Providing Dynamic Update in an Operating System

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TEASER

Our system can apply updates to the running kernel

- ✓ Negligible performance impact
- ✓ Applicable to a mainstream OS

Overview:

① Problem & background
② Design
③ Implementation in K42
④ Experiences & results
⑤ Open issues
⑥ Related work
⑦ Conclusion

Problem: System Availability / Patches

Down time is increasingly expensive, we want the OS to be highly available

OSes require frequent updates, patches, etc.

- ✗ Requires restarting services, often a reboot
- ✗ Trade off cost of down-time *vs.* risk of remaining unpatched

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Dynamic Update

DYNAMIC UPDATE

An established software technique (and field of research)

- ➜ Allows software updates to a running system while continuing to provide access to the resource managed by that software
- ➜ Previous work focused on update to applications and services
- ✓ This work focuses on dynamic update for operating systems

Issues in OS Dynamic Update

Classification of updates:

① code

② single-instance (global) data

③ multiple instance data structures

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Potential limitations:

➜ What parts of the OS can be changed?
  ➜ e.g. low-level exception code

➜ How critical is the timeliness?
  ➜ May need guarantees for security updates

➜ Are updates to system libraries or middleware supported?

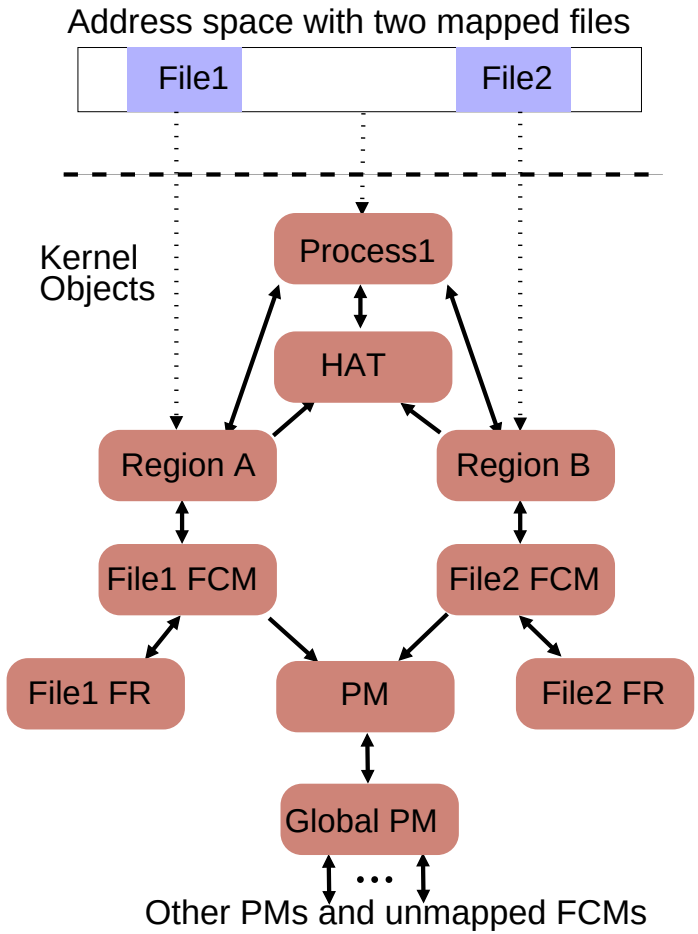
REQUIREMENTS

① Updatable unit
② Mechanism for detecting a safe point
③ State tracking
④ State transfer
⑤ Ability to redirect invocations
⑥ Version management

These could be provided in mainstream operating systems, such as Linux (further details in Linux.conf.au 2005).

THE K42 OPERATING SYSTEM

- Scalable research OS:
  - Open source
  - Supports Linux API/ABI
  - Good prototyping environment
- Object oriented:
  - Each resource managed by set of object instances
  - Helps achieve scalability
- Supports object hot-swapping



