QUICK! Check your Properties

(Random Testing on .Net with FsCheck)

`fscheck.github.io/`**`FsCheck`** | `github.com/pblasucci/`**`quickpbt`**

TODAY'S AGENDA

- ✓ *Introduction*
- ✓ Common Patterns
- ✓ Diagnostics
- ✓ Input Control
- ✓ Data Generation*
- ✓ Conclusion

RANDOM TESTING

“**Properties** are **described as** … **functions**, and can be **automatically tested on random input**… [or] custom test data generators.”

– *Claessen*, *Hughes* *(ICFP'00)*

FROM EXAMPLE TESTING... *TO PROPERTY TESTING*

```
[<Fact>]
let ``days should equal hours`` () =
  let today = Date.Now // NOTE: hard-coded value
  let days  = today + Time.FromDays(daysInAWeek)
  let hours = today + Time.FromHours(hoursInAWeek)

  Assert.Equal(days, hours)
```

```
TEST EXECUTION SUMMARY
Tests run: 1, Errors: 0, Failed: 0, Ignored: 0

✔  days should equal hours
    OK, Elapsed time: 0.0527666s
```

```
[<Property>]
let ``plus ignores unit of time`` (anyDate :Date) =
  // NOTE: lots of different, random values
  let days  = anyDate + Time.FromDays(daysInAWeek)
  let hours = anyDate + Time.FromHours(hoursInAWeek)

  days = hours
```

```
TEST EXECUTION SUMMARY
Tests run: 1, Errors: 0, Failed: 0, Ignored: 0

✔  plus ignores unit of time
    OK, Passed 100 tests
```

DOMAIN UNDER TEST

F#

```fsharp
type Date = System.DateTimeOffset
type Time = System.TimeSpan
type Zone = System.TimeZoneInfo
```

VB

```vb
Imports Dated = System.DateTimeOffset
Imports Timed = System.TimeSpan
Imports Zoned = System.TimeZoneInfo
```

C#

```csharp
using Date = System.DateTimeOffset;
using Time = System.TimeSpan;
using Zone = System.TimeZoneInfo;
```

PATTERNS: *Interchange & Invariance*

```
// interchange ... the property by which the order of two or more actions does not affect the outcome
public bool adding_and_changing_zone_can_be_reordered(Date anyDate, PositiveInt total) {
  var days = Time.FromDays((int) total);
  var addThenShift = Zone.ConvertTimeBySystemTimeZoneId(anyDate + days, CentralEuroTime);
  var shiftThenAdd = Zone.ConvertTimeBySystemTimeZoneId(anyDate, CentralEuroTime) + days;

  return addThenShift == shiftThenAdd;
}


// invariance ... the property by which something remains constant, despite action being taken
public bool adding_does_not_change_the_date_offset(Date anyDate, PositiveInt months) {
  var offset = anyDate.Offset;
  var shifted = anyDate.AddMonths((int) months);

  return shifted.Offset == offset;
}
```

PATTERNS: *Inversion & Idempotence*

```
' inversion ... the property by which one action “undoes” the work of another action
Public Function AddingAndSubtractingDaysAreInverses(anyDate As Dated, total As PositiveInt) As Boolean
  Dim days = Timed.FromDays(CInt(total))

  Return (anyDate + days) - days = anyDate
End Function


' idempotence ... the property of an action having the same effect no matter how many times it occurs
Public Function TakingTimeDurationIsIdempotent(anyTime As Timed) As Boolean
  Dim once = anyTime.Duration()
  Dim twice = anyTime.Duration().Duration()

  Return once = twice
End Function
```

DIAGNOSTICS: *Labelling Properties*

```
public bool zone_conversion_is_not_affected_by_detours (Date anyDate, Zone zone1, Zone zone2){
  var viaZone1 = Zone.ConvertTime(Zone.ConvertTime(anyDate, zone1), zone2);
  var directly = Zone.ConvertTime(anyDate, zone2);
  return (viaZone1 == directly)                    // same date
      && (directly.Offset == zone2.BaseUtcOffset); // same shift
}
```

```
TEST EXECUTION SUMMARY

Tests run: 1, Errors: 0, Failed: 1, Ignored: 0

✘  zone_conversion_is_not_affected_by_detours

    Falsifiable, after 4 tests (5 shrinks), (StdGen (199662269,296213481))

    Original: (1948-04-19 16:18:52 +04:59, (UTC+04:00), (UTC-05:00))
    Shrunk:   (1948-04-19 00:00:00 +00:00, (UTC+04:00), (UTC-05:00))
```

