TRABALHO COMPUTACIONAL

Daniela Amaral Sampaio - 2017074351
Matheus Brito Faria - 2017074386
Victor Emannuel - 2017074394

Universidade Federal de Minas Gerais
Teoria da Decisão - 02/2021

SUMÁRIO

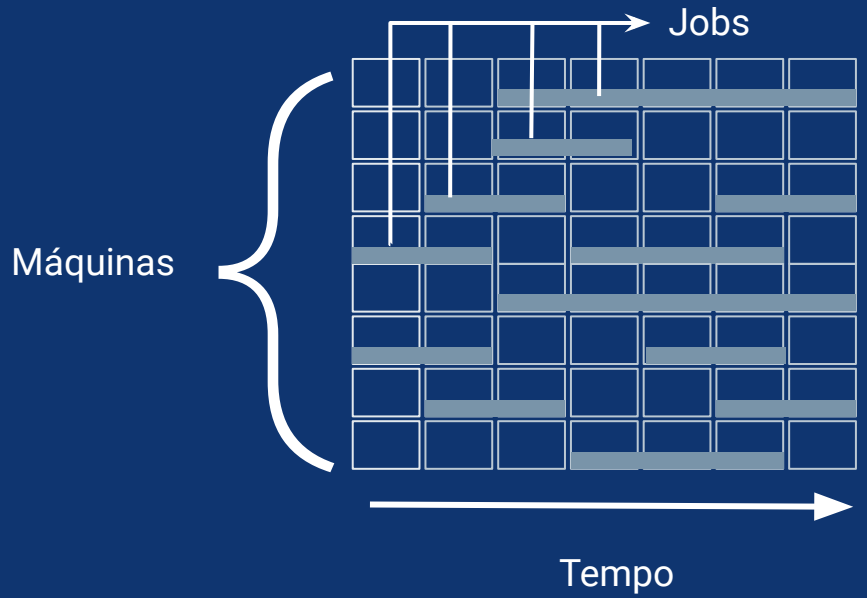
SUMÁRIO

01

INTRODUÇÃO

JOB SCHEDULING

É um problema de otimização que consiste em administrar tarefas (jobs) em máquinas de forma a otimizar o makespan e os custos dessas tarefas (nesse caso dos atrasos).



02

MODELAGEM MATEMÁTICA

I. Modelagem matemática

A. Parâmetros

M = número de máquinas, $i \in \{1, ..., M\}$
N = número de tarefas, $j \in \{0, ..., N\}$
t_{ij} = número de tarefas
d = data limite de entrega para cada tarefa j
w_j = penalidade proporcional ao atraso da tarefa j
L = número relativamente grande

B. Variáveis

C_{max} = makespan, tempo total para completar todas as tarefas

$$x_{ijk} = \begin{cases} 1, & \text{se a tarefa } j \text{ precede imediatamente a} \\ & \text{tarefa } k \text{ na máquina } i \\ 0, & \text{caso contrário} \end{cases}$$

$T_j = \max\{C_j - d, 0\} \rightarrow$ atraso da tarefa j
C_{ij} = término da tarefa j na máquina i

C. Funções objetivo

$$\min_x f_1(x) = C_{max} = \max_{i \in \{1,...,M\}} \left(\sum_{j=1}^{N} \sum_{k=1}^{N} t_{ij} x_{ijk} \right) \quad (1)$$

$$\min_x f_2(x) = \sum_{j=1}^{N} w_j T_j \quad (2)$$

$$\sum_{i=1}^{M} \sum_{k=1}^{N+1} x_{ijk} = 1, \quad \forall \quad j \in \{1, ..., N\} \quad (3)$$

$$C_{max} \geq \sum_{j=1}^{N} \sum_{k=1}^{N} t_{ij} x_{ijk}, \quad \forall \quad i \in \{1, ..., M\} \quad (4)$$

$$\sum_{k=1}^{N} x_{i0k} \leq 1, \quad \forall \quad i \in \{1, ..., M\} \quad (5)$$

$$\sum_{\substack{j=1 \\ j \neq h}}^{N+1} x_{ijh} - \sum_{\substack{k=1 \\ k \neq h}}^{N+1} x_{ihk} = 0, \quad \forall \quad h \in \{1, ..., N\} \quad \forall \quad i \in \{1, ..., M\} \quad (6)$$

$$C_{ik} \geq C_{ij} - L + (t_{ik} + L) x_{ijk}, \quad \forall \quad j \in \{1, ..., N\} \quad \forall \quad k \in \{1, ..., N\} \quad (7)$$

$$T_j \geq \max\left(\sum_{i=1}^{M} C_{ij} - d, \quad 0 \right), \quad \forall \quad j \in \{1, ..., N\} \quad (8)$$

$$C_{max} \in \mathbb{R}_+ \quad (9)$$

$$x \in \mathbb{B}^{M(N+1)(N+1)} \quad (10)$$

$$T \in \mathbb{R}_+^N \quad (11)$$

$$C \in \mathbb{R}_+^{MN} \quad (12)$$

FORMULAÇÃO EM CÓDIGO

```
schedule = [
            [ 1,  6, 14,  7, 23], # machine 0
            [24, 21,  0,  3,  9], # machine 1
            [19, 20, 18,  5, 11], # machine 2
            [ 2, 22, 15, 17, 10], # machine 3
            [13, 16,  8, 12,  4]  # machine 4
]
```

03

OTIMIZAÇÃO MONO-OBJETIVO

RVNS

VNS

Parte da solução corrente para obter uma solução vizinha aleatória dentro de uma vizinhança k ∈ K.

FIRST IMPROVEMENT*

O adicional dessa meta-heurística é que esta solução vizinha é então submetida a uma busca local.

FORMA ESTÓCASTICA

Foi implementado uma variação do first improvement onde a busca local é feita aleatoriamente até encontrar uma solução melhor que a atual.

