Conditions of ISA Virtualizability

References

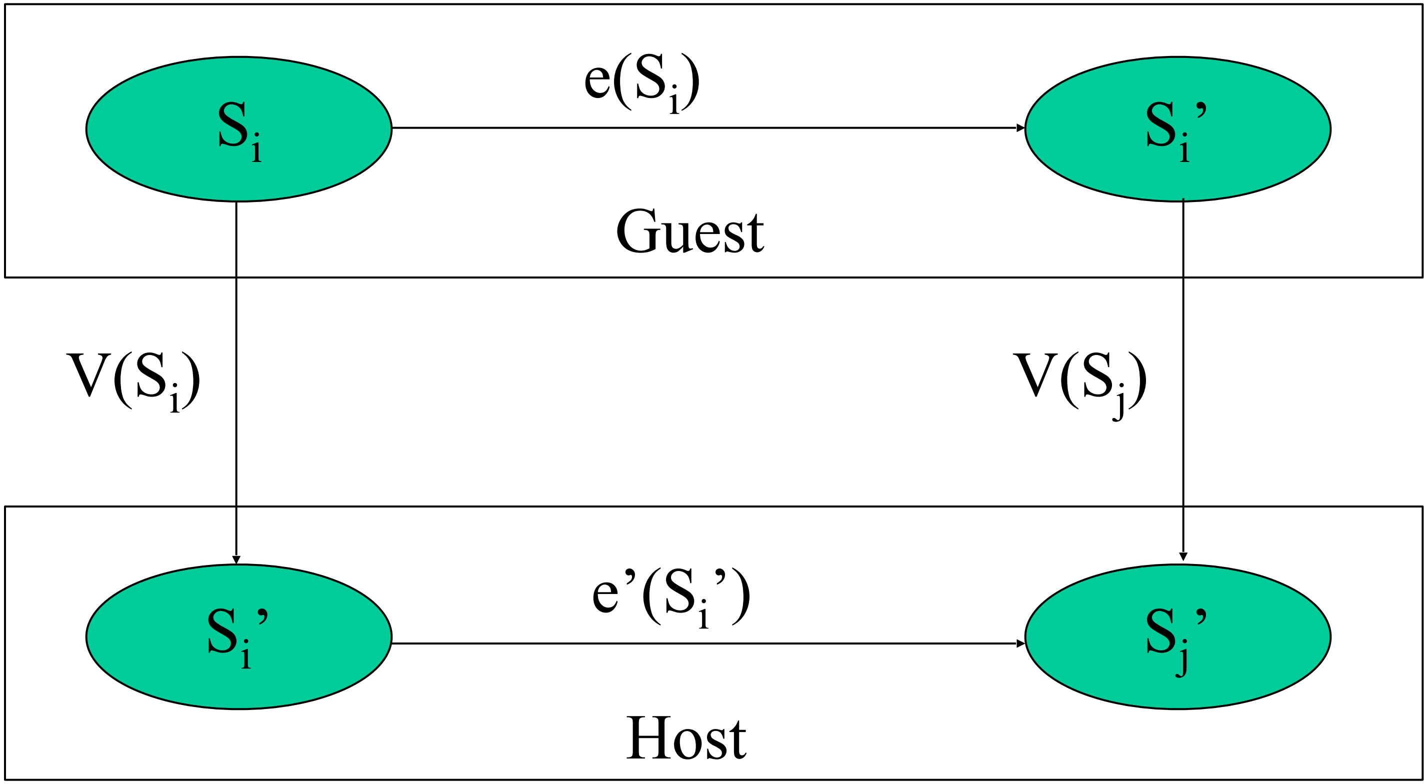
- HSSV book, Chapter 2
- Smith & Nair, Chapter 8

Popek-Goldberg Requirements for ISA Virtualizability

- Given a computer that meets [this] basic architectural model, under which precise conditions can a VMM be constructed, so that the VMM:
  - provides virtualization
    - can execute one or more virtual machines;
  - provides safety
    - i.e. is in complete control of the machine at all times;
  - provides equivalence
    - i.e. supports arbitrary, unmodified, and potentially malicious operating systems designed for that same architecture; and
  - maintains performance
    - be efficient to show at worst a small decrease in speed?

