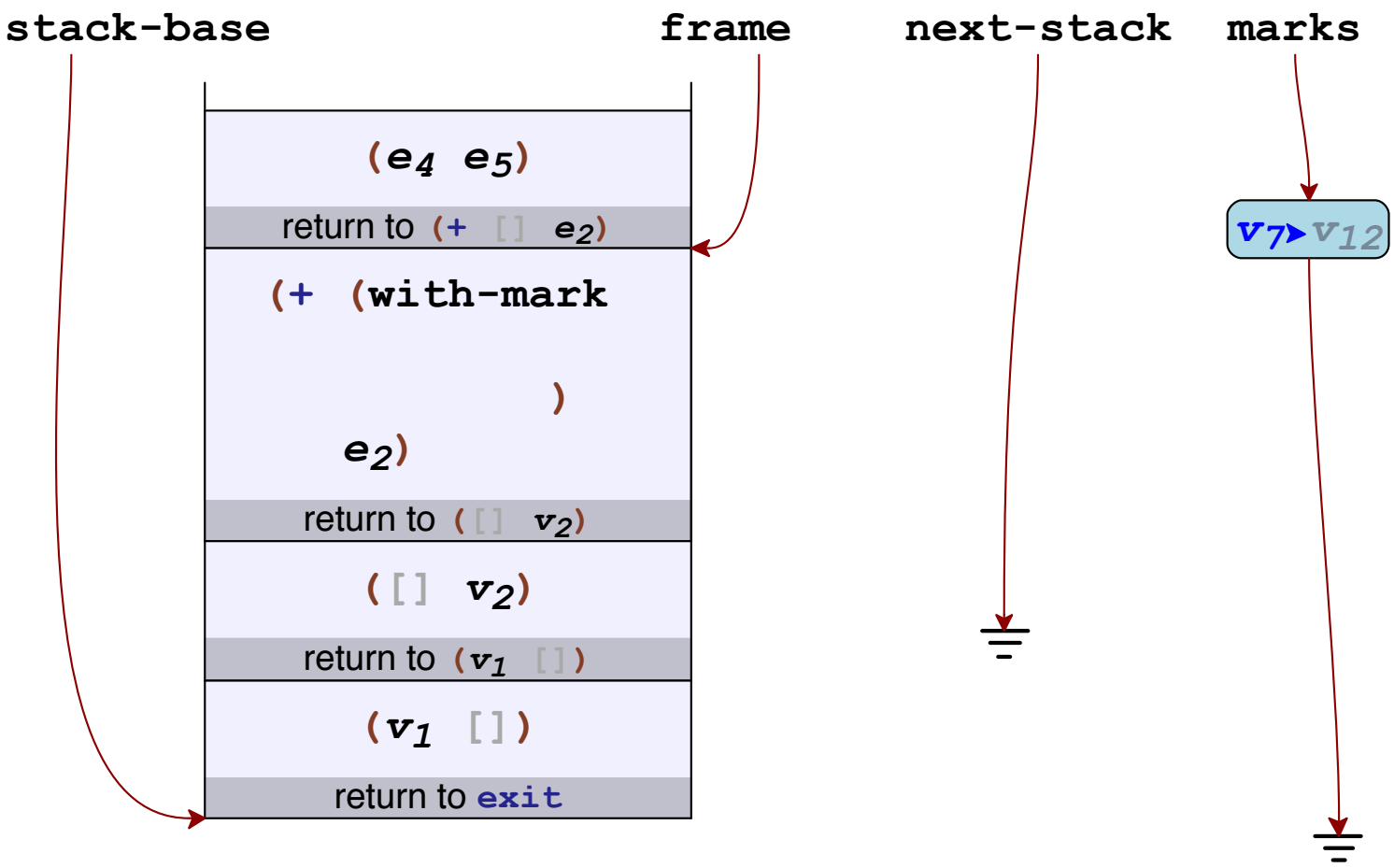
Non-Tail Marking with Primitive Operation