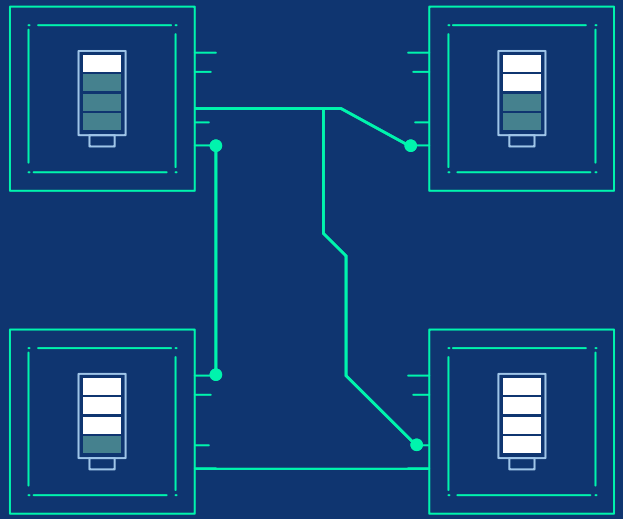
MUDANÇAS NAS ESTRUTURAS DE VIZINHANÇA

SHIFT

Troca um jobs de lugar numa mesma máquina

TASK MOVE

Move um job de uma máquina para outra



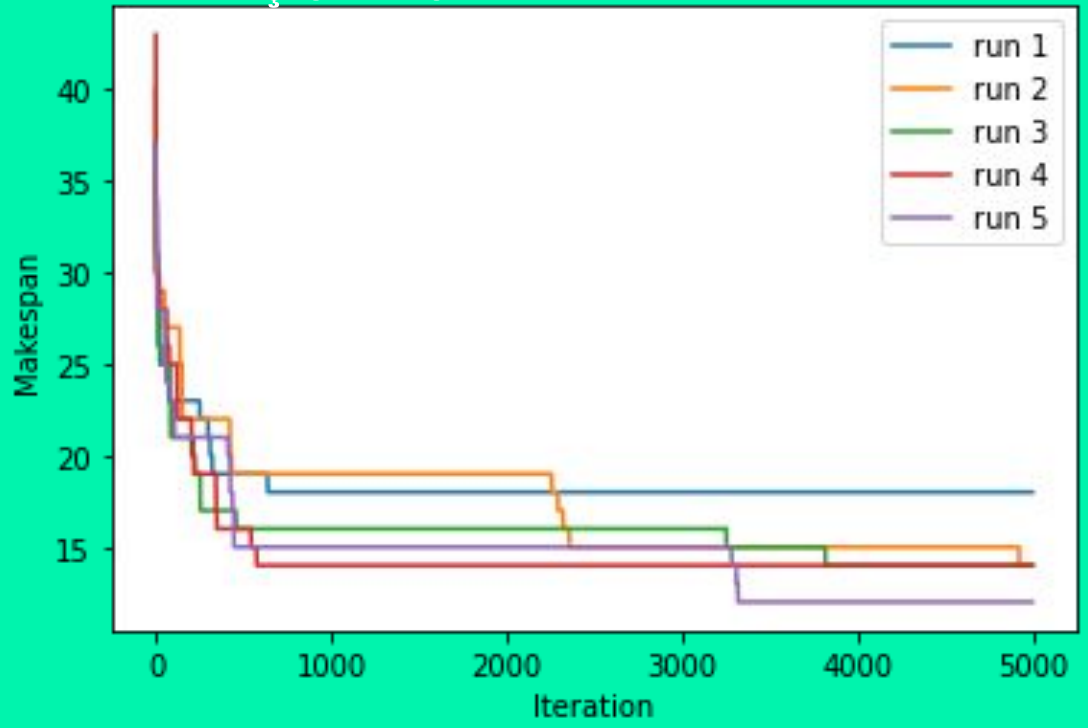
SWITCH

Troca dois jobs de lugar numa mesma máquina

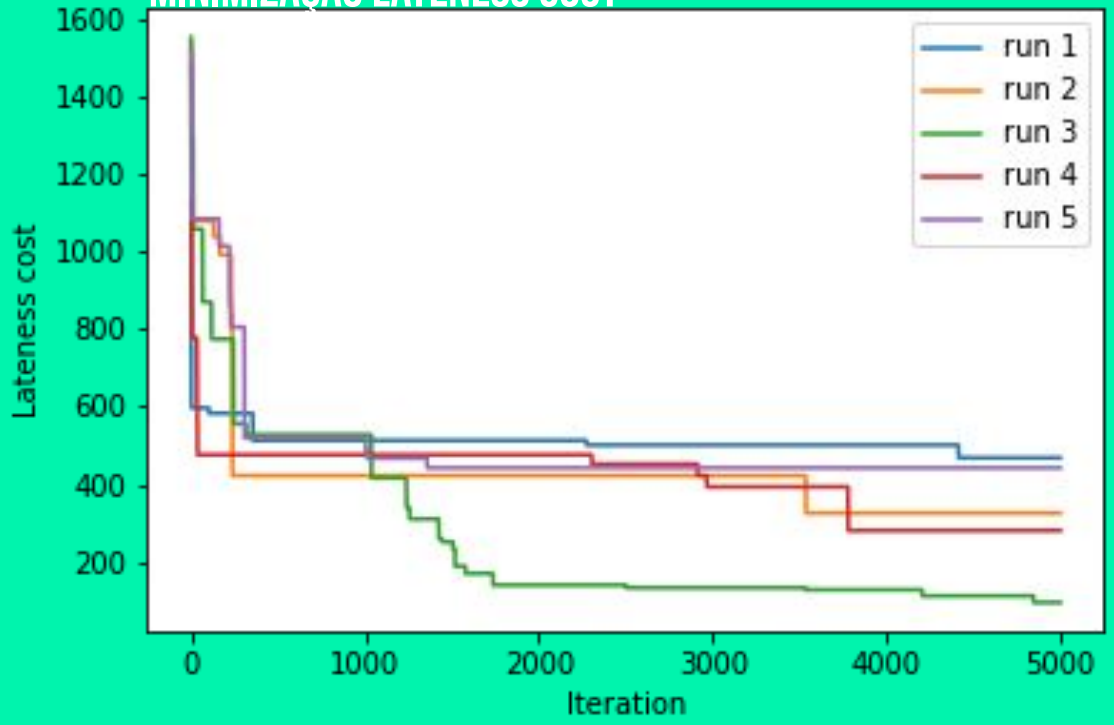
SWAP

Troca dois jobs de duas máquinas diferentes entre si

MINIMIZAÇÃO MAKESPAN



MINIMIZAÇÃO LATENESS COST



04

OTIMIZAÇÃO MULTIOBJETIVO

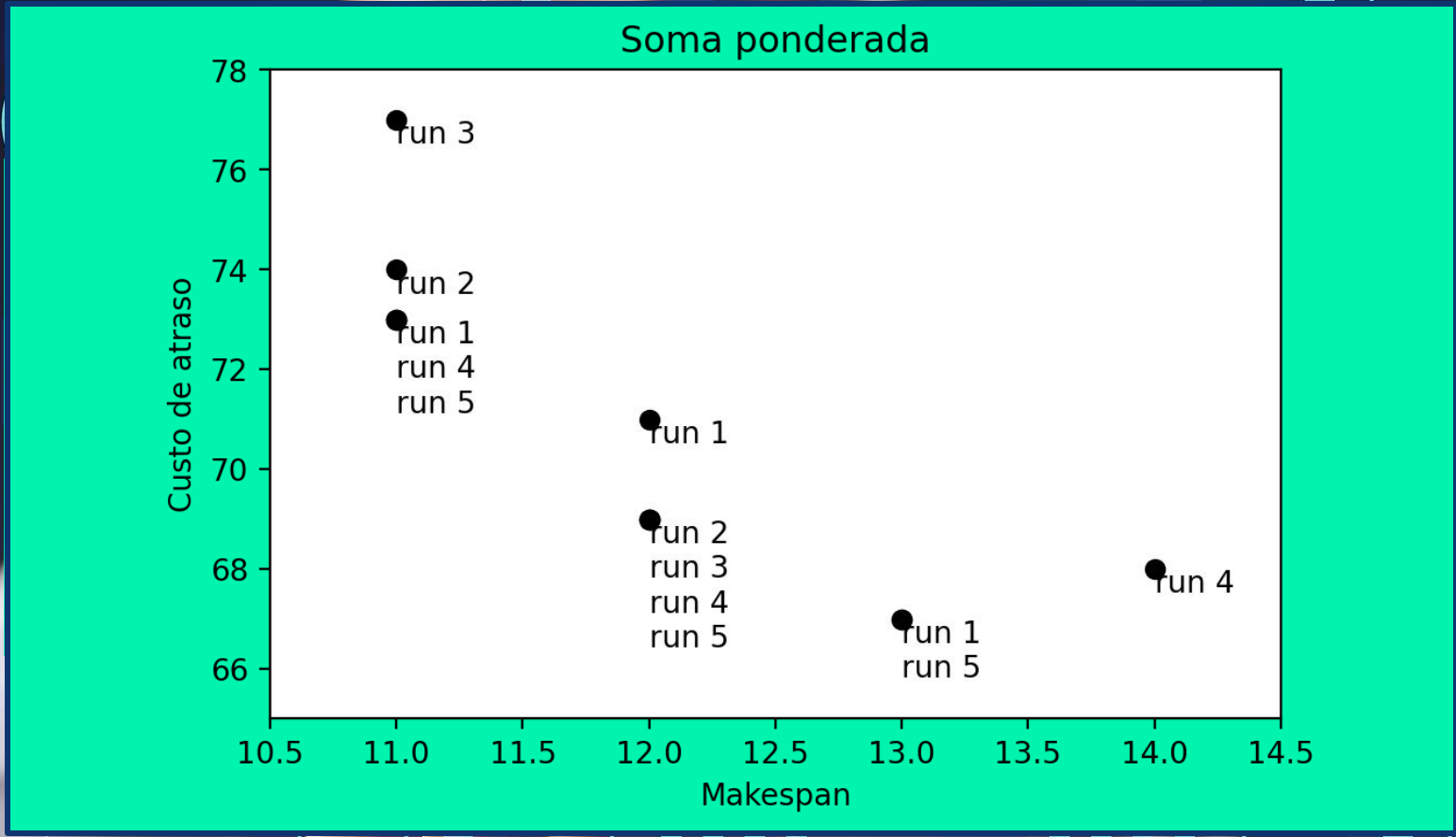
MÉTODOS UTILIZADOS

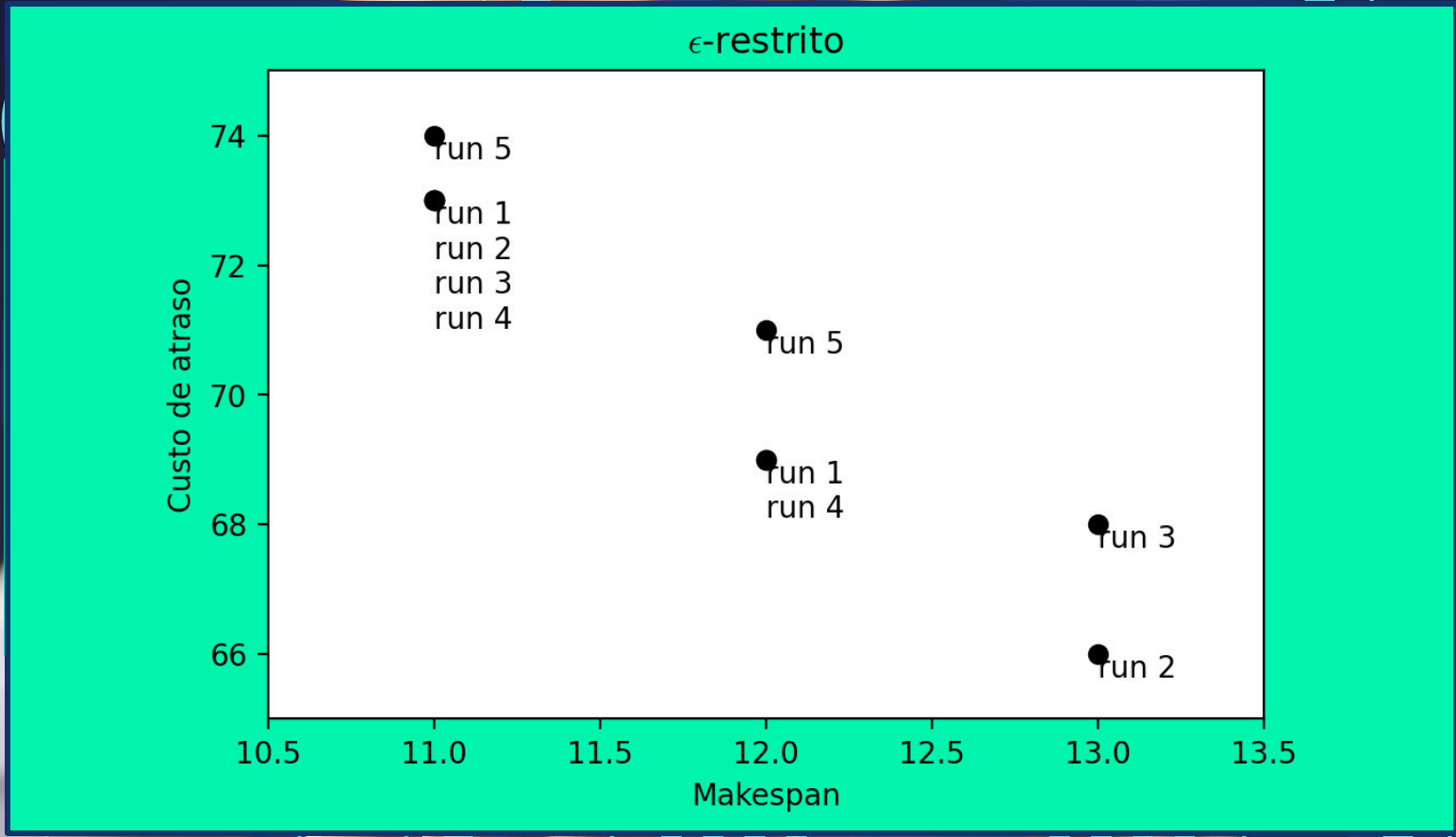
SOMA PONDERADA

- Coloca um peso em cada função e as soma
- Os valores são normalizados
- São gerados pesos aleatórios e o problema é resolvido N vezes

EPSILON RESTRITO

- Faz com que uma das funções se torne uma restrição menor que epsilon
- O valor de epsilon vai decrescendo
- O valor de epsilon inicial é definido pelo nadir da função objetivo


Soma ponderada
Custo de atraso
Makespan
78
76
74
72
70
68
66
10.5
11.0
11.5
12.0
12.5
13.0
13.5
14.0
14.5
run 3
run 2
run 1
run 4
run 5
run 1
run 2
run 3
run 4
run 5
run 4