Equivalence: Virtualization as Isomorphism

- Each guest state & transition must have a corresponding mapping to a host state & transition.



Safety: Resource Control

- ❑ Issue: How to retain control of resources in the VMM?
- ❑ Timer interval control performed by VMM
- ❑ Guest OS not allowed to read the timer value
  - Guest OS sees a virtual interval timer
- ❑ VMM also gains control whenever guest OS executes privileged instructions.

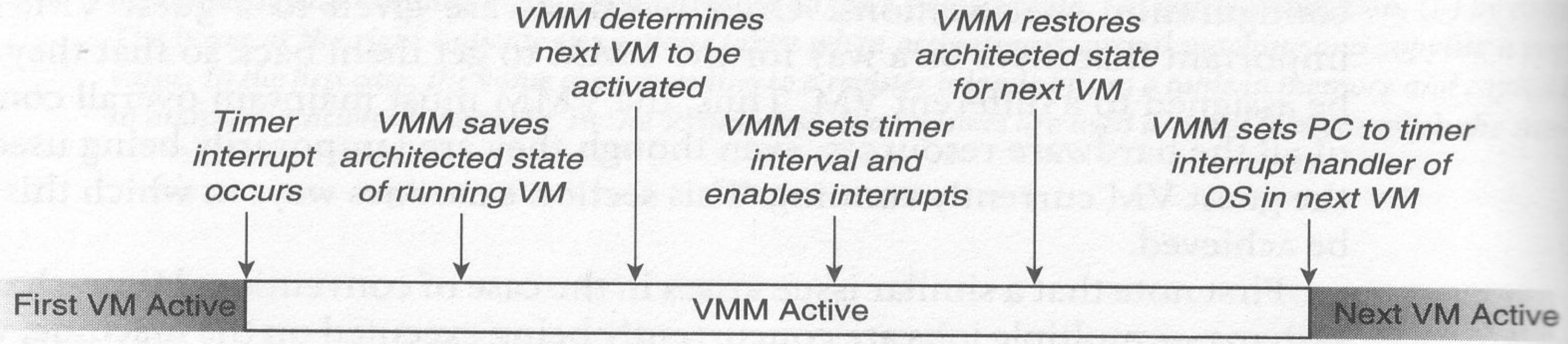

Timer interrupt occurs
VMM saves architected state of running VM
VMM determines next VM to be activated
VMM sets timer interval and enables interrupts
VMM restores architected state for next VM
VMM sets PC to timer interrupt handler of OS in next VM
First VM Active
VMM Active
Next VM Active

Figure 8.4 Actions Taken by the VMM in Retiring One Virtual Machine and Activating the Next Virtual Machine

Instruction Types

❑ Non-privileged: Do not cause traps

❑ Privileged : Cause Traps

❑ Sensitive: Change/depend upon system state

❑ Innocuous: Not “sensitive”

