

# A beginner-friendly environment for exploring error messages in the Clojure programming language.

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# Clojure Language and Syntax

## What is Clojure?

- Clojure is a part of the Lisp language family
  - prefix notation (operators before operands)
  - expressions are surrounded by parentheses

Example: `(/ 9 3)` denotes 9 divided by 3

- Clojure is an interpreted language
- It's implemented in Java and runs on the Java Virtual Machine (JVM) interpreter

Clojure code → Java code → JVM bytecode → executed on JVM

# Clojure Language and Syntax

## Clojure's REPL

- Interactive environment for code evaluation
- Read → Evaluate → Print → Loop (REPL)

```
Clojure 1.11.4
user=> (count [-1 0 1])
3
user=>
```

# Clojure's Error Messages

## Clojure Exceptions

- All exceptions in Clojure are Java exceptions
- Clojure syntax errors will also result in an exception

## Error Messages

- Generate when an exception occurs
- Provide error type, cause, and location

# Clojure's Error Messages

## Anatomy of a Clojure Error Message

```
=> (/ 9 0)
```

```
Execution error (ArithmeticException) at user/eval1  
(REPL:1).
```

Divide by zero

- `ArithmeticException`: The type of error that occurred
- `user/eval1 (REPL:1)`: The location where the error happened (in this case, REPL, line 1)
- `Divide by zero`: The description of the error's cause

# Motivation

- UMN Morris has been teaching functional languages first (Scheme, Racket) to students for over 30 years
- Historically done at other major institutions, including MIT
- This practice has many pedagogical benefits
- Clojure is good to learn due to its popularity and widespread industry use, but has flaws in its presentation of error messages

# Goals of Babel

- Designed to be an interactive, beginner-friendly tool for understanding error data in Clojure
- Simplifies error messages to be more intuitive, removing jargon and clutter
- Utilizes tools to make Clojure errors more descriptive and detailed for formatting messages



## Current State of Babel

- Our group began working after error replacement was largely achieved
- Present goals include exploring more interactive, IDE-like tools that integrate with Babel
- Need the capacity to support testing and usability
- Lots of refactoring work is being done to support this, as well as refining Babel itself

# Motivation and Goals

## Example

Consider the error produced by the form below. What does it mean?

```
=> (count 1)
```

```
Execution error (UnsupportedOperationException) at  
user/eval1529 (REPL:1).
```

```
count not supported on this type: Long
```

## On Clojure *spec*

Babel is based on an existing Clojure library called *spec*:

- Allows specifying requirements on arguments of functions
- Requirements are predicates: can check argument types, count, values, etc.
- We bind specs to core Clojure functions
- If requirements aren't met then a *spec* error happens
- Error reports from *spec* are more detailed than native Clojure error messages

# Overview

Babel tool:

- Replaces native Clojure error messages
- Messages produced by Babel broadly fall into two types:

Spec errors:

- Babel uses *spec* to specify conditions on Clojure functions
- *spec* provides information to make error messages more precise

Non-spec errors:

- When *spec* cannot be provided, e.g. syntax errors, regex is used to identify error messages
- We use a dictionary to rephrase these errors

# Usage

- Launching a REPL server in the Babel repository allows the tool to “hook” to it
- Babel can report errors on a loaded Clojure file
- Babel catches Clojure errors, including our *spec* reports
- Error messages are replaced with modified ones
- Currently only supports REPL, not IDE

# Setup

```
user=> (count 1)
Execution error (UnsupportedOperationException) at user/eval1531 (REPL:1).
count not supported on this type: Long
```

**Figure:** A default error on the `(count)` function, caused by a mistake that a student typically makes.

# Setup

```
babel.middleware=> (count 1)
Function count does not allow a number as an argument in this position.

In Clojure interactive session on line 1.
Call sequence:
[Clojure interactive session (repl)]
```

**Figure:** The error message on the same form produced by Babel, containing a description of the potential problem in plain English.

# Morse

- We would like to expand error message handling from REPL strings to interactive visual environments
- Joe Lane (Nubank) suggested a new tool called *Morse*
- Morse is a third party data visualization and navigation tool
- Morse provides a customizable set of viewers for different data structures, like text, maps, or HTML content
- We are developing a custom set of viewers for error messages
- We need to label different parts of error message for different viewers