DIAGNOSTICS: *Labelling Properties*

```
public bool zone_conversion_is_not_affected_by_detours(Date anyDate, Zone zone1, Zone zone2) {
  var viaZone1 = Zone.ConvertTime(Zone.ConvertTime(anyDate, zone1), zone2);
  var directly = Zone.ConvertTime(anyDate, zone2);
  bool sameDate () => (viaZone1 == directly);
  bool sameShift() => (directly.Offset == zone2.BaseUtcOffset);
  return sameDate ().Label($"Same Date?  ({viaZone1} = {directly})")
    .And(sameShift().Label($"Same Shift? ({zone2.BaseUtcOffset} = {directly.Offset})"));
}
```

```
TEST EXECUTION SUMMARY

Tests run: 1, Errors: 0, Failed: 1, Ignored: 0


✘  zone_conversion_is_not_affected_by_detours

    Falsifiable, after 4 tests (5 shrinks), (StdGen (199662269,296213481))

    Label of failing property: Same Shift? (03:00:00 = 02:28:00)

    ...
```

DIAGNOSTICS: *Labelling Properties*

```
public bool zone_conversion_is_not_affected_by_detours(Date anyDate, Zone zone1, Zone zone2) {
  var viaZone1 = Zone.ConvertTime(Zone.ConvertTime(anyDate, zone1), zone2);
  var directly = Zone.ConvertTime(anyDate, zone2);
  bool sameDate () => (viaZone1 == directly);
  bool sameShift() => (directly.Offset == zone2.GetUtcOffset(directly));
  return sameDate ().Label($"Same Date?  ({viaZone1} = {directly})")
    .And(sameShift().Label($"Same Shift? ({zone2.BaseUtcOffset} = {directly.Offset})"));
}
```

```
TEST EXECUTION SUMMARY

Tests run: 1, Errors: 0, Failed: 1, Ignored: 0

✔ zone_conversion_is_not_affected_by_detours

    OK, Passed 100 tests
```

DIAGNOSTICS: *Gathering Observations*

```
// trivial observation partitions data into two buckets
let ``trivial daylight savings support``
  (aDate :Date)
  (aZone :Zone)
  (NonNegativeInt total) =
    let days = Time.FromDays(total)
    let addShift = Zone.ConvertTime(aDate + days,aZone)
    let shiftAdd = Zone.ConvertTime(aDate,aZone) + days

    (addThenShift = shiftThenAdd)
    |> Prop.trivial anyZone.SupportsDaylightSavingTime
```

TEST EXECUTION SUMMARY

```
Tests run: 1, Errors: 0, Failed: 1, Ignored: 0

✔ trivial daylight savings support
    OK, Passed 100 tests
    53% true
    47% false
```

DIAGNOSTICS: *Gathering Observations*

```
' classification partitions into N, labelled buckets
Public Function ClassifyMeridianPosition(
  aDate As Dated,
  aZone As ZOned,
  total As NonNegativeInt
) As [Property]
  Dim days = Timed.FromDays(CInt(total))
  Dim addShift = Zoned.ConvertTime(aDate + days, aZone)
  Dim shiftAdd = Zoned.ConvertTime(aDate, aZone) + days
  Return (addShift = shiftAdd)_
         .Classify(aDate.Offset < Timed.Zero, "< GMT")_
         .Classify(aDate.Offset = Timed.Zero, "|GMT|")_
         .Classify(aDate.Offset > Timed.Zero, "GMT <")
End Function
```

```
TEST EXECUTION SUMMARY

Tests run: 1, Errors: 0, Failed: 1, Ignored: 0


✔  ClassifyMeridianPosition

    OK, Passed 100 tests

    55% GMT <
    43% < GMT
     2% |GMT|
```