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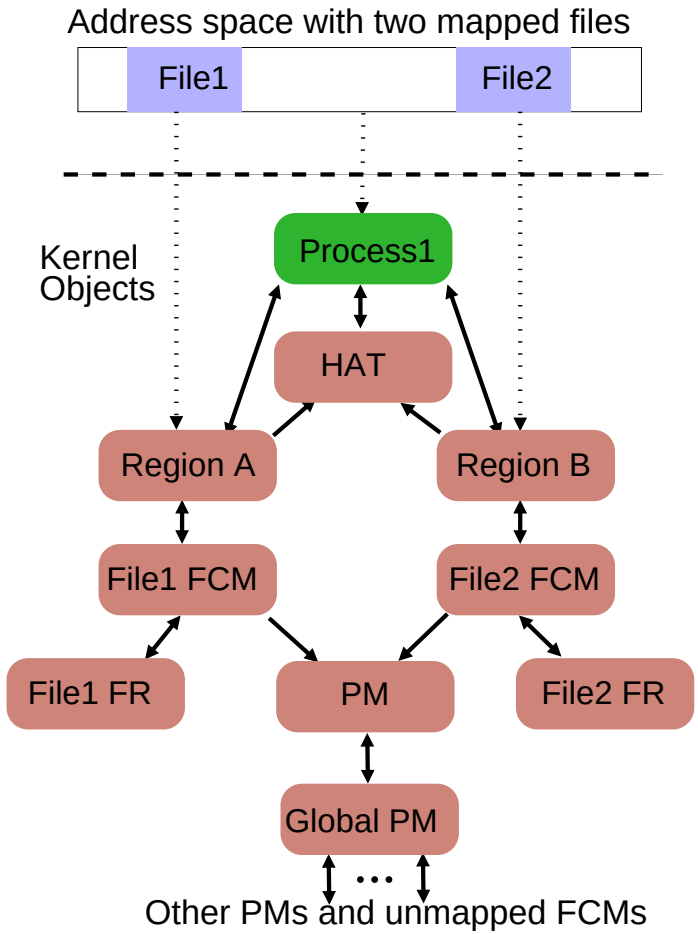

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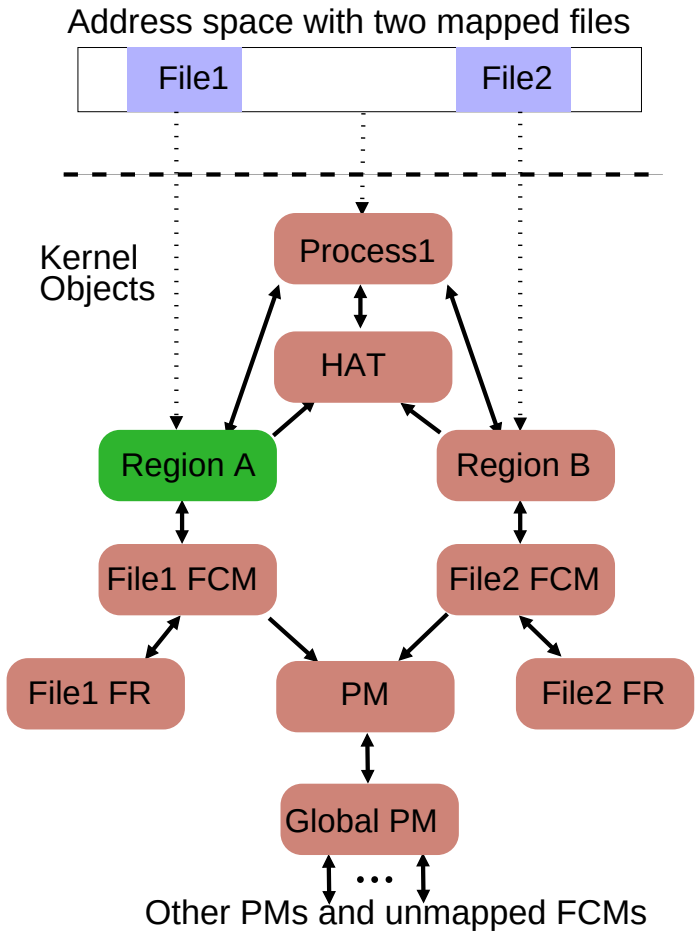