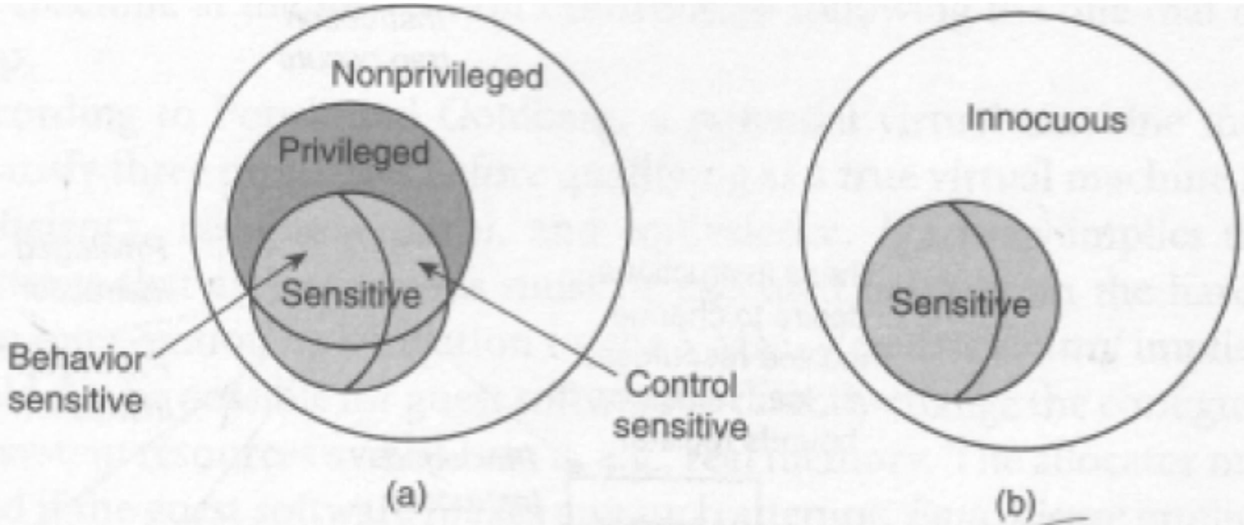
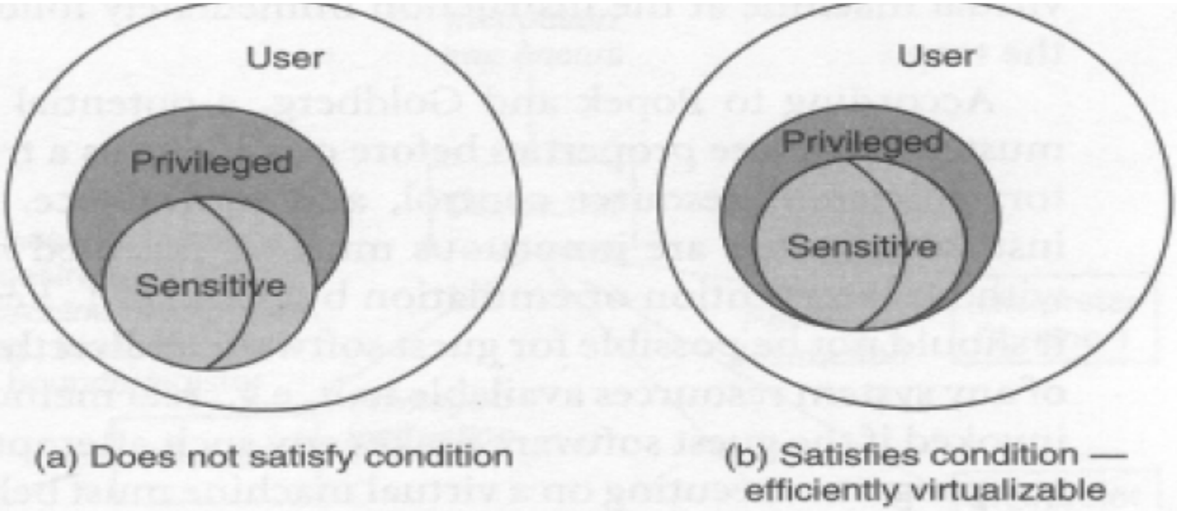


Figure 8.6 Types of Instructions. *(a) Sensitive and privileged instructions overlap (although not necessarily completely). (b) Sensitive instructions and innocuous instructions are complements of each other.*

Conditions of ISA Virtualizability

- Theorem: A computer architecture is fully virtualizable if the set of sensitive instructions for that computer is a subset of the set of privileged instructions.