run 1
run 5


ϵ-restrito
Custo de atraso
Makespan
74
72
70
68
66
10.5
11.0
11.5
12.0
12.5
13.0
13.5
run 5
run 1
run 2
run 3
run 4
run 5
run 1
run 4
run 3
run 2

05

TOMADA DE DECISÃO MULTICRITÉRIO

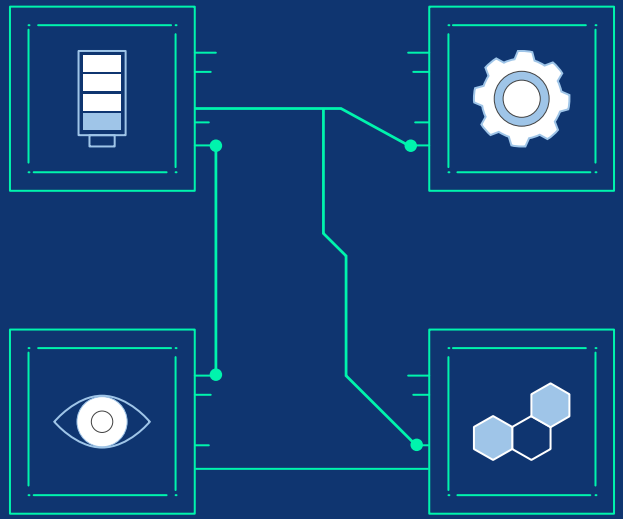
CRITÉRIOS UTILIZADOS

MAKESPAN

Tempo mínimo para a conclusão de todos os jobs

VALOR ENTREGUE

Soma dos custos dos jobs que foram entregues no prazo



CUSTO DE ATRASO

Soma dos custos de atraso de todos os jobs não concluidos

JOBS ENTREGUES

Número de jobs que foram entregues no prazo

AHP

CALCULA MATRIZ DE CRITÉRIOS

Tanto das soluções quanto dos próprios critérios

CALCULA VETOR DE PRIORIDADES

Tanto das soluções quanto dos próprios critérios

CALCULA OS SCORES

Multiplicandos os vetores de prioridades temos os scores

VALORES DOS CRITÉRIOS

	MAKESPAN	LATENESS COST	ADVANCE SAVE	JOBS DONE
SOLUTION 1	-11	-73	290	15
SOLUTION 2	-12	-69	196	14
SOLUTION 3	-13	-66	245	14

PONDERAÇÃO DOS CRITÉRIOS

	MAKESPAN	LATENESS COST	ADVANCE SAVE	JOBS DONE
MAKESPAN	1	1/7	1/9	3
LATENESS COST	7	1	1/3	7
ADVANCE SAVE	9	3	1	9
JOBS DONE	1/3	1/7	1/9	1

