



## Introduction

NA	0.30	0.50	NA	NA	NA	NA	1	2
NA	NA	NA	0.90	NA	NA	0.40	1	3
NA	NA	NA	NA	NA	NA	NA	2	4
NA	NA	NA	NA	0.60	NA	NA	4	5
NA	NA	NA	NA	NA	NA	NA	2	7

I need to transform the matrix on the left into the matrix on the right (position of non-empty values).  
Can you code it?

Matrices are a very common way of representing and working with data  
There are a Lot of functions in different programming languages  
What if I don't have programming knowledge?

**Problem: Induce R programs to transform an input matrix to an output matrix using only few examples from the result**

## Problem Definition

Considering:

1	3	5
4	NA	6
NA	NA	7

An input  
matrix  $A$   
( $m \times n$ )

.	2	.
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A partially filled  
matrix  $B$   
( $m' \times n'$ )

"How to know the number of NA  
in each column"

Optionally, some textual  
hint  $T$  in natural  
language

We look for a combination of functions (in R<sup>1</sup>)  $f$  such that  $f(A) = S$

`colSums(is.na(A)) =`

1	2	0
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where  $S$  is a matrix ( $m' \times n'$ ), such that for every non-empty  $b_{ij} \in B$  there is a  $s_{ij} \in S$  such that  $b_{ij} = s_{ij}$

## Method

### Dimensional Constraints:

Each primitive  $g$  in the background knowledge  $G$  includes a tuple  $(m_{min}, n_{min}, \tau)$

- $m_{min}, n_{min}$ : minimum size for the input.
- $\tau: \mathbb{R}^{2'} \rightarrow \mathbb{R}^2$ : type function which maps the dimension of input to output.

### Probabilistic Model:

We guide the search using the probability:

$$p(g|T, A, B) = \gamma \cdot p(g) + (1 - \gamma) \cdot p_0(g|T)$$

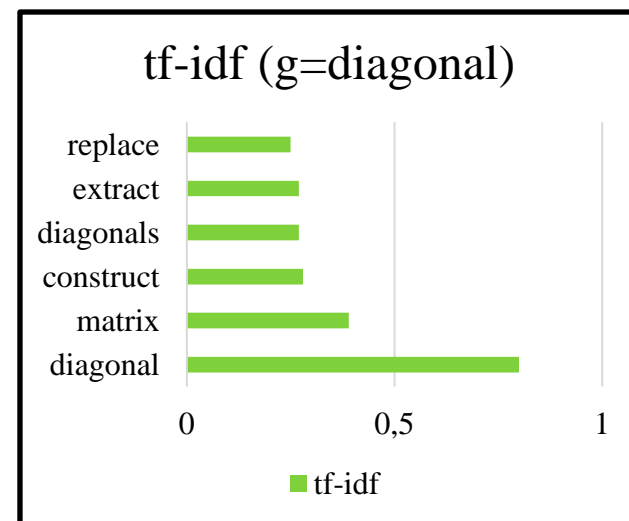
**Prior Probability**

Frequency of use of the 2000 most  
used R functions on GitHub<sup>2</sup>

	Function	Freq.
1	length	0,33
2	nrow	0,09
3	is.na	0,08
...	...	...

**Frequency Model**

tf-idf values from R help  
documentation



Text hint provided by  
the user

$T = \text{"How to extract the  
diagonal of a matrix in R"}$

$s(H_g, T) = \text{cosine similarity}$

Being  $n_g$  the absolute frequency of  
use:

$$p(g) = \frac{n_g}{\sum_{g \in G} n_g}$$

The text hint probability is defined as:

$$p_0(g|T) = \frac{s(H_g, T)}{\sum_{g \in G} s(H_g, T)}$$

### Weights:

- Final Dimension:  $\alpha$  gives more weight to those transformations where the output size matches the size of  $B$

$$p^*(g_1 g_2 \dots g_d) = (1 + \alpha m) \prod_{i=1}^d p(g_i | g_{i-1} g_{i-2} \dots g_1, T, A, B)$$

