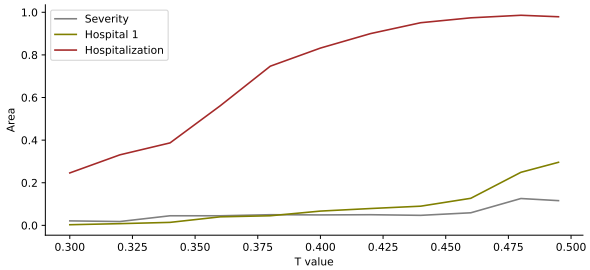
1 Additional Results

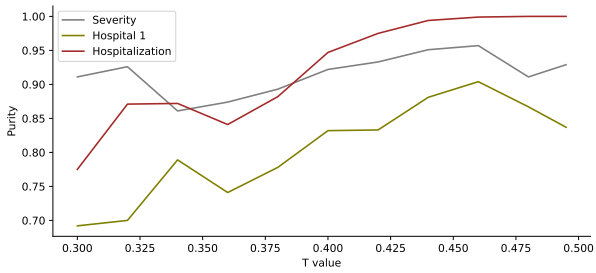
Next we present additional results, divided by experiments.

1.1 Footprint Analysis

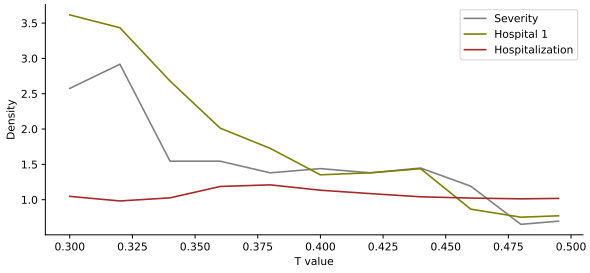
Figure 1 shows how the purity, density and area of the hard footprints change with T values variation. Figure 2 shows the how the easy and hard footprints change according to some of the T values explored. As the T increases, we expect that more instances are considered hard (and easy too). This is true for the dataset *Hospital 1* that shows an intermediate hardness profile. It is possible to see that for each T value both footprints have their size increased to encompass new instances. In the other profiles only the hard footprints has a significant increase, although this happens for different reasons. In *Severity* all of the easy instances are already present from the first footprints generated. While for the *Hospitalization* dataset, even for low values of T the easy footprint is not formed.



(a) Area



(b) Purity



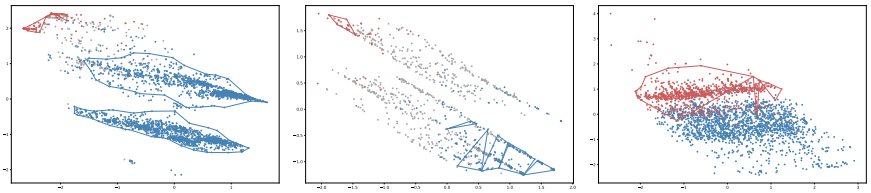
(c) Density

Fig. 1. Hard and easy footprints in datasets of distinct hardness profile. Footprints consider different values of T, increasing with a step = 0.04.

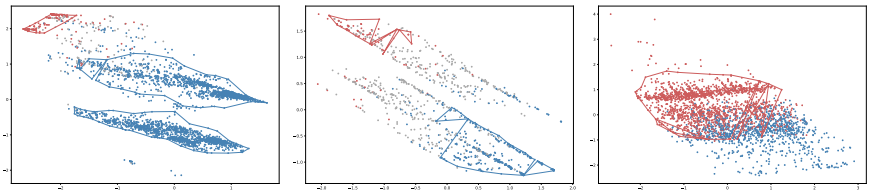
1.2 Visually inspecting the hardness embedding

In this section we extend the analyse inside subgroups of the instance space for *Severity* and *Hospital 1* datasets.

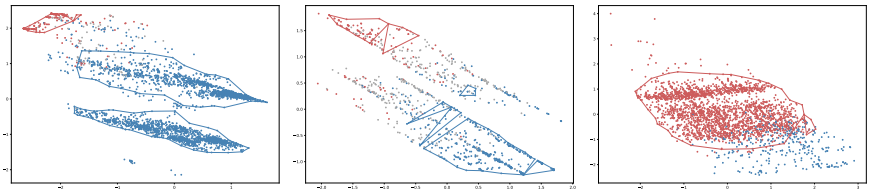
***Severity* dataset** Figure 3a and 3b presents the IS colored by some of the meta-features employed in the framework and figure 3c shows the IS colored by the original class as well as the four groups delineated.