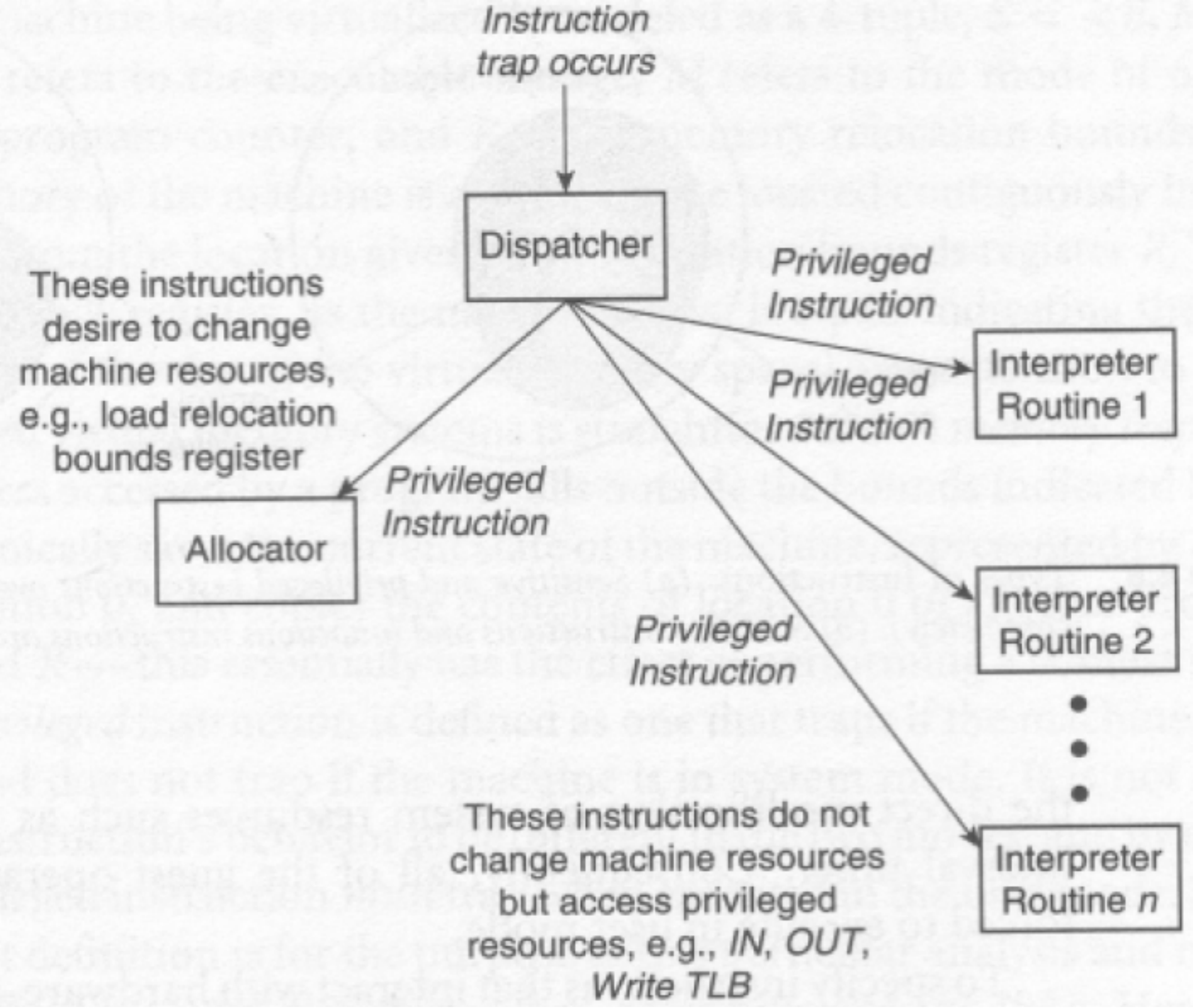


(a) Does not satisfy condition

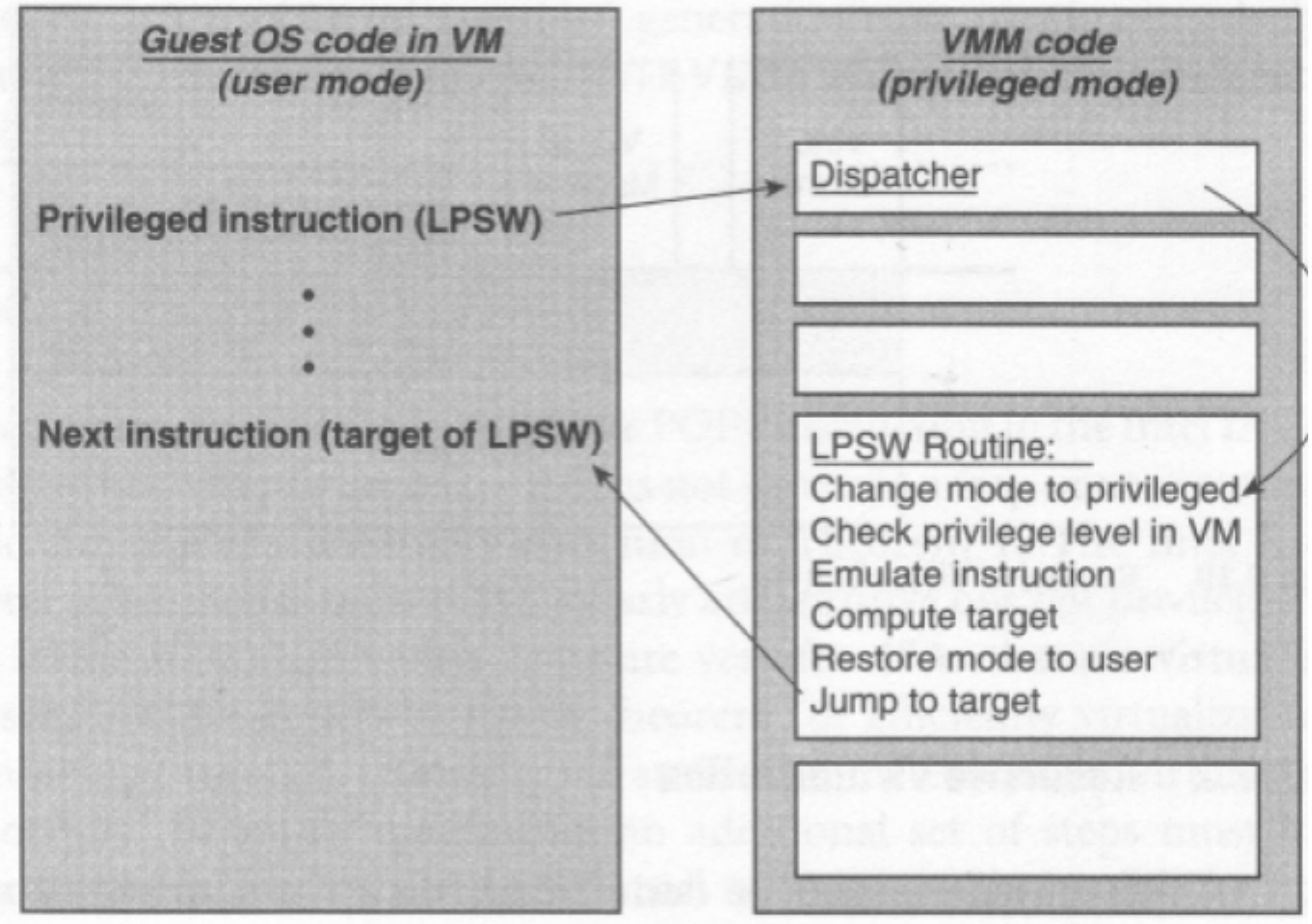
(b) Satisfies condition — efficiently virtualizable

Figure 8.8 Illustrating Popek and Goldberg's Theorem 1. *In (a), the sensitive instructions are not a subset of the privileged instructions and hence the system may not be efficiently virtualizable. On the other hand, the system in (b) satisfies the condition of Theorem 1.*

Execution of Privileged Instruction


Instruction trap occurs
Dispatcher
These instructions desire to change machine resources, e.g., load relocation bounds register
Privileged Instruction
Allocator
Privileged Instruction
Interpreter Routine 1
Privileged Instruction
Interpreter Routine 2
Privileged Instruction
Interpreter Routine *n*
These instructions do not change machine resources but access privileged resources, e.g., *IN*, *OUT*, *Write TLB*

Handling Privileged Instructions in a Guest OS



Hybrid VMM Requirements

- A hybrid virtual machine monitor may be constructed for any conventional third-generation machine in which the set of user-sensitive instructions are a subset of the set of privileged instructions.

- User-sensitive instructions
  - Instructions that are control or behavior-sensitive only in supervisor mode
  - E.g. JRST in PDP-10 or pop in x86 fail silently in user mode.