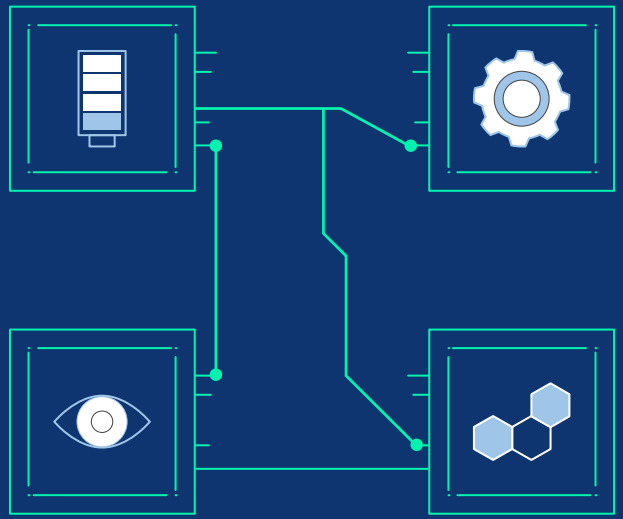
PRIORIDADES DOS CRITÉRIOS

MAKESPAN

7.81%

CUSTO DE ATRASO

30.03%



VALOR ENTREGUE

57.80%

JOBS ENTREGUES

4.34%

SCORES

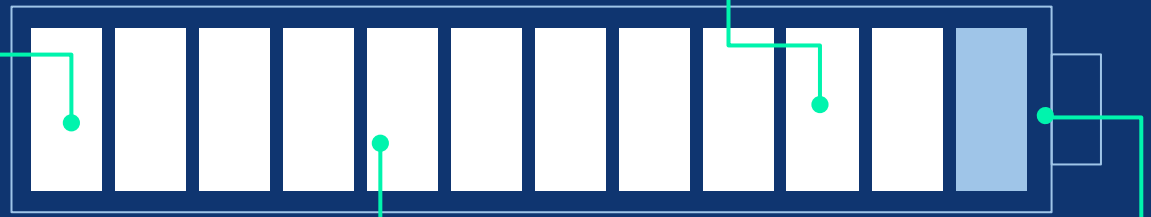
	MAKESPAN	LATENESS COST	ADVANCE SAVE	JOBS DONE	SCORES
SOLUTION 1	***-11***	***-73***	***290***	***15***	***37.37%***
SOLUTION 2	-12	-69	196	14	29.48%
SOLUTION 3	-13	-66	245	14	33.14%

ELECTRE I

CALCULA J+, J-, J=

Comparação par a par de cada solução e cada critério

CALCULA MATRIZ DE CONCORDÂNCIA E DISCORDÂNCIA



CALCULA P+, P-, P=

Para cada matriz J é multiplicado o peso do critério correspondente

USA LIMITES E CRIA OS GRAFOS COM AS DEFINIÇÕES

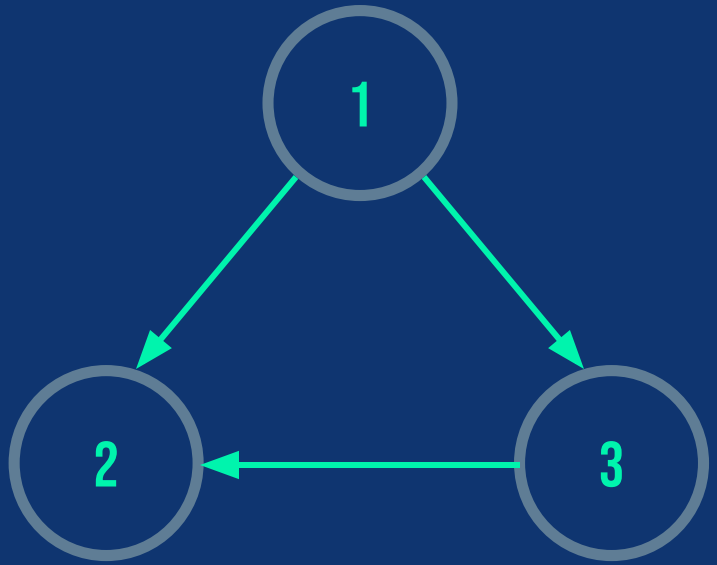
CONCORDÂNCIA

	SOLUTION 1	SOLUTION 2	SOLUTION 3
SOLUTION 1	-	V	V
SOLUTION 2	F	-	F
SOLUTION 3	F	V	-

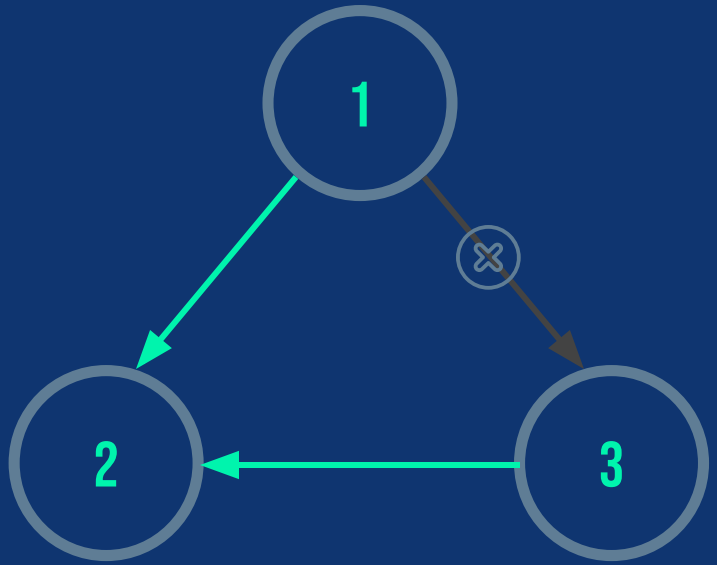
DISCORDÂNCIA

	SOLUTION 1	SOLUTION 2	SOLUTION 3
SOLUTION 1	-	V	F
SOLUTION 2	F	-	V
SOLUTION 3	F	V	-

GRAFO DE CONCORDÂNCIA



GRAFO DE DISCORDÂNCIA

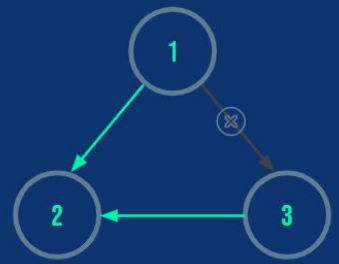


06

CONCLUSÕES

DECISÕES

	SCORES
SOLUTION 1	37.37%
SOLUTION 2	29.48%
SOLUTION 3	33.14%



AHP

ELECTRE I

Baseado nesses dois métodos podemos perceber que ambos chegam na conclusão que as soluções 1 e 3 são melhores que a 2. Com nosso espaço de decisão reduzido podemos optar pela opção 1 que no método AHP foi a que se saiu melhor.

OBRIGADO!