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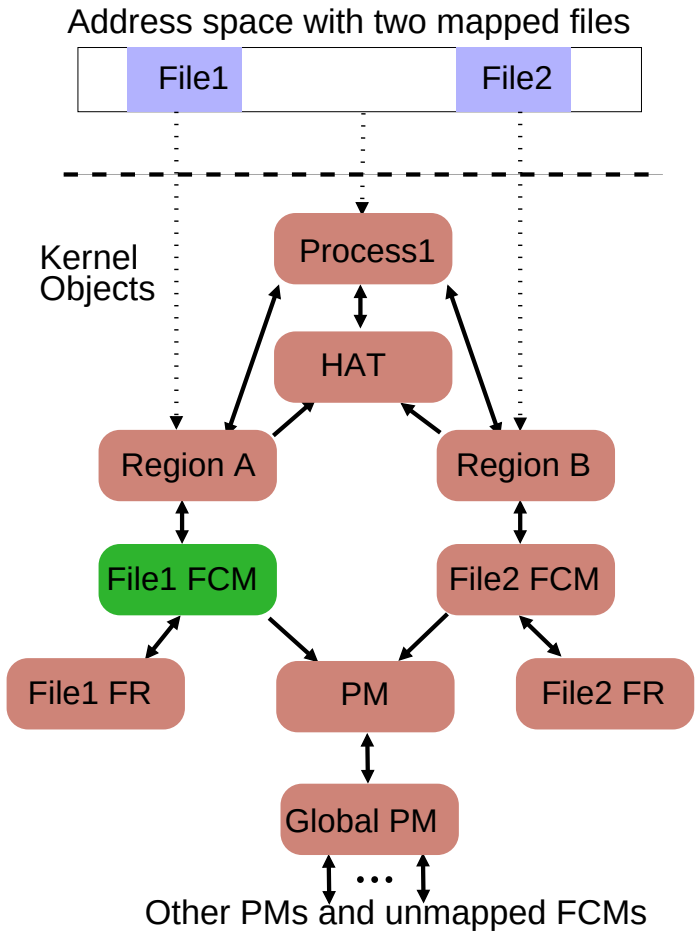
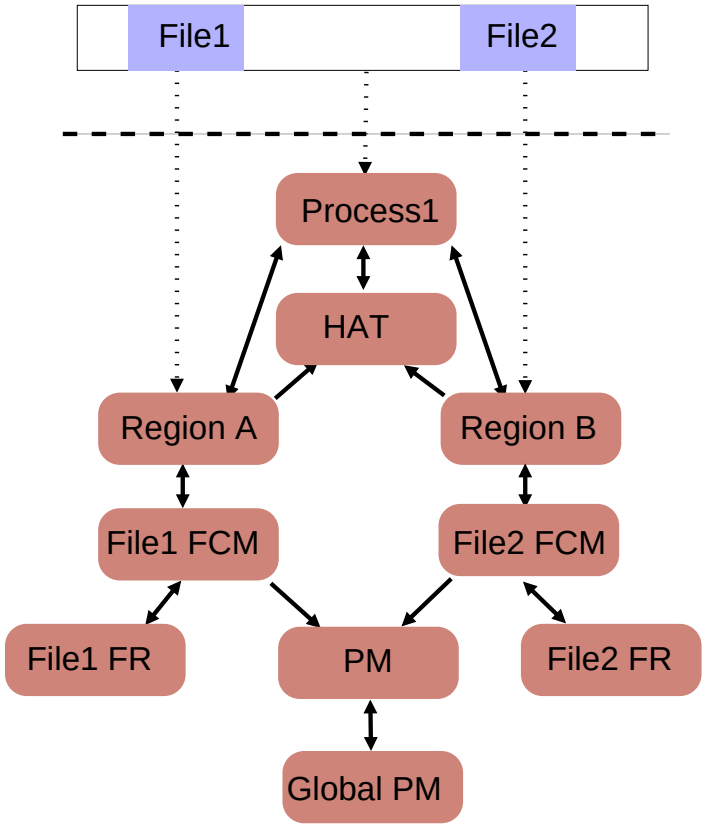


OBJECT HOT-SWAPPING

- ➜ Specific object instance substituted on-the-fly
- ➜ Designed for adaptation, customisability
  - ➜ e.g. change caching/prefetching policy
- ✓ Basis of dynamic update implementation