DIAGNOSTICS: *Gathering Observations*

```
// instead of a boolean data, collect reports any value
public Property collect_weekday_name(
  Date aDate,
  Zone aZone,
  NonNegativeInt total
){
  var days = Time.FromDays((int) total);
  var addShift = Zone.ConvertTime(aDate + days, aZone);
  var shiftAdd = Zone.ConvertTime(aDate, aZone) + days;
  return (addShift == shiftAdd)
         .Collect(anyDate.DayOfWeekName());
}
```

```
TEST EXECUTION SUMMARY

Tests run: 1, Errors: 0, Failed: 1, Ignored: 0


✔  collect_weekday_name

   OK, Passed 100 tests

   20% Monday
   19% Saturday
   17% Sunday
   14% Tuesday
   13% Thursday
    9% Friday
    8% Wednesday
```

DIAGNOSTICS: *Gathering Observations*

```
// observations may be combined as much as is desired
let ``many observations combined``
  (aDate :Date)
  (aZone :Zone)
  (NonNegativeInt total) =
    let days = Time.FromDays(total)
    let addShift = Zone.ConvertTime(aDate + days,aZone)
    let shiftAdd = Zone.ConvertTime(aDate,aZone) + days

  (addThenShift = shiftThenAdd)
    |> Prop.trivial  anyZone.SupportsDaylightSavingTime
    |> Prop.classify (aDate.Offset < Time.Zero) "< GMT"
    |> Prop.classify (aDate.Offset = Time.Zero) "|GMT|"
    |> Prop.classify (aDate.Offset > Time.Zero) "GMT <"
    |> Prop.collect  (weekdayName anyDate)
```

```
TEST EXECUTION SUMMARY

Tests run: 1, Errors: 0, Failed: 1, Ignored: 0


✔ many observations combined

   OK, Passed 100 tests

   8% Saturday,  GMT <, trivial
   8% Monday,    < GMT
   7% Sunday,    GMT <, trivial
   5% Friday,    < GMT, trivial
   5% Wednesday, GMT <
   5% Tuesday,   < GMT
   2% Thursday,  < GMT
   1% Monday,    |GMT|, trivial
   …
```

Input Control: *Conditional Properties*

```
' naive test fails (because the range of inputs is too broad)
Public Function DaylightSavingsTestOracle(anyDate As Dated) As Boolean
  ' NOTE: this test also demonstrates the common pattern of the "test oracle" pattern
  Dim eastern   = Zoned.FindSystemTimeZoneById(ZoneName)
  Dim eastDate  = Zoned.ConvertTime(anyDate, eastern)

  Return Zone.InUnitedStatesDaylightTime(eastDate) = eastern.IsDaylightSavingTime(eastDate)
End Function
```

```
TEST EXECUTION SUMMARY

Tests run: 1, Errors: 0, Failed: 1, Ignored: 0


✘  DaylightSavingsTestOracle

    Falsifiable, after 1 test (4 shrinks), (StdGen (2119435949,296213433))

    Original: 1908-04-23 23:48:57 -04:02
    Shrunk:   1908-04-23 00:00:00 +00:00
```

Input Control: *Conditional Properties*

```
' naive test fails (because the range of inputs is too broad)
Public Function DaylightSavingsTestOracle(anyDate As Dated) As Boolean
  Dim eastern   = Zoned.FindSystemTimeZoneById(ZoneName)
  Dim eastDate  = Zoned.ConvertTime(anyDate, eastern)

  Dim check = Function() Zone.InUnitedStatesDaylightTime(eastDate)
  Return check().When(anyDate.Year >= 2007 AndAlso eastern.IsDaylightSavingTime(eastDate))
End Function
```

```
TEST EXECUTION SUMMARY

Tests run: 1, Errors: 0, Failed: 1, Ignored: 0

✔  DaylightSavingsTestOracle

    OK, Passed 100 tests
```

