Panel: Context-Dependent Evaluation of Tools for NL RE Tasks: Recall vs. Precision, and Beyond

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Vocabulary

CBS = Computer-Based System

SE = Software Engineering
RE = Requirements Engineering
RS = Requirements Specification

NL = Natural Language
NLP = Natural Language Processing
IR = Information Retrieval

HD = High Dependability

HT = Hairy Task

NLP for RE?

After Kevin Ryan observed in 1993 that NLP was not likely to ever be powerful enough to do RE, …

RE researchers began to apply NLP to build tools for a variety of *specific* RE tasks involving NL RSs

NLP for RE!

Since then, NLP has been applied to

- **abstraction finding,**
- **requirements tracing,**
- **multiple RS consolidation,**
- **requirement classification,**
- **app review analysis,**
- **model synthesis,**
- **RS ambiguity finding, and its generalization,**
- **RS defect finding**

These and others are collectively NL RE tasks.

Task Vocabulary

A *task* is an instance of one of these or other NL RE tasks.

A task *T* is applied to a collection of documents *D* relevant to one RE effort for the development of a CBS.

A *correct answer* is an instance of what *T* is looking for.

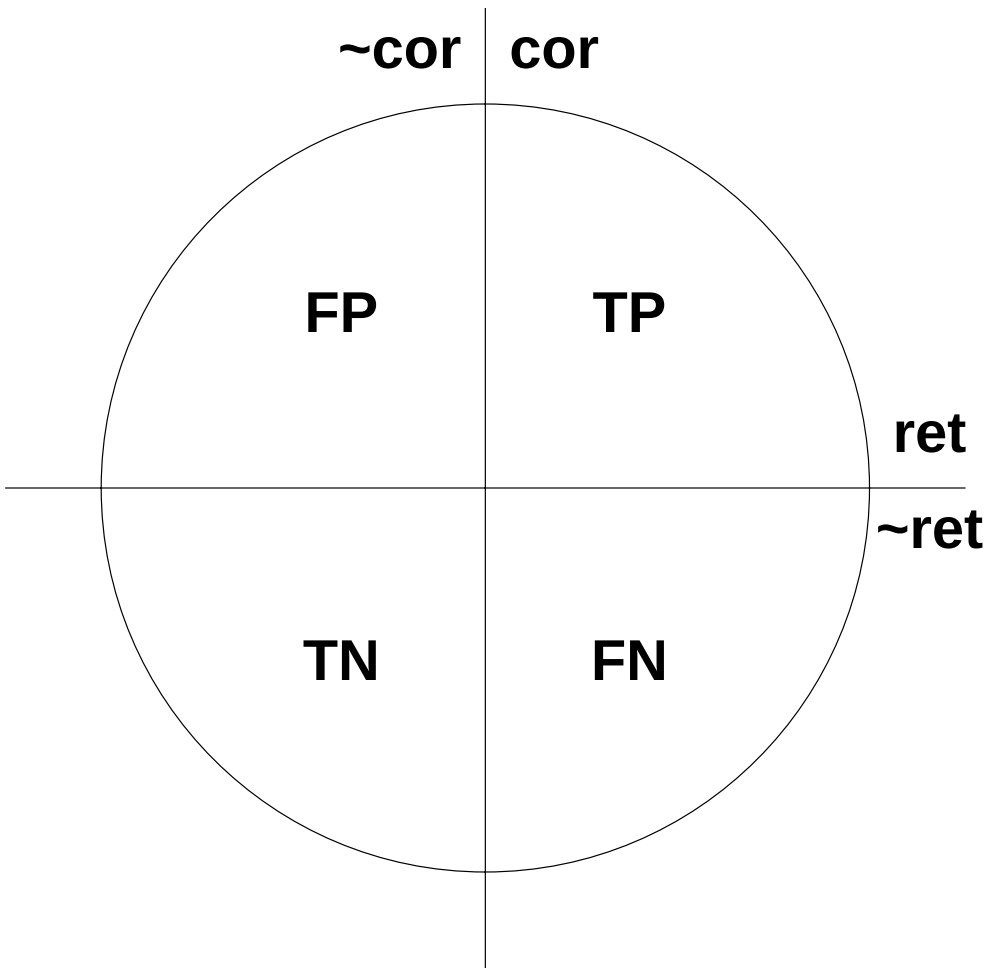
Task Vocabulary, Cont'd

A correct answer is somehow derived from *D*.