- Hybrid VMM interprets in software 100% of the instructions in guest-supervisor mode.

Hybrid VMM example:
Dynamic binary patching in early VMWare ESX server

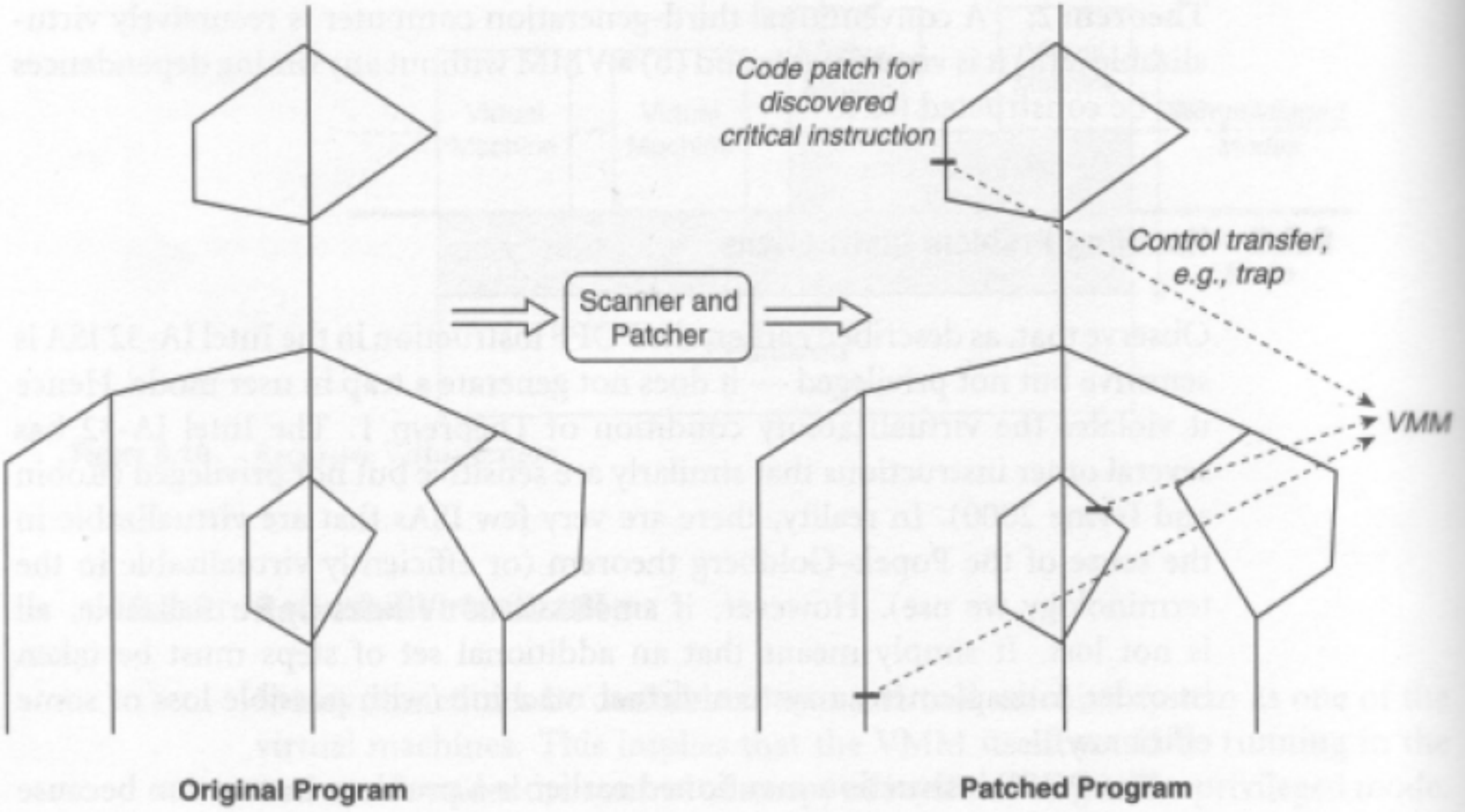


Figure 8.11 Scanning and Patching Code in a Hybrid Virtual Machine System.