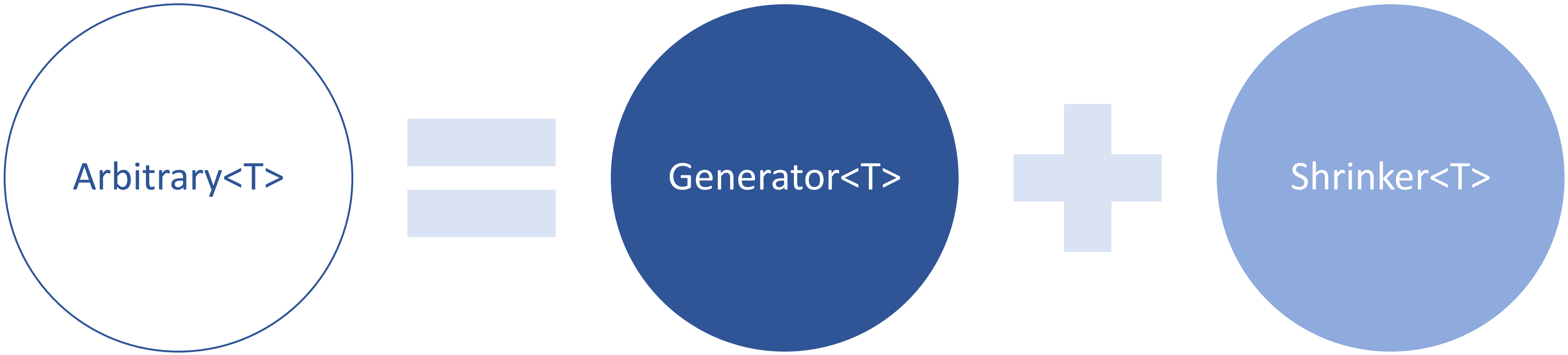
Input Control: *Universal Quantifiers*

```fsharp
// instead of a conditional property, here we use a IArbitrary with a "universal quantifier"
let ``zone is unchanged through round-trip serialization`` () =
  // define a simple test
  let check (zone :Zone) =
     let deflated = zone.ToSerializedString() in Zone.FromSerializedString(deflated) = zone

  // arbitrary generators can be easily defined
  let zones = Zone.GetSystemTimeZones() |> Gen.elements |> Arb.fromGen

  // "for all" zones, run a test...
  Prop.forAll zones (fun z -> lazy (check z))
```