A *tool* for *T* returns to its users *answers* that it believes to be correct.

The job of a tool for *T* is to return correct answers and to avoid returning incorrect answers.

Universe of an RE Tool



Adopting IR Methods

RE field has often adopted (and adapted) IR algorithms to develop tools for NL RE tasks.

Quite naturally RE field has adopted also IR's measures:

- **precision, *P*,**
- **recall, *R*, and**
- **the *F*-measure**

Precision

***P* is the percentage of the tool-returned answers that are correct.**

$$P = \frac{|\ ret \cap cor\ |}{|\ ret\ |}$$

$$= \frac{|\ TP\ |}{|\ FP\ | + |\ TP\ |}$$

Recall

***R* is the percentage of the correct answers that the tool returns.**

$$R = \frac{|\ ret \cap cor\ |}{|\ cor\ |}$$

$$= \frac{|\ TP\ |}{|\ TP\ | + |\ FN\ |}$$

F-Measure

F*-measure: harmonic mean of *P* and *R
(harmonic mean is the reciprocal of the arithmetic mean of the reciprocals)

Popularly used as a composite measure.

$$F = \frac{1}{\frac{\frac{1}{P} + \frac{1}{R}}{2}} = 2 \cdot \frac{P \cdot R}{P + R}$$

Weighted *F*-Measure

For situations in which *R* and *P* are not equally important, there is a weighted version of the *F*-measure:

$$F_\beta = (1+\beta^2) \cdot \frac{P \cdot R}{\beta^2 \cdot P + R}$$

Here, β is the ratio by which it is desired to weight *R* more than *P*.

Note That

$F = F_1$

As β grows, F_β approaches R (and P becomes irrelevant).

High-Level Objective

High-level objective of this panel is to

> **explore the validity of the tacit assumptions the RE field made …**

in simply adopting IR's tool evaluation methods to …

evaluate tools for NL RE tasks.

Detailed Objectives

The detailed objectives of this panel are:

- **to discuss *R*, *P*, and other measures that can be used to evaluate tools for NL RE tasks,**
- **to show how to gather data to decide the measures to evaluate a tool for an NL RE task in a variety of contexts, and**
- **to show how these data can be used in a variety of specific contexts.**

Plan for Panel

The present slides are an overview of the panel's subject.

After this overview, panelists will describe the evaluation of specific tools for specific NL RE tasks in specific contexts.

Plan, Cont'd

We will invite the audience to join in after that.

In any case, if *anything* is not clear, please ask for clafification immediately!

***But*, please no debating during anyone's presentation.**

Let him or her finish the presentation, and *then* you offer your viewpoint.

R vs. *P* Tradeoff

_P_ and _R_ can usually be traded off in an IR algorithm:

- **increase _R_ at the cost of decreasing _P_, or**
- **increase _P_ at the cost of decreasing _R_**

Extremes of Tradeoff

Extremes of this tradeoff are:

1. **tool returns all possible answers, correct and incorrect: for**

   $R = 100\%$, $P = C$,

   where $C = \frac{\#\ \text{correctAnswers}}{\#\ \text{answers}}$

2. **tool returns only one answer, a correct one: for**

   $P = 100\%$, $R = \varepsilon$,

   where $\varepsilon = \frac{1}{\#\ \text{correctAnswers}}$

Extremes are Useless

Extremes are useless, because in either case, …

the entire task must be done manually on the original document in order to find *exactly* the correct answers.

Historically, IR Tasks

IR field, e.g., for search engine task, values *P* higher than *R*:

Valueing P more than R

Makes sense:

Search for a Portuguese restaurant.

All you need is 1 correct answer:

$$R = \frac{1}{\#\ a\text{correctAnswers}}$$

But you are *very* annoyed at having to wade through many FPs to get to the 1 correct answer, i.e.,

with low *P*

NL RE Task

Very different from IR task:

- **task is hairy, and**
- **often critical to find all correct answers, for *R* = 100%, e.g. for a safety- or security-critical CBS.**

Hairy Task

On small scale, finding a correct answer in a single document, a hairy NL RE task, …

e.g., deciding whether a particular sentence in one RS has a defect, …

is easy.

Hairy Task, Cont'd

However, in the context of typical large collection of large NL documents accompanying the development of a CBS, the hairy NL RE task, …

e.g., finding in all NL RSs for the CBS, all defects, …

some of which involve multiple sentences in multiple RSs, …

becomes *unmanageable*.