- Sequential Dependencies:  $\beta$  reduces the weight to those transformations repeating functions

$$p(g_i | g_{i-1} \dots g_1, T, A, B) = \beta p(g_i | T, A, B) + (1 - \beta) p(g_i | g_{i-1} g_{i-2} \dots g_1, T, A, B)$$

$$p(g_i | g_{i-1} g_{i-2} \dots g_1, T, A, B) = 0 \quad \text{if } g_i \in \{g_{i-1}, g_{i-2}, g_{i-3}\}$$

$$= p(g_i | T, A, B) \quad \text{otherwise} \quad \beta \in [0, 1]$$

## Experiments & Results

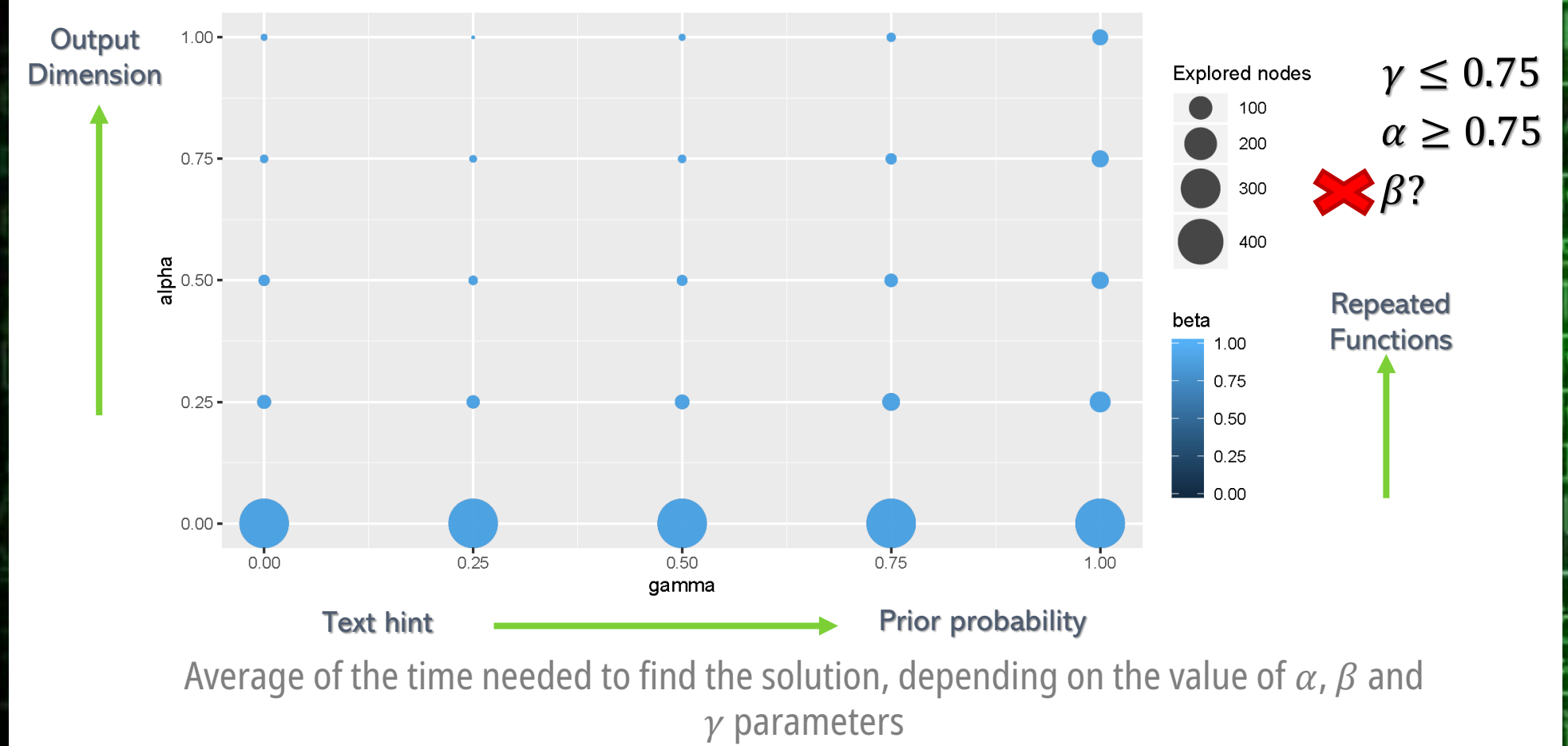
### Background Knowledge (functions)

34 R functions related to matrices (base, stats and Matrix packages)

### Data

- Artificial data: 400 pairs of matrices A,B (with 80% empty cells).
- 30 questions/answers from stackoverflow