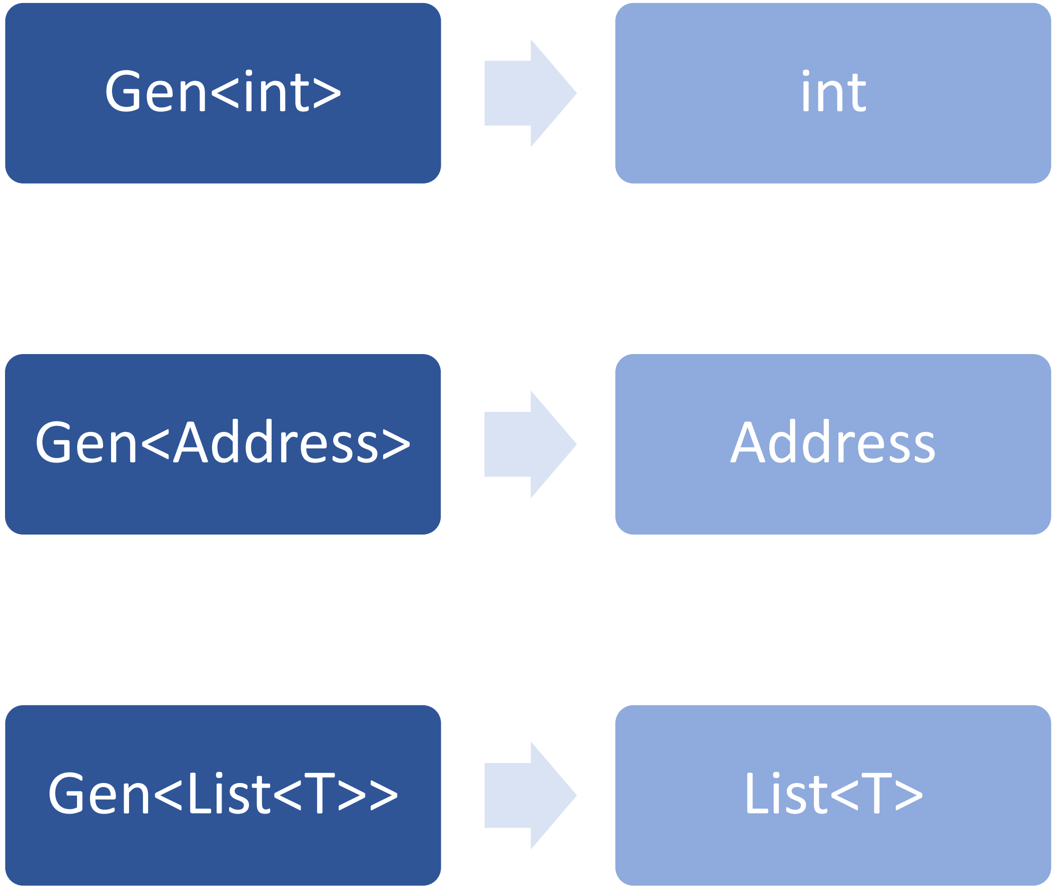
CUSTOM DATA GENERATION



Arbitrary<T> = Generator<T> + Shrinker<T>

CUSTOM DATA GENERATION

Generators



Gen<int>

int

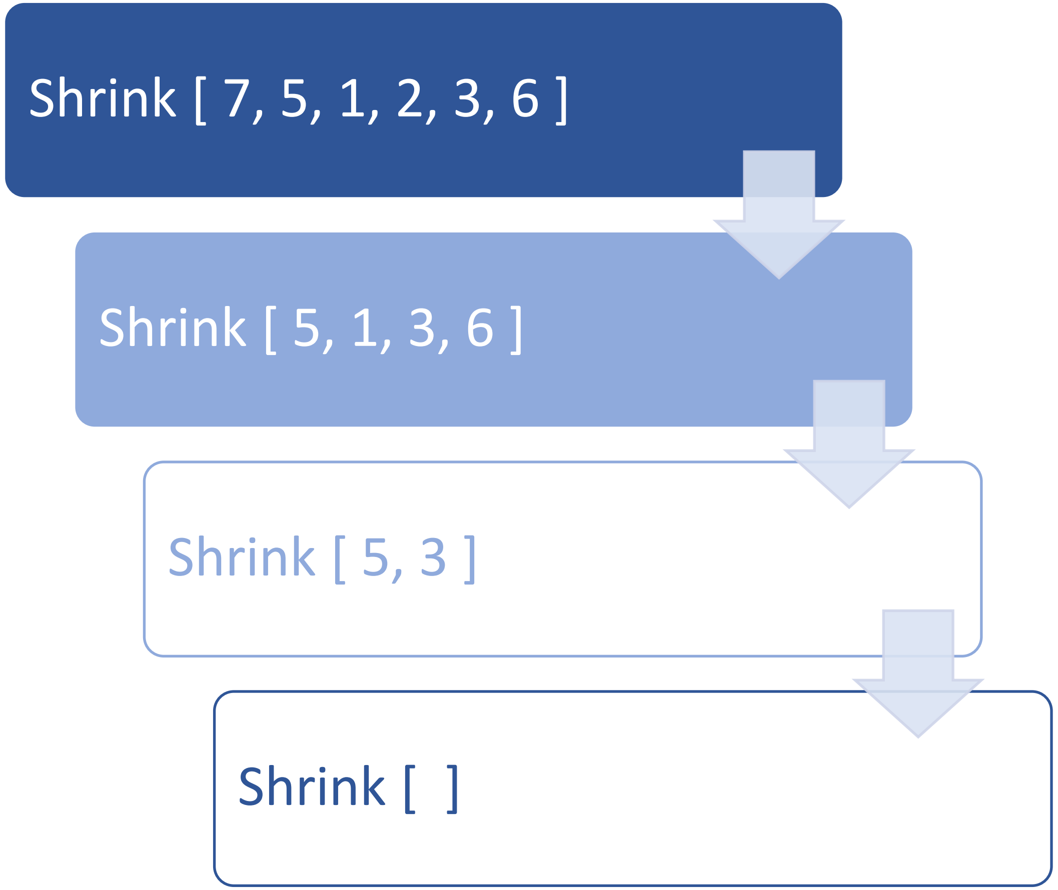
Gen<Address>

Address

Gen<List<T>>

List<T>

Shrinkers



Shrink [7, 5, 1, 2, 3, 6]