SCORES

	SCORES
SOLUTION 1	*37.37%*
SOLUTION 2	29.48%
SOLUTION 3	33.14%

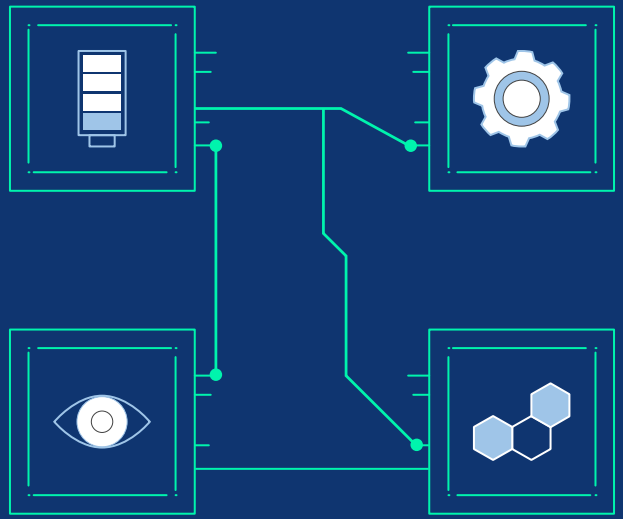
WHAT WE ARE WORKING ON

MARS

Despite being red, it’s a cold place full of iron oxide dust

SATURN

Yes, Saturn is the ringed one. It’s a gas giant



JUPITER

It’s a gas giant and the biggest planet in the Solar System

MERCURY

It’s the closest planet to the Sun and the smallest

ABOUT THE PROJECT

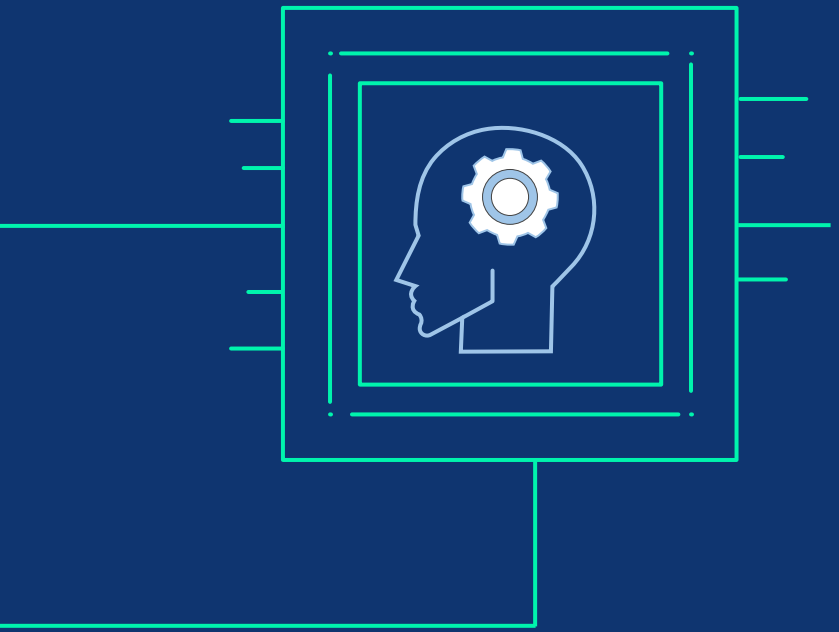
Mercury is the closest planet to the Sun and the smallest one in the Solar System—it's only a bit larger than the Moon. The planet's name has nothing to do with the liquid metal

“This is a quote, words full of wisdom that someone important said and can make the reader get inspired.”

—SOMEONE FAMOUS

NOW

It’s terribly hot—even hotter than Mercury—and its atmosphere is extremely poisonous. It’s the second-brightest natural object in the night sky after the Moon



FUTURE

Jupiter is a gas giant, the biggest planet in the Solar System and the fourth-brightest object in the night sky. It’s named after the Roman god of the sky and lightning

MAJOR REQUIREMENTS

MERCURY

Mercury is the closest planet to the Sun

JUPITER

It’s a gas giant and the biggest planet

MARS

Despite being red, Mars is a cold place

VENUS

Venus is the second planet to the Sun

SATURN

Saturn is the ringed one and a gas giant

NEPTUNE

It’s the farthest planet from the Sun

01

NAME OF THE SECTION

You could enter a subtitle here if you need it

CONTENTS OF THIS TEMPLATE

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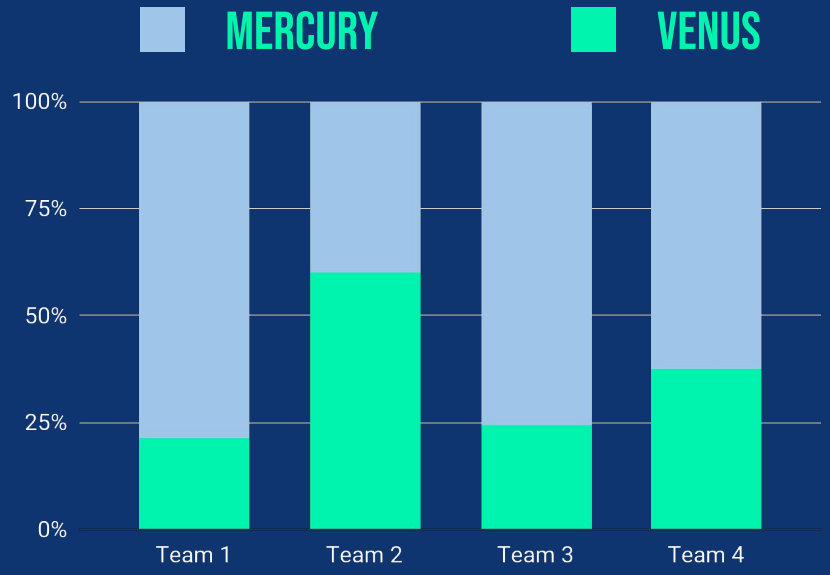


To modify this graph, click on it, follow the link, change the data and paste the new graph here

$50,000,000

Social Media	Social Media
Shop	Shop
TV	TV

PROJECT GOALS

MERCURY

It’s the closest planet to the Sun and the smallest one in the Solar System—it’s only a bit larger than the Moon

VENUS

It has a beautiful name and is the second planet from the Sun. It’s terribly hot, even hotter than Mercury

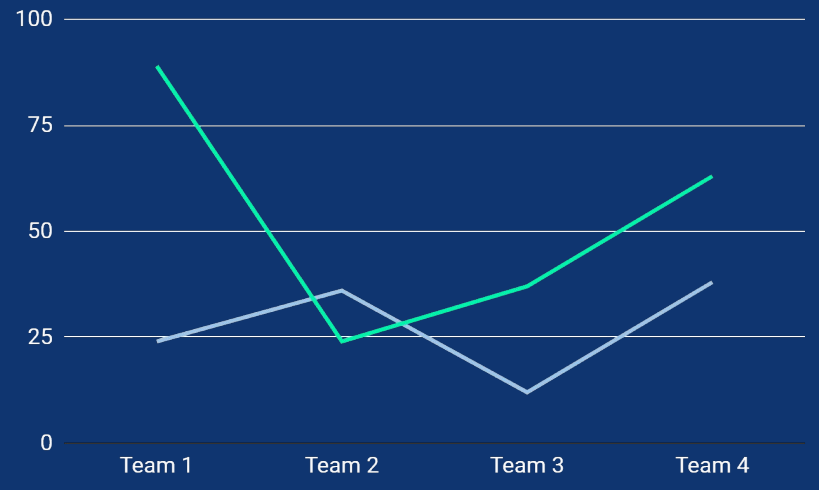
PREDICTED RESULTS

$ 20,000,000

Expected income for 2020

100

New employees next year



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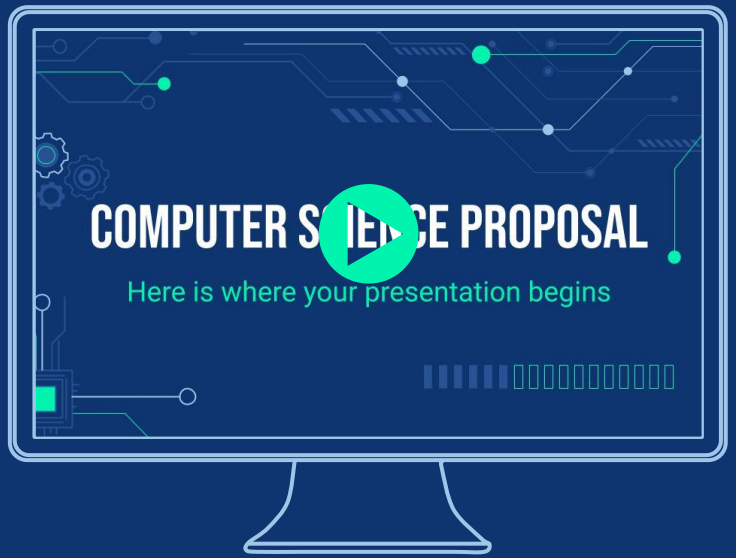
SNEAK PEEK