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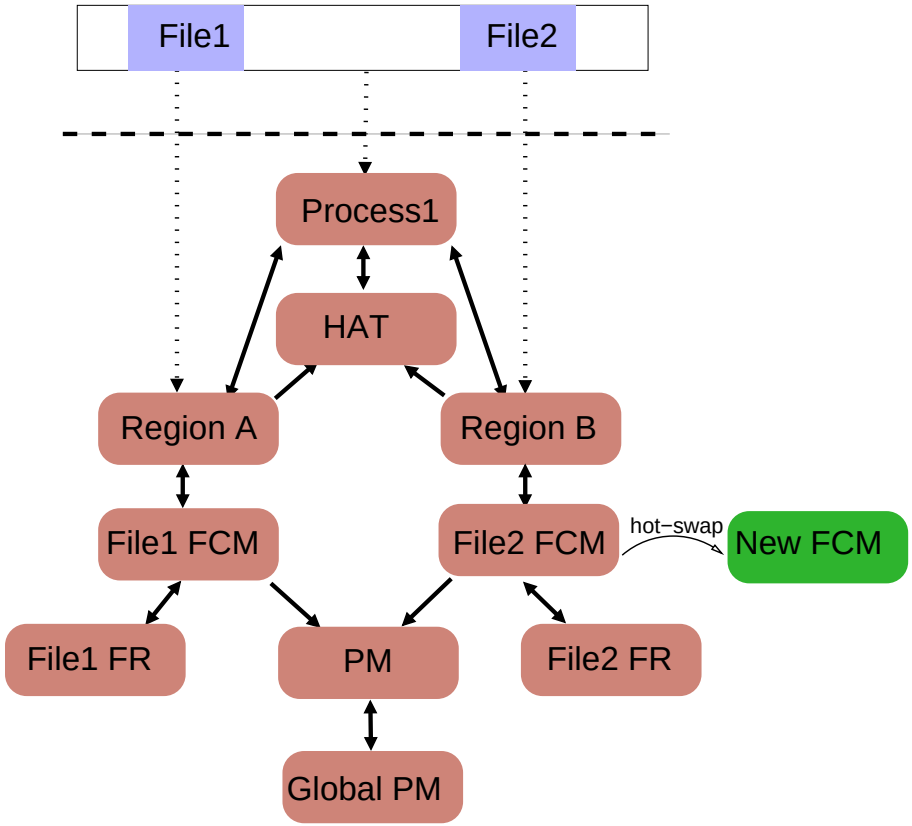

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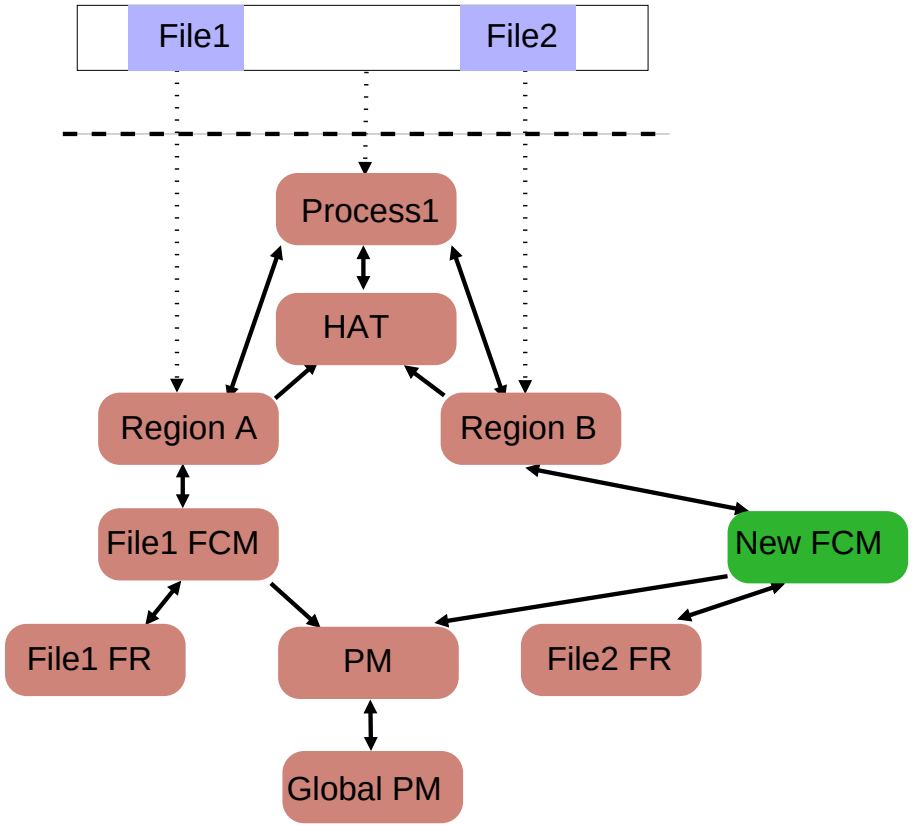