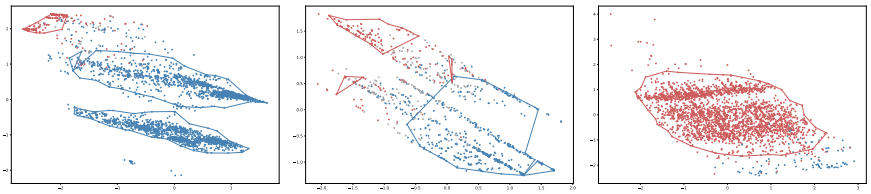
(a) *Severity* - $T = 0.032$ (b) *Hospital 1* - $T = 0.032$ (c) *Hospitalization* - $T = 0.032$



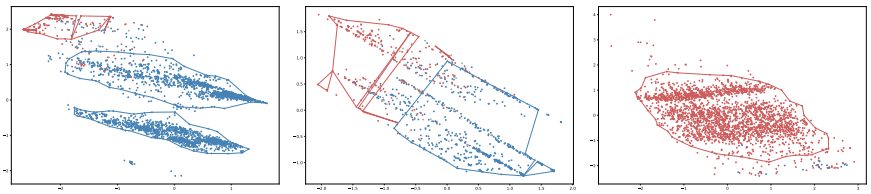
(d) *Severity* - $T = 0.036$ (e) *Hospital 1* - $T = 0.036$ (f) *Hospitalization* - $T = 0.036$



(g) *Severity* - $T = 0.040$ (h) *Hospital 1* - $T = 0.040$ (i) *Hospitalization* - $T = 0.040$

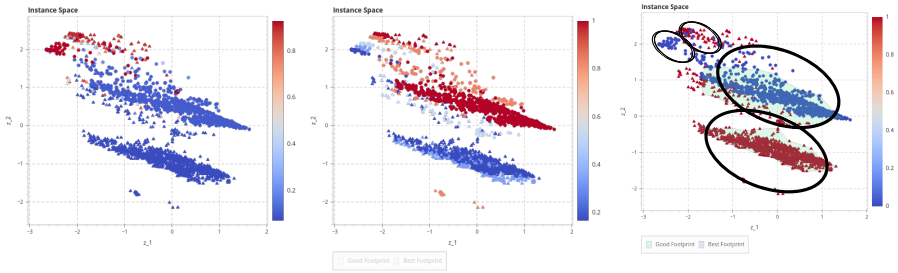


(j) *Severity* - $T = 0.044$ (k) *Hospital 1* - $T = 0.044$ (l) *Hospitalization* - $T = 0.044$



(m) *Severity* - $T = 0.048$ (n) *Hospital 1* - $T = 0.048$ (o) *Hospitalization* - $T = 0.048$

Fig. 2. Hard and easy footprints in datasets of distinct hardness profile. Footprints consider different values of T, increasing with a step = 0.04.



(a) *Severity* IS colored by feature CL

(b) *Severity* IS colored by feature TD_P

(c) *Severity* IS colored by original class.

Fig. 3. IS of *Severity* dataset colored according to meta-feature values e original class values. In (c) we highlight four groups formed in the IS.

Next we filtered instances inside each group using their meta-feature values. Table 1 presents meta-features used in this step, as well as a summary of feature values in each group.

Group 1 contains severe features that are easy do classify. Analysing feature values we can see that three attributes are strongly correlated with the severe class: low oxygen saturation, respiratory distress and other risks. Indeed, all instances inside group 1 contain at least one of these symptoms or comorbidities. This is also reveled by meta-feature values since this group presents low TD_P values, meaning that when one of these attributes are present the models can easily classify the instance as severe, on the other hand if they are not present another attributes should be take on account. This is why instances in group 4 show a higher TD_P.

For group 2 we add to the previous analysis an interpretation of the meta-features. This group is caracterized by high values of CL meaning they have a low probablity of belonging tho their own classes, which in some cases proved to be true after further investigations. The TD_P are low for these instances, since they have attributes strongly correlated with the opposite class, in this way they are classified in the opposite class, showing a high hardness level.

