Run-Time Support for Optimizations Based on Escape Analysis

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Escape Analysis for the Java HotSpot™ VM

- Detection of method-local/thread-local objects
  - Scalar replacement of fields
  - Stack allocation
  - Synchronization removal
- Interprocedural analysis
  - Inlining decisions
  - Stack allocation of parameters
  - Removal of synchronization on return value
Example

```java
static void draw(Shape shape) {
    Color color = new Color(0x6699ff);
    shape.stroke = new BasicStroke();
    Figure figure = new Figure(shape, color);
    figure.draw();
}

final synchronized void draw() {
    Canvas canvas = getCanvas();
    canvas.render(this);
}
```
Example

```java
static void draw(Shape shape) {
    Color color = new Color();
    color.rgb = 0x6699ff;
    shape.stroke = new BasicStroke();
    Figure figure = new Figure();
    figure.shape = shape;
    figure.rgb = color.rgb;
    synchronized (figure) {
        Canvas canvas = getCanvas();
        canvas.render(figure);
    }
}
```
Example

```java
static void draw(Shape shape) {
    int rgb = 0x6699ff;
    shape.stroke = new BasicStroke();
    Figure figure = new Figure(); // on the stack
    figure.shape = shape;
    figure.rgb = rgb;

    Canvas canvas = getCanvas();
    canvas.render(figure);
}
```
Run-Time Support

- Card marking
  - Extended write barrier
- Garbage collection
  - Pointers in stack objects
- Deoptimization
  - Reallocation and relocking
  - Debugging information
Write Barriers

```java
static void draw(Shape shape) {
    int rgb = 0x6699ff;
    shape.stroke = new BasicStroke();
    Figure figure = new Figure(); // on the stack
    figure.shape = shape;
    figure.rgb = rgb;
    Canvas canvas = getCanvas();
    canvas.render(figure);
}
```

```assembly
shr  eax, 9
sub  eax, firstIndex
cmp  eax, arraySize
jae  label
mov  byte ptr [eax+arrayBase], 0
label:  ...
```
static void draw(Shape shape) {
    int rgb = 0x6699ff;
    shape.stroke = new BasicStroke();
    Figure figure = new Figure(); // on the stack
    figure.shape = shape;
    figure.rgb = rgb;
    Canvas canvas = getCanvas();
    canvas.render(figure);
}

void do_oop(oop obj) {
    if (is_in_heap(obj)) {
        wrapped_closure.do_oop(obj);
    } else if (!obj.has_been_scanned()) {
        obj.set_has_been_scanned();
        obj.iterate_oop_fields(this);
    }
}
static void draw(Shape shape) {
    int rgb = 0x6699ff;
    shape.stroke = new BasicStroke();
    Figure figure = new Figure(); // on the stack
    figure.shape = shape;
    figure.rgb = rgb;
    Canvas canvas = getCanvas();
    canvas.render(figure);
}
Deoptimization

- Upon class loading
  - Identify dependent methods
  - Patch machine code for lazy deoptimization
  - Reallocate and relock stack objects
- Lazy deoptimization
  - Reallocate and relock scalar-replaced objects
  - Set up interpreter frame
- Continue execution in interpreter
Reallocation of Stack Objects
Reallocation of Stack Objects
Information for GC and Deoptimization

- Oop maps
  - Location of root pointers
  - Registration of stack objects
- Method dependencies
  - Use of interprocedural escape information
- Debugging information
  - Local variables and operand stack
  - Type and field values of scalar-replaced objects
  - Position of stack objects
  - Objects for which synchronization was removed
Conclusions

- Abstraction from stack objects
  - Extended write barrier
  - Wrapper for oop closures
- Debugging information
  - Representation of optimized objects
- Deoptimization
  - Reallocation and relocking
  - Lazy reallocation of scalar-replaced objects
- Implemented in production system