Dynamic Update in K42

Our prototype addresses the requirements:

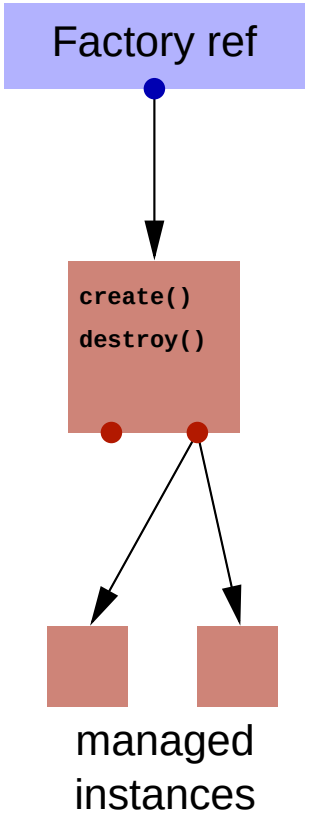
①	Updatable unit	Hot-swappable object instance
②	Safe point/quiescence	Read copy update (RCU) techniques
③	State tracking	Factory objects
④	State transfer	Transfer functions
⑤	Redirect invocations	Object translation table
⑥	Version management	Version numbers on factory objects

Factory Objects

- ➜ Use the factory design pattern
- ➜ Create and destroy objects of a specific class
- ➜ Track and manage object instances
- ✓ Improved model of object creation and management (over statically-bound calls)

Allow us to:

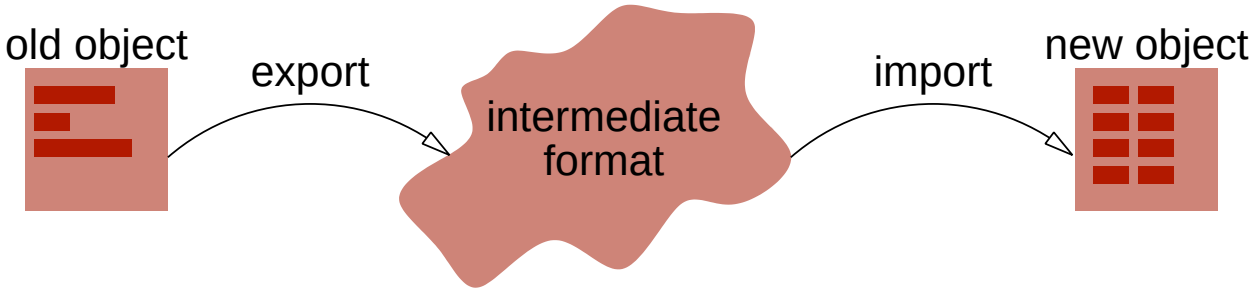
- ➜ Locate and update every instance
- ➜ Ensure future instantiations use the update



TRANSFER FUNCTIONS

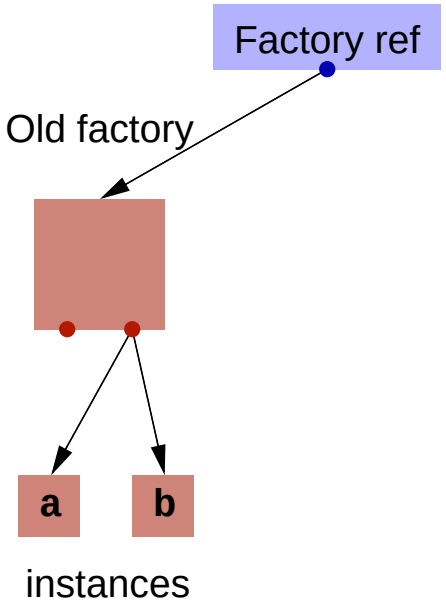
Support arbitrary changes in object representation

