An encoding of Any for Leon

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Motivation

```
def reverse(lst: Any): Any = {
  if (lst == Nil()) Nil()
  else reverse(lst.tail) ++ Cons(lst.head, Nil())
} ensuring (_.contents == lst.contents)

def reverseReverseIsIdentity(lst: Any) = {
  reverse(reverse(lst)) == lst
}.holds
```

Implementation

```scala
case class Box(value: Int)

def double(x: Any): Any = x match {
    case n: Int => n * 2
    case Box(n) => Box(n * 2)
    case _      => x
}

double(42)
```

Example

```scala
sealed abstract class Any1
case class Any1Int(value: Int) extends Any1
case class Any1Box(value: Box) extends Any1

def double(x: Any1): Any1 = x match {
    case Any1Int(n)       => Any1Int(n * 2)
    case Any1Box(Box(n)) => Any1Box(Box(n * 2))
    case _                => x
}

double(Any1Int(42))
```

Declare constructors

Rewrite functions types to replace Any with Any1

Rewrite pattern matches to peel the constructors off

Lift expressions into Any1

Extract implicit classes as case classes

Add extension methods to Any

```scala
sealed abstract class Expr
case class Lit(n: Int)              extends Expr
case class Add(l: Expr, r: Expr) extends Expr

abstract class Any1
case class Any1Expr(value: Expr) extends Any1
case class Any1Int(value: Int)   extends Any1
```

Rewrite functions types

```scala
def id(x: Any): Any = x

case class Box(value: Any) {
    def map(f: Any => Any): Box = Box(f(value))
    def contains(other: Any): Boolean = value == other
}
```

```
def id(x: Any1): Any1 = x

case class Box(value: Any1) {
    def map(f: Any1 => Any1): Box = Box(f(value))
    def contains(other: Any1): Boolean = value == other
}
```

```
def id(x: Any1): Any1   = x
def toAny(x: Int): Any1 = x

def double(x: Any1): Any1 = x match {
  case i: Int     => x * 2
  case b: Boolean => !b
  case _          => x
}
```

Lift expressions

```scala
def id(x: Any1): Any1    = x
def toAny(x: Int): Any1 = Any1Int(x)

def double(x: Any1): Any1 = x match {
  case i: Int     => Any1Int(i * 2)
  case b: Boolean => Any1Boolean(!b)
  case _          => x
}
```

Rewrite pattern matches

```
def double(x: Any1): Any1 = x match {
  case Any1Int(i: Int)          => Any1Int(i * 2)
  case Any1Boolean(b: Boolean) => Any1Boolean(!b)
  case _                        => x
}
```

```scala
@library
implicit class BooleanOps(val underlying: Boolean) {
  def holds : Boolean = {
    assert(underlying)
    underlying
  }
  def ==> (that: Boolean): Boolean = {
    !underlying || that
  }
}
```

Extract implicit classes

```scala
@library
case class BooleanOps(underlying: Boolean) {
  def holds: Boolean = {
    assert(underlying)
    underlying
  }
  def ==> (that: Boolean): Boolean = {
    !underlying || that
  }
}

@library
def BooleanOps(x: Boolean): BooleanOps = BooleanOps(x)
```

Add extension methods to Any

```scala
@library
implicit class Any1Ops(val lhs: Any) {
  def *(rhs: Any): Any = (lhs, rhs) match {
    case (l: Int, r: Int)       => l * r
    case (l: BigInt, r: BigInt) => l * r
    case (l: String, r: BigInt) => l repeat r
    case _                      =>
      error[Any]("operation not supported")
  }
}
```

Limitations

Because child types must form a simple bijection with parent class type, it is currently impossible to synthesize constructors for polymorphic type such as `Option[T]`:

```
abstract class Any1
case class Any1Option[T](x: Option[T]) extends Any1
```

Structural types parametrized by Any

Because ADTs cannot contain recursive references through non-structural types such as `Set`, it is currently impossible to define types such as:

```
abstract class Any1
case class Any1SetAny(value: Set[Any1]) extends Any1
```

Hack

Mutable types

```
id.setType(Any1Type)
```

Current implementation mutates `Identifiers` type.

Only meant as a temporary hack, will be fixed soon.

What's left?

Preconditions

Currently not possible to write:

```
def reverse(lst: Any): Any = {
  require(lst.isInstanceOf[List])
  if (lst == Nil()) Nil()
  else reverse(lst.tail) ++ Cons(lst.head, Nil())
} ensuring (_.size == lst.size)
```

Can't handle this in translation to Z3:
require(lst.isInstanceOf[Any1List])

Without those preconditions, counter-examples are yielded for postconditions.

Implicit case classes show up as counter-examples, which is something we might not want.

Other applications

Type inference for uni-typed programs

Type inference for uni-typed programs

Port theorems from ACL2 to Leon

Thank you