Callability Control

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Conventions

We will consider C♯ (or other .Net or JVM languages), since it

- is statically-typed,
- supports named/identifiable functions (e.g. static/instance methods and constructors),
- supports dynamic dispatch (with interfaces, virtual methods, etc.),
- supports dynamic code loading, and
- supports dynamic function lookup and invocation (with reflection).

For brevity I will omit accessibility modifiers and allow free standing static functions.

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interface I { void Run(); }
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3. How about this?

```
static void M3(String url) {
  // Load code (possibly from the internet)
  Assembly code = Assembly.LoadFrom(url);
  code.GetMethod("M").Invoke(null, null); } // call M()
```

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Restatement of the Problem:

1. What is the callability of `Sign`? (Where `Sign` is a static method.)
2. What is the callability of `x.Run`? (Where `x` is of an interface type `I`.)
3. What is the callability of `M`? (Where `M` was a dynamically loaded static-method.)

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1. $g \in Calls(f) \Rightarrow f \rightsquigarrow g$, i.e. f is annotated with `calls[ ... ,g, ... ]`.

   Example:
   ```
   static void Write(String s) calls[WriteChar] {
       foreach (Char c in s) WriteChar(c); }
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2. $(\forall h \in Calls(g) \bullet f \rightsquigarrow h) \Rightarrow f \rightsquigarrow g$, i.e. if f can call every function in the `calls[ ... ]` annotation of g.

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   ```
   static void WriteLine(String s) calls[WriteChar] {
       Write(s + "\n"); }
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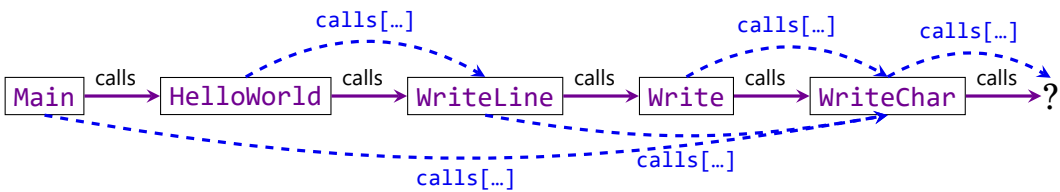
The previous rules apply transitively, and always allow for recursive calls.

Example:
```
static void HelloWorld() calls[WriteLine] {
    WriteLine("Hello World!"); }
static void Main(String[] args) calls[WriteChar] {
    HelloWorld(); }
```



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```

2. `Restricted` can only be directly called by functions who name it in their `calls`:

```
static Object Restricted(String op, params Object[] args)
  calls[Restricted];
```

   Example:
```
static void WriteChar(Char c) calls[Restricted] {
          Restricted("CCall", "putchar", c); }
```

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3. also (indirectly) perform *any* `Restricted` operation:
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Consider this:

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interface I<'a> { void Run() calls['a]; }
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Example:

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class HelloWorld: I<[WriteLine]> {
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2. Also print lines to standard-output:
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2. Also print lines to standard-output:
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   static void M2(I<[WriteLine]> x) calls[WriteLine] { x.Run(); }
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3. Perform any `Restricted` operation:
   ```
   static void M3(I<[Restricted]> x) calls[Restricted] { x.Run(); }
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3. Perform any `Restricted` operation:
   ```
   static void M3(I<[Restricted]> x) calls[Restricted] { x.Run(); }
   ```
4. Defer the decision to the caller of `M3`:
   ```
   static void M3<'a>(I<['a]> x) calls['a] { x.Run(); }
   ```

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In C♯ to dynamically invoke a static or instance method, you simply write:

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For our system to be sound, we could declare `Invoke` like this:

```
/// Represents a method m
class MethodInfo {
  …
  /// Throws an exception if Invoke<'a> ↛ m,
  /// otherwise calls receiver.m(args)
  Object Invoke<'a>(Object receiver, Object[] args) calls['a] { … }
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```

```
static void M3(String url) {
  // Load code (possibly from the internet)
  Assembly code = Assembly.LoadFrom(url);
  // call M(), but only if it can only perform Unrestricted operations
  code.GetMethod("M").Invoke<[]>(null, null); }
```

Conclusion

1. No need to look at the body of methods to determine what they can do.
2. No need to look at *every* piece of code we are compiling with.
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Future Work

- Make our annotations less verbose:
  - Infer `calls` annotations?
  - Support wild-cards?
  - Allow named groups of functions?
- Support sound reasoning about unsafe operations (like executing arbitrary machine code).
- Improve support for dynamic code loading:
  - Allow calling newly loaded functions, even if they have themselves in their `calls` annotation.
- Formalise the reasoning properties we want from our system:
  - Prove them!