The planet’s name has nothing to do with the liquid metal since it was named after the Roman messenger god, Mercury



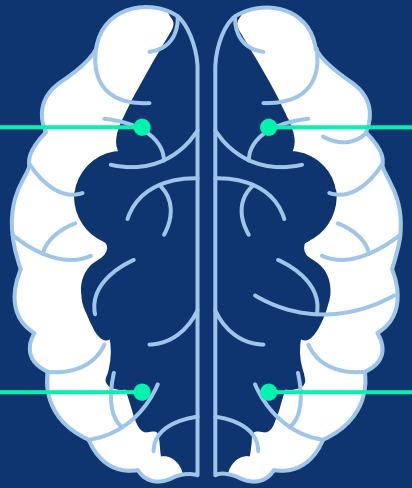
PROJECT STAGES

MARS

Despite being red, Mars is a cold place

SATURN

Yes, Saturn is the ringed one. It’s a gas giant



JUPITER

It’s a gas giant and the biggest planet in the Solar System

MERCURY

It’s the closest planet to the Sun and the smallest

PROJECT STAGES

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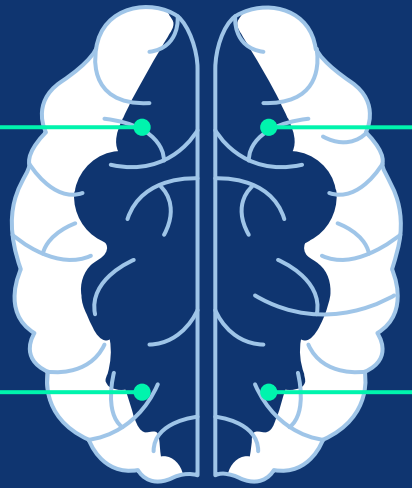


JUPITER

It’s a gas giant and the biggest planet in the Solar System

MERCURY

It’s the closest planet to the Sun and the smallest

4,498,300,000

Big numbers catch your audience’s attention

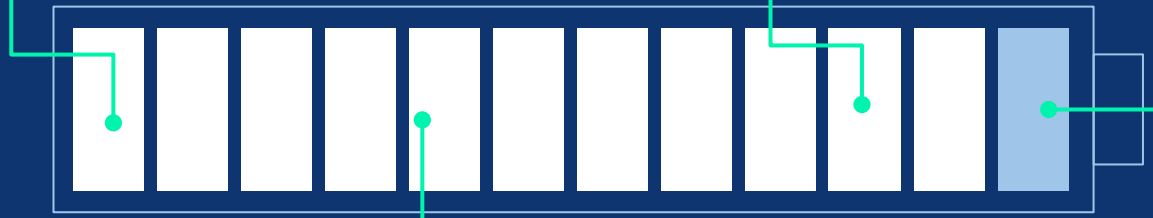
TIMELINE

2017

It’s the closest planet to the Sun

2019

It’s the second planet to the Sun



2018

Despite being red, Mars is a cold place

2020

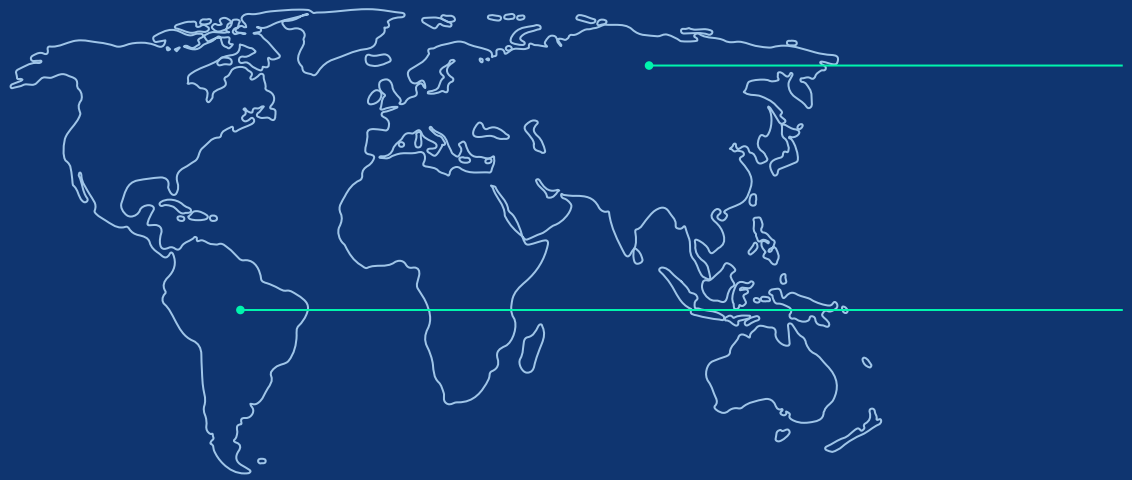
It’s a gas giant and the biggest planet


AWESOME WORDS

THIS IS A TABLE

	MERCURY	MARS	JUPITER
2018	647	984	268
2019	752	546	875
2020	455	856	340

THIS IS A MAP



60%

It’s the closest planet to the Sun

78%

It’s the second planet to the Sun

OUR PARTNERS

VENUS

Venus is the second planet to the Sun

SATURN

Saturn is the ringed one and a gas giant

NEPTUNE

It’s the farthest planet from the Sun

OUR TEAM

RICHARD ROE

You can talk about this person here

JENNA DOE

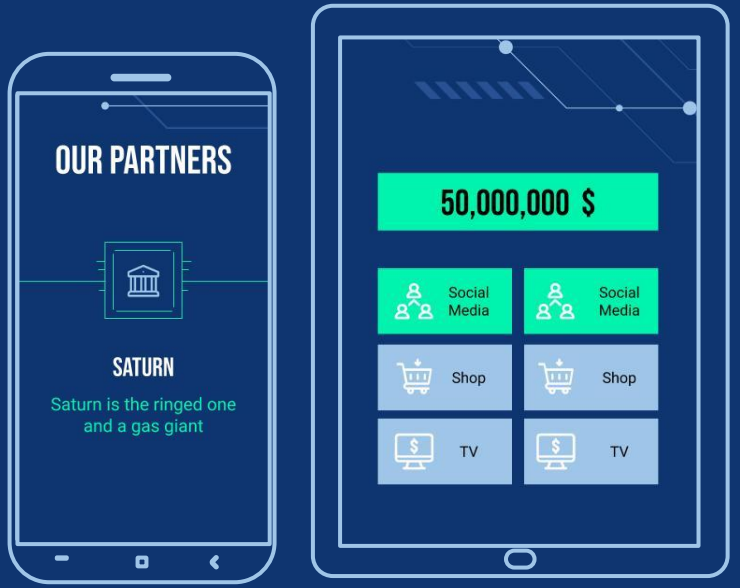
You can talk about this person here

JOHN SMITH

You can talk about this person here

MOCKUP

You can replace the image on the screen with your own work. Just delete this one, add yours and center it properly