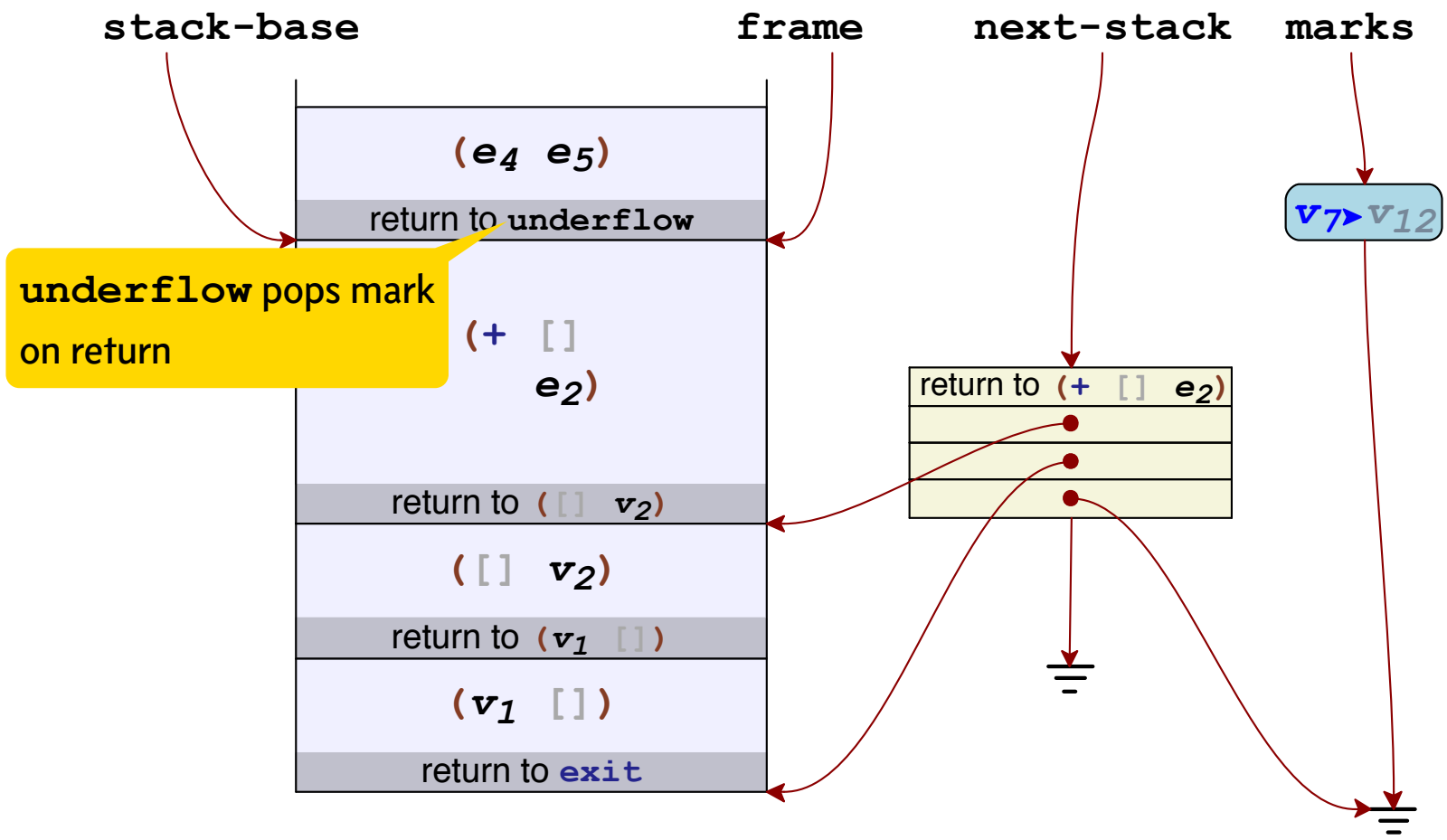
Non-Tail Marking with Non-Tail Call



Non-Tail Marking with Non-Tail Call



Non-Tail Marking with Non-Tail Call



Optimization Effectiveness

speedup relative to optimization disabled

	contracts	*applications*	
Optimisitic 1-shot	×**1.4**	×**1.04** – ×**1.05**	±0.03
Intraframe `with-mark`	×**2.0**	×**1.01** – ×**1.07**	±0.03
Non-marking primitives	×**1.4**	×**1.00** – ×**1.04**	±0.03
Runtime + optimizations	×**3.4**	×**1.10** – ×**1.25**	±0.03

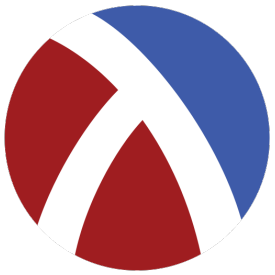
Continuation Marks

Enable

- dynamic scope
- control introspection

Compatible with

- optimizing compilation
- delimited control, concurrency, parallelism



Implement using

- stack-based continuations
- specific optimizations