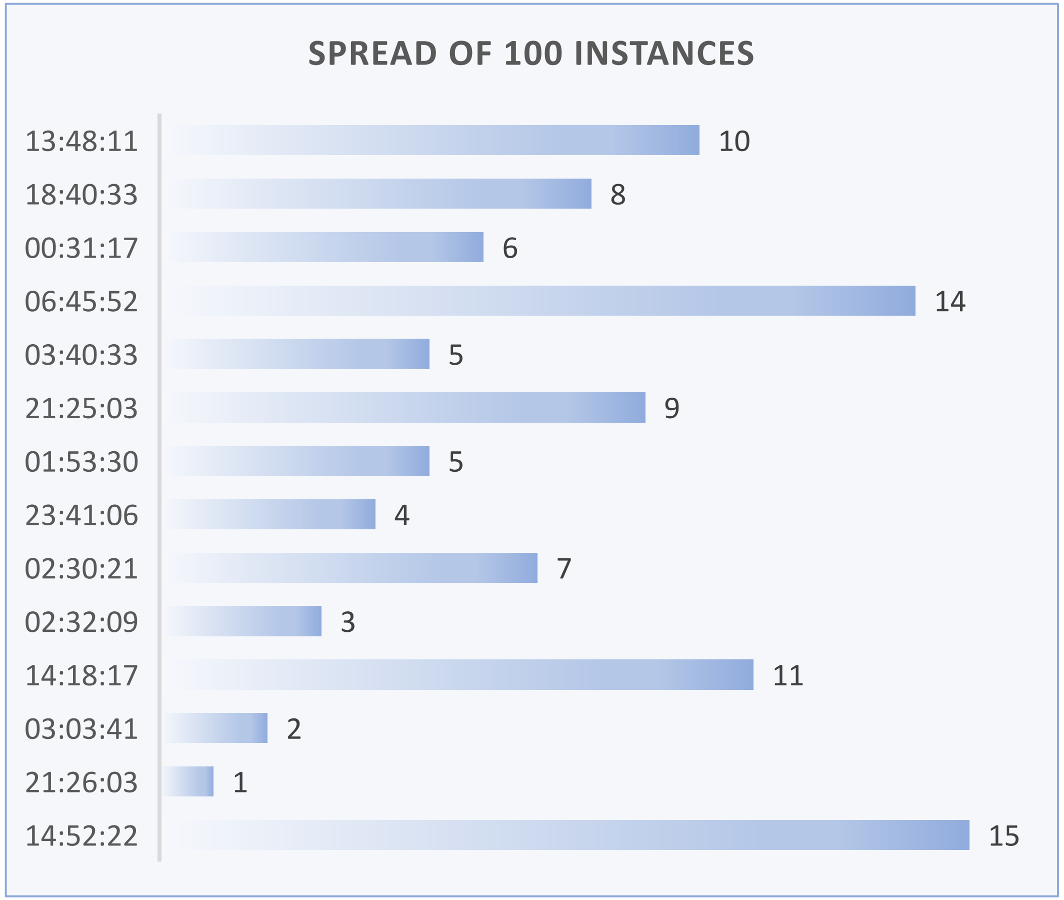
Shrink [5, 1, 3, 6]

Shrink [5, 3]

Shrink [ ]

DATA GENERATION: *Arb with Gen & Shrinker*

```
/// encapsulates several IArbitrary instances
type Generator =
  /// generates PositiveTime instances
  static member PositiveTime =
    let inline isPositive t = Time.Zero < t
    Arb.fromGenShrink
      ( // generator
        Arb.generate<Time>
        |> Gen.where isPositive
        |> Gen.map positiveTime
      , // shrinker
        (fun (PositiveTime t) ->
            Arb.shrink t
            |> Seq.where isPositive
            |> Seq.map positiveTime) )
```