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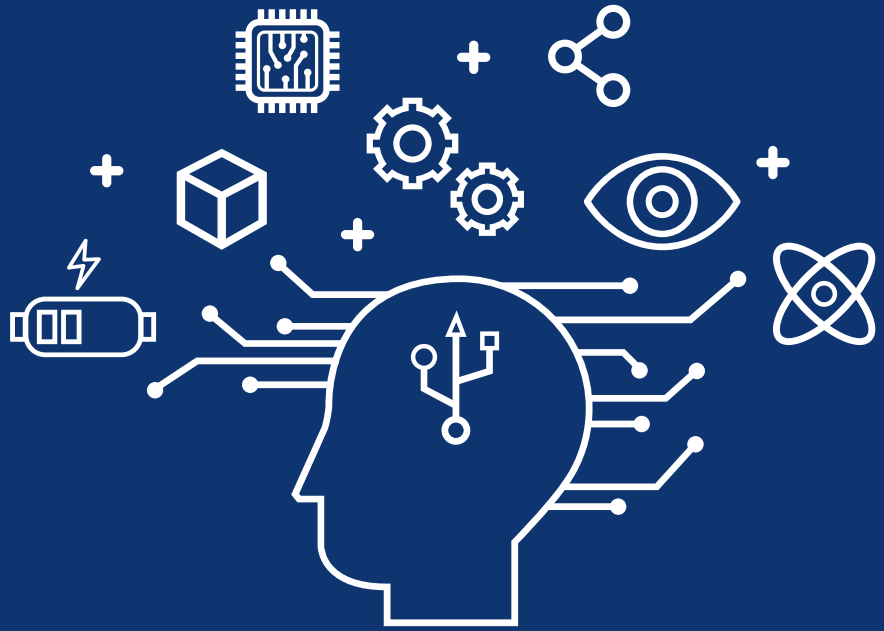

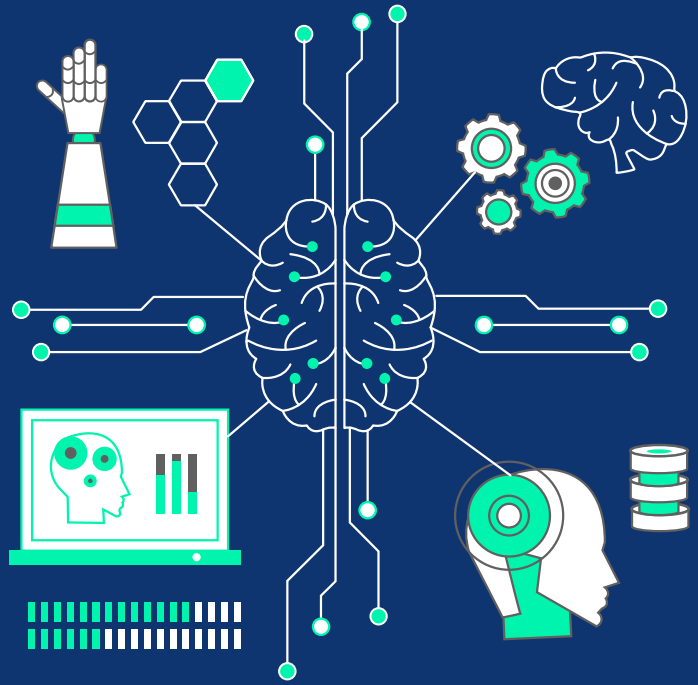

RESOURCES

VECTORS

- Flat artificial intelligence background
- Flat artificial intelligence background
- Flat artificial intelligence background

PHOTOS

- Close-up of humans handshake with tech background
- Futuristic technology screen interface
- Group of people with laptops

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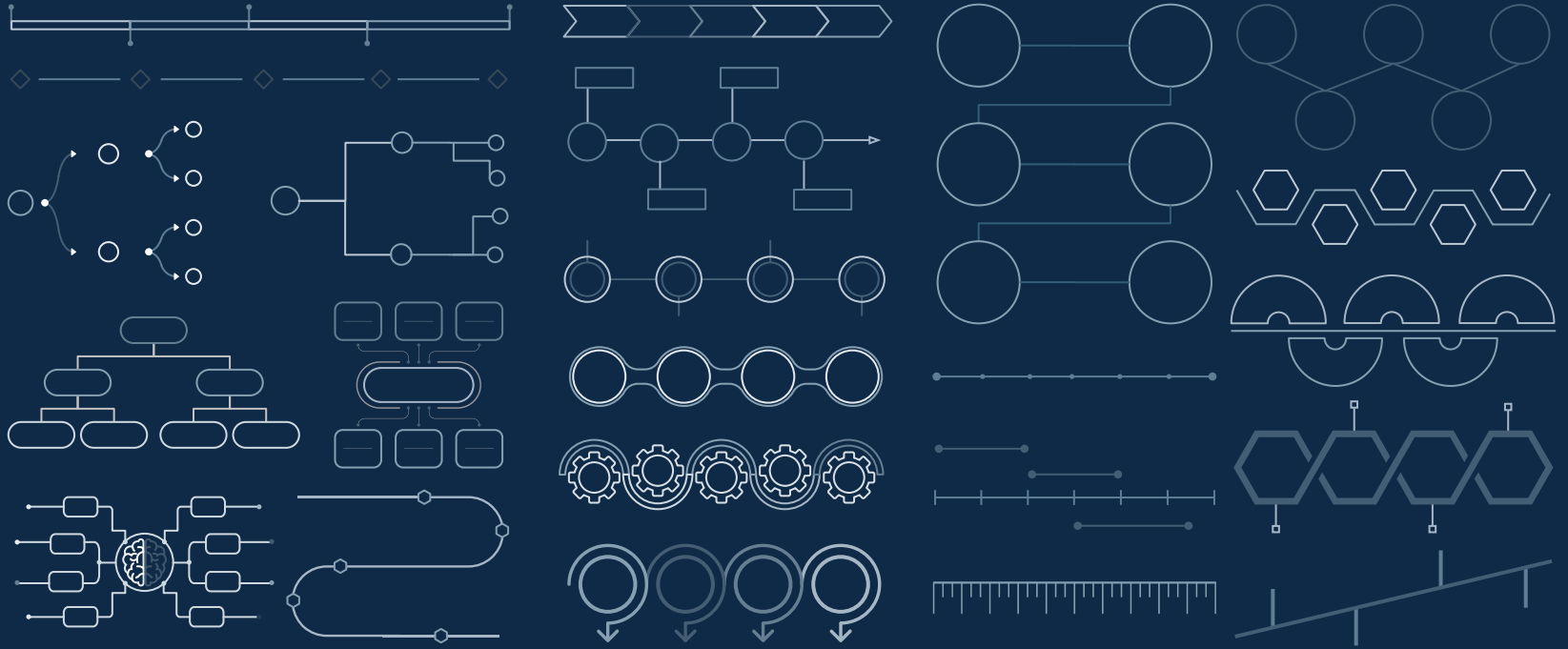

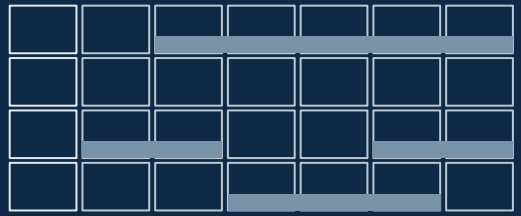

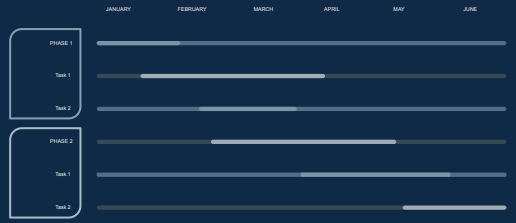
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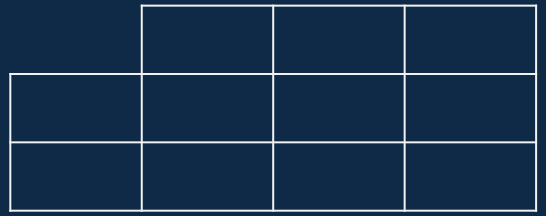