- ➜ Objects must provide export and import methods



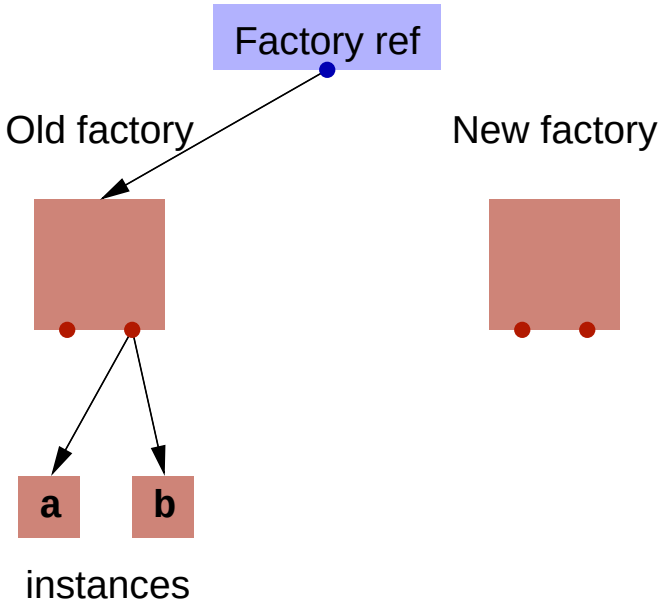
- ➜ Usually, intermediate format = old internal format
- ➜ Can avoid copying

Dynamic Update Implementation

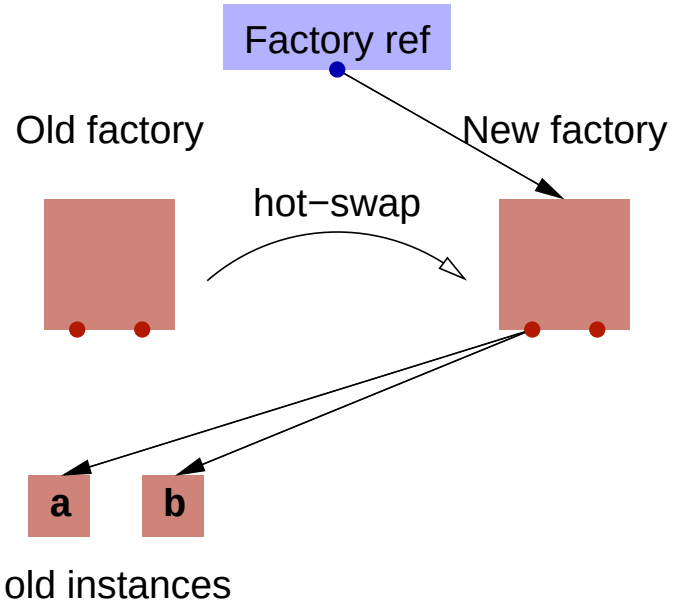


① Before update, the old factory tracks instances of a class

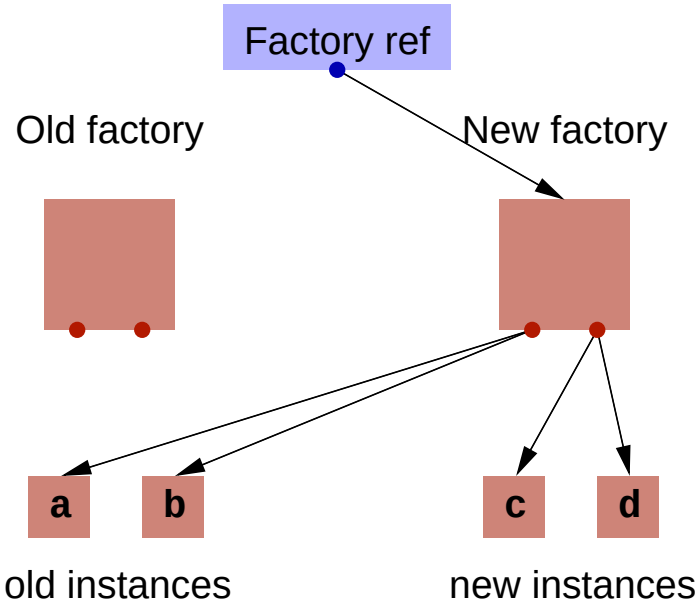
➜ Updated code compiled together with initialisation code as a loadable module