Hairy Task, Cont'd

It is the problem of finding *all* of the *few* matching pairs of needles distributed throughout multiple haystack.

Hairiness Needs Tools

The very hairiness of a HT is what motivates us to develop tools to assist in performing the HT, …

particularly when, e.g. for safety- or security-critical CBS, …

***all* correct answers, …**

e.g., ambiguities, defects, or traces …

***must* be found.**

Hairiness Needs Tools, Cont'd

For such a tool, …

***R* is going to be more important than *P*, and …**

β in F_β will be > 1

What Affects *R* vs. *P* Tradeoff?

Three partially competing factors affecting relative importance of *R* and *P* are:

- **the value of β as a ratio of two time durations,**
- **the real-life cost of a failure to find a TP, and**
- **the real-life cost of FPs.**

Value of β

The value of β can be taken as ratio of

the time for a human to find a TP in a document

over

the time for a human to reject a tool-presented FP.

We will see how to get estimates during gold-standard construction.

Some Values of β

The panel paper gives some β values

ranging from 1.07 to 73.60 for the tasks:

predicting app ratings, estimating user experiences, & finding feature requests from app reviews;

finding ambiguities; and

finding trace links.

Gold Standard for *T*

Need a representative same document *D* for which a group *G* of humans have *T* manually to obtain a list *L* of correct answers for *T* on *D*.

This list *L is* the gold standard.

***L* is used to measure *R* and *P* for any tool *t*, by comparing *t*'s output on *D* with *L*.**

Gather Data During *L*'s Construction

During *L*'s construction, gather following data

- **average time for anyone to find any correct answer = β's numerator,**
- **average time to decide the correctness of any potential answer = lower upper bound estimate for β's denominator, independent of any tool's actual value,**

During *L*'s Construction, Con't

- **average *R* of any human in *G*, relative to final *L* = estimate for humanly achievable high recall (HAHR).**

Tool vs. Manual

Should we use a tool for a particular HT *T*?

Have to compare tool's *R* with that of humans manually performing the *T* on the same documents.

Goal of 100% *R* ?

For a use of the HT in the development of a safety- or security-critical CBS, we need the tool to achieve *R* close to 100%.

Goal of 100% *R*, Cont'd

However,

- **achieving *R* = 100% for *T* is probably impossible, even for a human!**
- **there's no way to be sure that a tool or person has achieved *R* = 100% because the only way to measure *R* is to compare the tool or person's output with the set of all correct answers, which is impossible to obtain!**

Reality

For any task *T*, we aim to build a tool whose *R* beats that of a human manually performing *T*.

Summary

To evaluate a tool *t* for a task *T*, we need

- **to have effective empirical ways to measure tool's and humans' *R* and *P*, and times to do *T*,**
- **to take into account the value of β and the real-life costs, and**
- **to compare tool's *R* and *P* and humans' *R* and *P* on the same set of documents.**

Now Panelists Take Over

The panelists consider the evaluation of tools …

for a variety of HTs …

in a variety of contexts.

Example Tool Evaluation

Tracing tool developed and evaluated by Merten et al [REFSQ16]

***R* = 1.0, *P* = .02, F_1 = .039, F_2 = .093**

Mining Some Estimates

In their description of their gold standard construction process, I was able to mine some estimates, which were validated by e-mail with Merten:

- **Time to find a correct link: 17.84 person-minutes**
- **Time to consider a potential link: 14.54 person-seconds (independent of any tool)**

$\therefore$ β **= 73.6 and** F_β **= .990**

Mining More Estimates

Based on facts:

- **There was an upfront discussion, leading to consensus, on criteria for TP links.**
- **About 5% of the considered links needed a discussion during the construction.**

I estimate that HAHR is [95% – 90%]

Verdict on the Tool

Is the tool worth using?

It depends! ☺

Certainly, the tool's *R* beats HAHR!

So, it gets down to whether the tool makes the remaining manual job easier, i.e., smaller or faster.

Verdict, Cont'd

The problem with such *R* and *P* is that they are close to those of the useless' tool that returns every answer.

If the tool's answers summarize the original documents, i.e.,

the tool's answers contain every correct link, *and* are smaller than the original documents, so that the human has less work to do …

If …, Cont'd

Or the tool presents the information relevant to vetting a link in a form that makes the vetting time less than 14.54 seconds, …

then the tool is worth using

else the tool is not worth using

when you need 100% *R*.