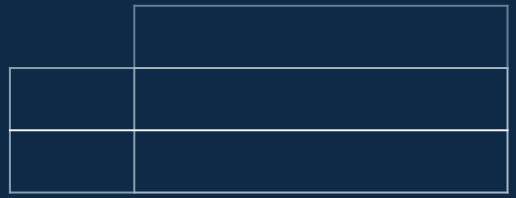

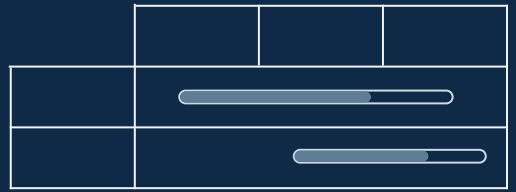

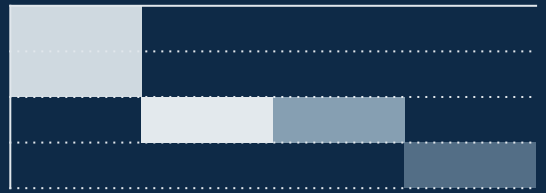

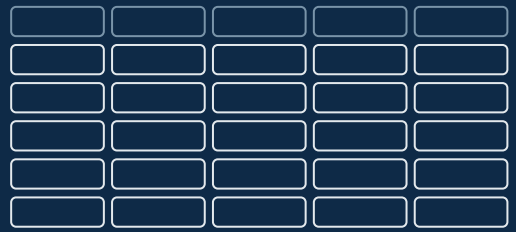

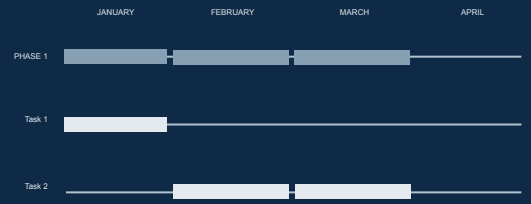
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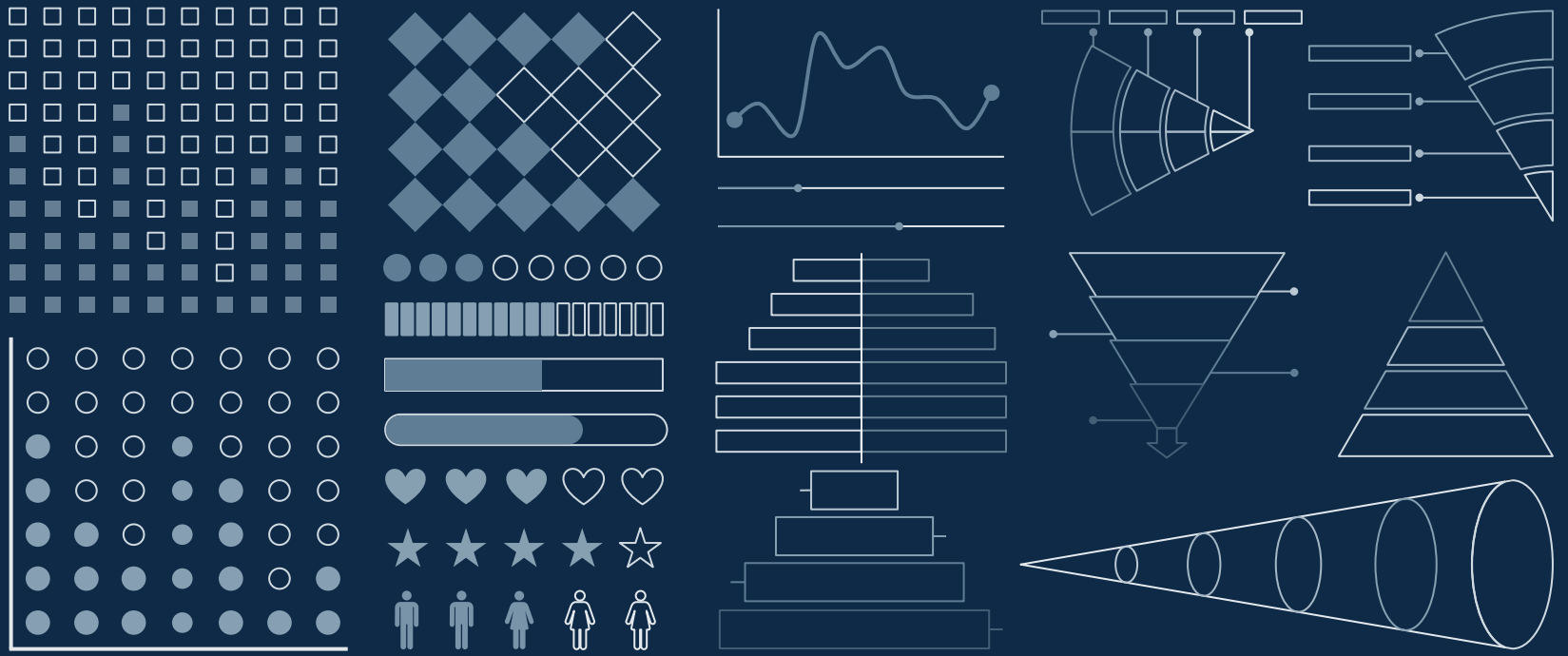

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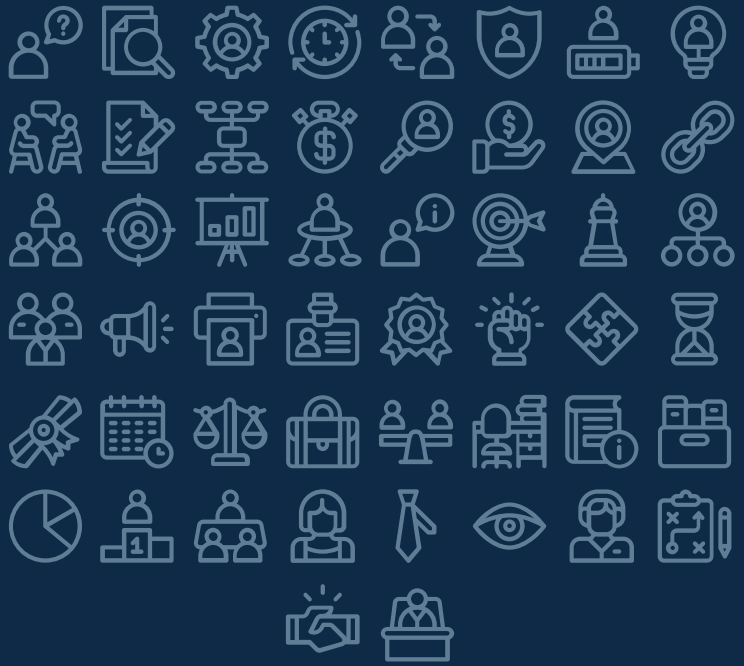

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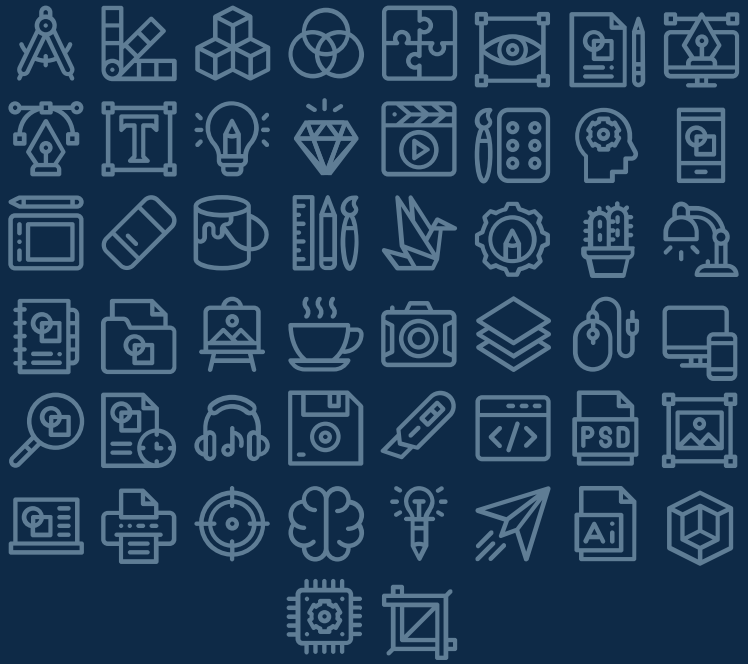

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