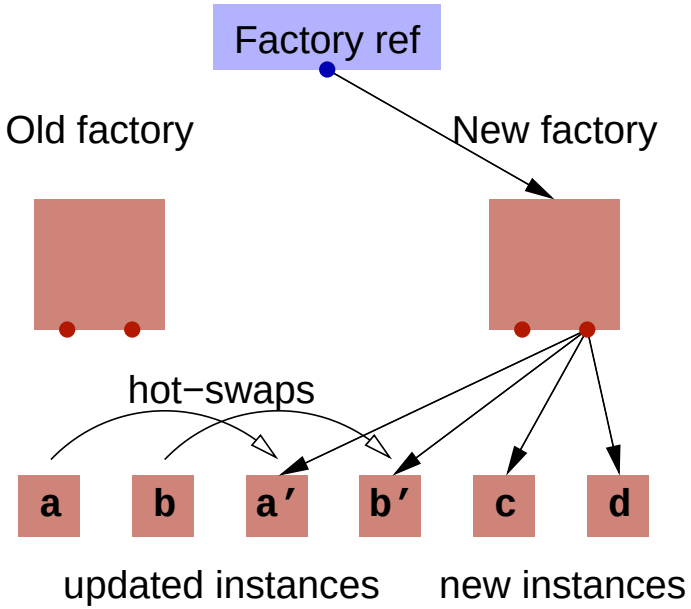
② Instantiate a new factory for the updated class



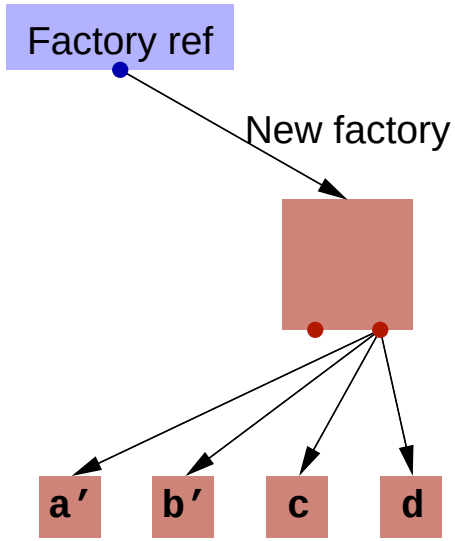
③ Hot-swap old factory with its replacement (transferring set of instances)



④ New instantiations handled by the updated factory



⑤ Hot-swap each old instance to updated replacement (in parallel on each CPU)



⑥ Destroy old factory

EXPERIENCES

Example updates applied (actual developer changes):

- ➜ New kernel API for partitioned memory region
  - ✓ Adds new functionality to kernel
- ➜ Fix for memory allocator race condition
  - ✓ Adds lock and locking code to crucial kernel object
- ➜ File cache manager optimisation for *unmapPage*
  - ✓ Affects each open file instance, demonstrating factory mechanism

RESULTS

Microbenchmarks for creation cost using factories:

object	*overhead*
dummy	12%
file	5.6%
process	0.73%

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- ➜ No noticeable performance degradation on system throughput, as measured by a version of SPEC SDET

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Other results:

- ➜ No noticeable performance degradation on system throughput, as measured by a version of SPEC SDET
- ➜ Update time significant, 20ms to update 100 dummy objects
  - ➜ Implementation not yet optimised
  - ✓ System still responsive & usable during update

Open Issues & Future Work

- Performance: hot-swapping not optimised for concurrent swaps
- Updates affecting multiple address spaces: requires central service to track factories and coordinate updates
- Timeliness of updates: plan to add completion notification, and investigate lazy updating
- Changes to interfaces: would require mechanism to locate potential callers of an object, and atomic hot-swaps of multiple objects

Related Work

- ➜ Existing dynamic update systems for application software
  - ✗ rely on run-time language or system support
- ➜ Commercial OS features, Solaris Live Upgrade
  - ✓ Changes can be tested without affecting system
  - ✗ Requires reboot
- ➜ Restart services in component- or microkernel-based system
  - ✗ Still suffers downtime
- ➜ Modify extensible operating systems
  - ✗ Limited to those parts with hooks for extensibility
  - ✗ Not applicable to commodity operating systems
- ➜ Nooks supports recovery and restart of drivers
  - ✗ Not as applicable to other parts of OS
  - ✗ Shadows would have high performance overhead