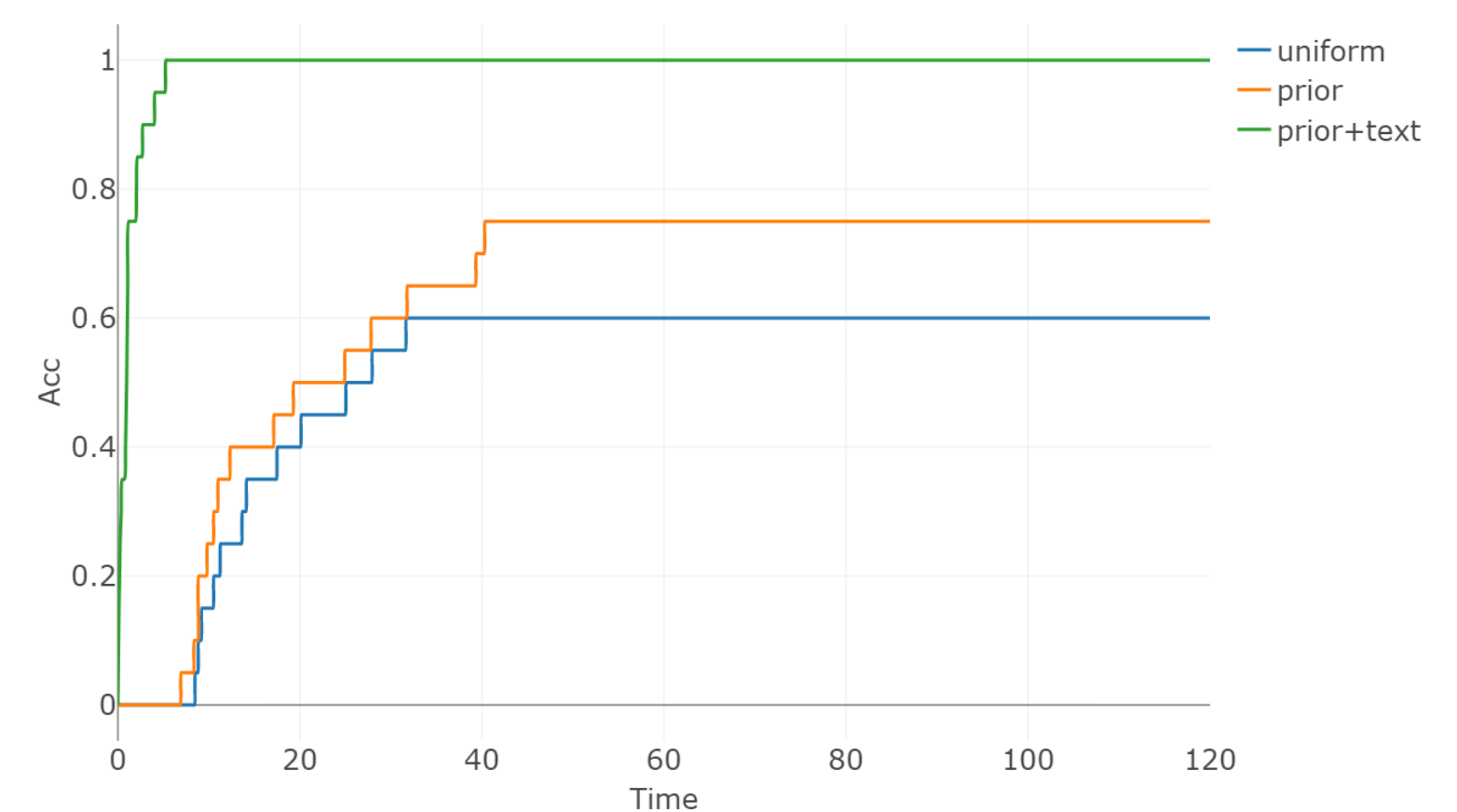
### Parameter Setting



### Strategies

- Uniform:** Considering  $p(g)$  uniform.
- Prior:** Building a Dynamic Background Knowledge using the prior probability
- Prior + Text:** Building a Dynamic Background Knowledge using the prior probability and the frequency model generated with  $T$

### Results



Percentage of cases that are solved and the time needed to find the solution

## Conclusions

We have created a new system able to solve matrix transformations:

- Based on a breadth-search approach; Pruned by the dimensions of the matrices; Guided by a strategy based on dynamic probabilities from:
  - A prior value depending on the primitive frequency on Github.
  - tf-idf values of text hints provided by the user and the R help documentation of the functions.

### Future work:

- Add new characteristics (constraints)
- Include more primitives and new data structures
- Create a visual interface or R package
- Replicate for other languages such as Python.

<sup>1</sup>R: <https://www.r-project.org/>  
<sup>2</sup>The 2000 most used R  
functions on GitHub :  
[shorturl.at/pDFRZ](https://shorturl.at/pDFRZ)