# Morse Default

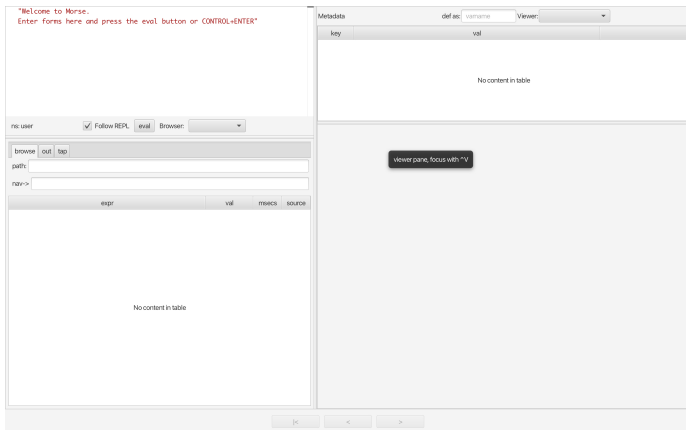


Figure: The default view of the Morse tool.

# Morse Lists

The screenshot shows the Morse viewer interface. On the left, the 'ns: user' section has tabs for 'Follow REPL', 'eval', and 'Browser'. The 'eval-history' tab is active, showing a table with columns 'expr', 'val', 'msecs', and 'source'. The first row contains the expression '(map inc [1 2 3])', the value '(2 3 4)', the time '1', and the source 'Morse 2'. On the right, the 'Metadata' section has a 'def as' field with 'x: name' and a 'Viewer' dropdown menu set to 'reba/coll'. Below this is a table with columns 'idx' and 'val'. The first three rows contain the values 0, 1, and 2, with corresponding values 2, 3, and 4.

idx	val
0	2
1	3
2	4

expr	val	msecs	source
(map inc [1 2 3])	(2 3 4)	1	Morse 2

Figure: Morse viewer for vector data for the form `(map inc [1 2 3])`.

## Integrating with Morse

- In order to connect to a Morse session, we introduce a new session layer that exposes communication hooks for other tools.
- `:init` Behavior on startup, launches a new Morse session connected to the current REPL.
- `:eval` Behavior on form evaluation. Stores the command and sends it to REPL and Morse.
- `:caught` Behavior on caught exception. Processes the error in Babel, and changes the Exception→String processing to instead create a vector of labelled pairs.

## Our Morse Viewer

- We used the existing WebView structure within Morse to render error messages.
- We use HTML to add color coding for important terms, and mono-space fonts to highlight code chunks within the message.
- The exact design of the final viewers are still a work in progress.

```
user=> (even? 1 2)  
Execution error (ArityException) at user/eval2044 (REPL:1).  
Wrong number of args (2) passed to: clojure.core/even?
```

**Figure:** The output for the form `(even? 1 2)` in default Clojure.

```
babel.middleware=> (even? 1 2)  
Wrong number of arguments in (even? 1 2): the function even? expects one  
argument but was given two arguments.  
In Clojure interactive session on line 1.  
Call sequence:  
[Clojure interactive session (repl)]
```

**Figure:** The output for the form `(even? 1 2)` in Babel through the REPL.

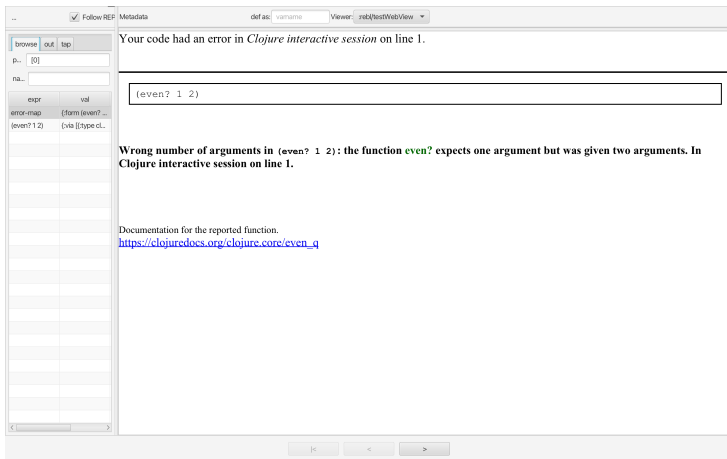


Figure: The output for the form `(even? 1 2)` in Babel with Morse.

# Current Work

## Work in Progress

- This year's work has involved exploring interactions between Babel and Morse
- Babel outputs only strings to REPL, Morse needs labeled data to apply viewers
- We are focusing on information flow between REPL and Morse
- We are also prototyping models for Morse viewers



## Future Work

We want to:

- finalize data labeling and corresponding viewers
- explore interactive capabilities of Morse, e.g. hover text to clarify terms, hyperlinks to documentation
- develop Morse viewers for other information, such as the stack trace, and full Java error messages
- conduct usability studies with our developments
- explore IDE (VS Code) integration for workflow refinements

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Questions?