CONCLUSION

Our system can apply updates affecting code and data to a running kernel

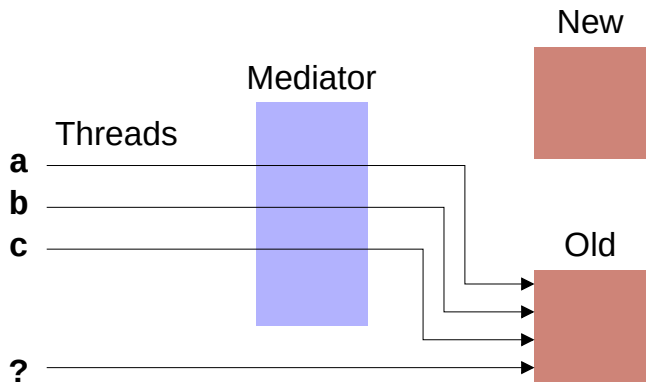
- ✓ Negligible performance impact
- ✓ Applicable to a mainstream OS

THE END

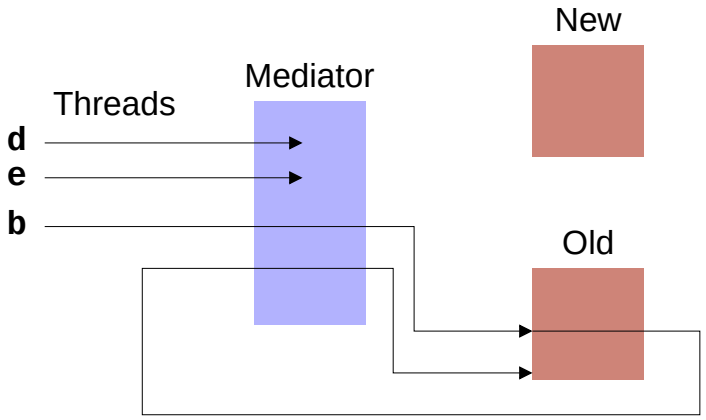
Questions?

HOT-SWAPPING IMPLEMENTATION

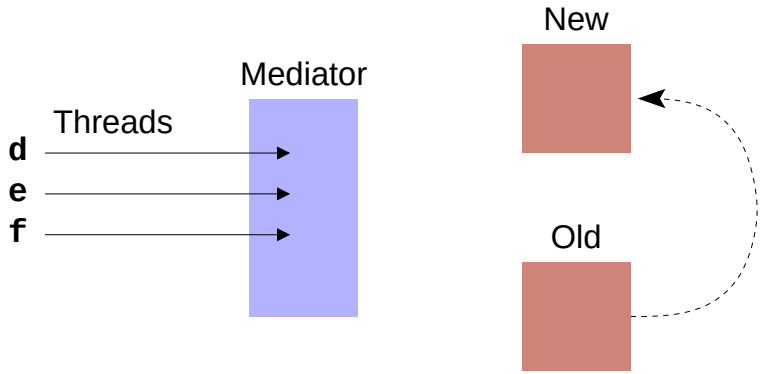
① Prior to hot-swap, an object is invoked by multiple threads



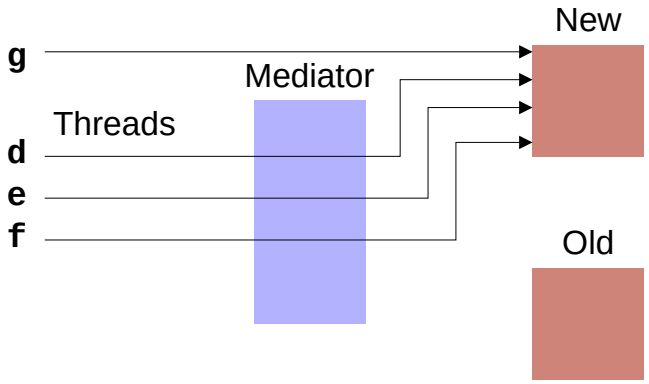
② A mediator object is interposed and tracks calls to the object (via object translation table)



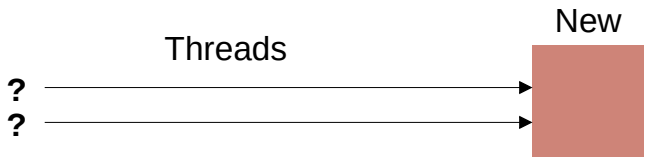
③ Once existing calls have completed, the mediator blocks new calls and waits for tracked calls to complete



④ Object is quiescent, state is transferred



⑤ Mediator updates the object reference and forwards blocked calls



⑥ Mediator and old object are destroyed