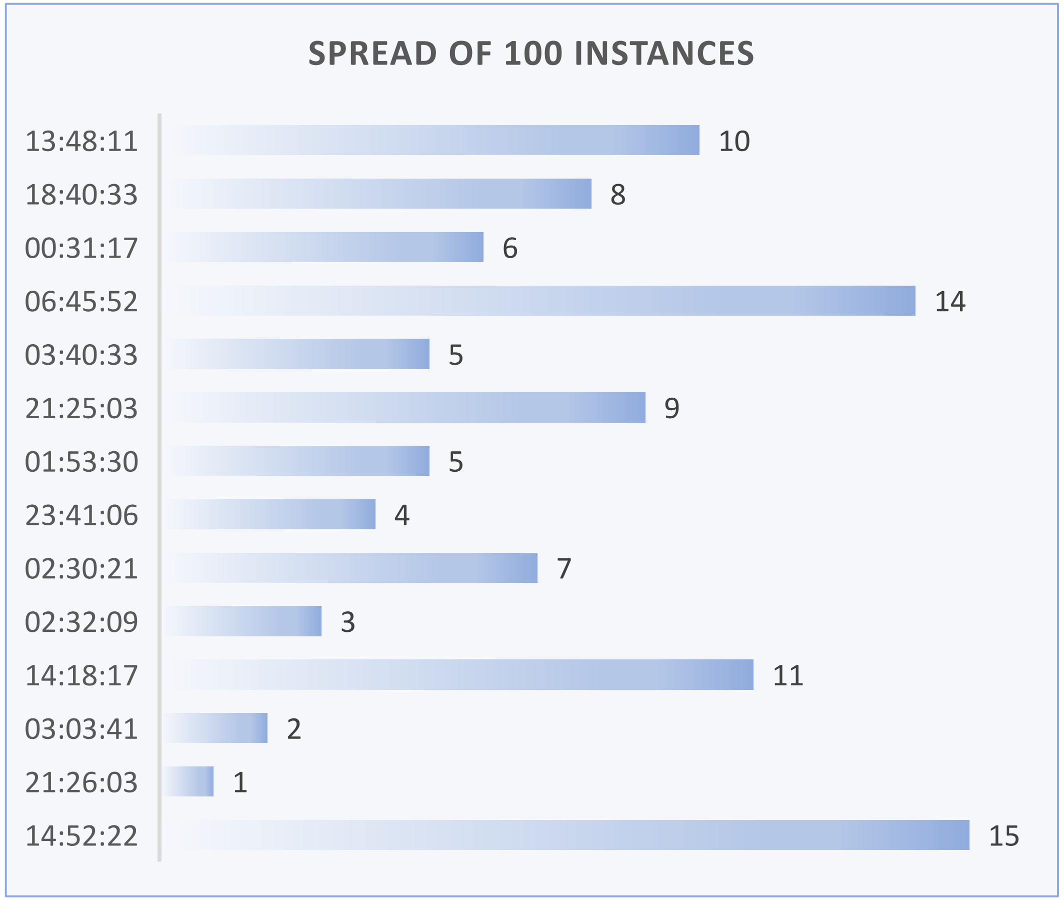


DATA GENERATION: *Arb with Gen & Shrinker*

```
/// a time value which is always greater then zero
/// (note: only meant for use with FsCheck)
type PositiveTime = private PosTime of Time

/// returns a new PositiveTime instance,
/// throwing an exception on values less than zero
let positiveTime value =
  if value <= Time.Zero then
    invalidArg "value" "value must be greater than 0"
  PosTime value

/// extracts the TimeSpan from a PositiveTime instance
let (|PositiveTime|) (PosTime value) = value
```



RANDOM TESTING

“One of the major advantages… is that it **encourages** us to formulate **formal specifications**, thus **improving** our **understanding**…”

– *Claessen, Hughes (ICFP'00)*