Group 3 individuals developed a severe condition although they did not present the most correlate symptoms to severity. This is why this group presents high values of TD_P, when these attributes are not present, the decision tree includes other ramifications to classify such instances. Analysing the original data base we looked for possible reasons why this patients developed a severe condition without presenting some important severe symptoms. Three observations are mislabeled again, while 27 were hospitalizad between 10 -14 days. This last group can be considered instances in the overlap regions since they are between the two classes, and would be considered non-severe if we had adopted an slightly different proxy to define severity. A group of 78 patients progressed to death after hospitalization, for them the number of days between test and hospitalization is in average 5, so they could have developed the symptoms after

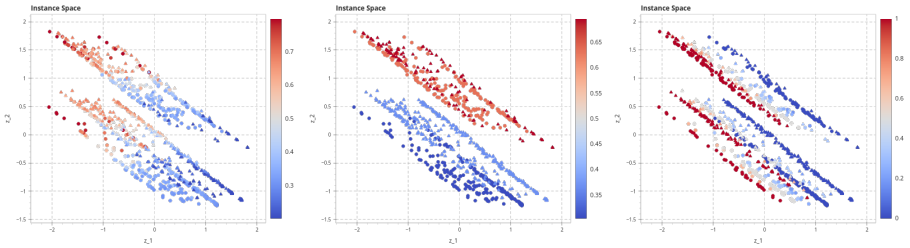
Table 1. Summary of subgroups from dataset *Severity* with meta-features threshold used to filter data and feature values inside each group.

	Group 1	Group 2	Group 3	Group 4
Number of instances	1380	90	124	1529
Original class	Severe	Non-severe	Non-severe	Severe
Hardness level	<0.4	>0.6	>0.6	<0.4
Feature CL	<0.4	>0.6	>0.6	<0.4
Feature TD_P	<0.4	<0.4	>0.6	<0.6
Fever	0.53	0.53	0.69	0.69
Cough	0.72	0.78	0.85	0.81
Sore throat	0.17	0.18	0.35	0.59
Dyspnea	0.83	0.81	0.50	0.28
Respiratory distress	0.64	0.62	0	0
Low oxygen saturation	0.84	0.87	0	0
Diarrhea	0.09	0.11	0	0
Vomit	0.06	0.07	0	0
Other symptoms	0.53	0.63	0.80	0.76
Chronic cardiovascular disease	0.5	0.42	0.27	0.12
Immunodeficiency	0.03	0.02	0	0
Diabetes mellitus	0.40	0.37	0.19	0.09
Obesity	0.08	0.11	0	0
Other risks	0.54	0.42	0	0
Chronic respiratory disease	0.01	0.01	0.04	0.04
Sex (female)	0.41	0.46	0.38	0.54
Age (mean)	66.0	54.54	52.59	40.39
Age (min - max)	6 - 108	2 - 92	2 - 94	0 - 86

testing. We do not discharge the possibility of mistakes in data collection since the forms were first filled by hand when the patient went to the pharmacy of hospital for testing.

Inspecting Group 4, we see that these patients do not present any symptom correlated with severity and consequently they are correctly classified.

***Hospital 1* dataset** Figure 4 presents the IS colored by some of the meta-features employed in the framework.



(a) *Hospital 1* IS colored by feature CL

(b) *Hospital 1* IS colored by feature DCP

(c) *Hospital 1* IS colored by feature $N1$.

Fig. 4. IS of *Severity* IS colored according to meta-feature values.

Contrasting meta-features values we identified six groups inside the hardness profile and proceed a further inspection to obtain insights about how and why instances in each group are difficulty to classify. We filtered instances inside each group using their meta-feature values. Table 2 presents meta-features used in this step.

Table 2. Summary of subgroups from dataset *Severity* with meta-features threshold used to filter data and feature values inside each group. The value *0* for the original class corresponds to *non-severe* class and the value *1* to the *severe* class.

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Number of instances	8	12	30	30	12	7
Original class	0	1	0	1	0	1
Feature CL	>0.6	>0.6	>0.6	<0.6	>0.6	>0.6
Feature DCP	<0.4	<0.4	>0.6	<0.6	>0.6	<0.6
Feature $N1$	>0.6	<0.6	>0.6	<0.6	<0.4	<0.4
Age (min - max)	52 - 58	62 - 83	62 - 87	27 - 61	62 - 89	42 - 61

In this analysis all groups have hardness level >0.6, the same is true for feature CL values. Groups 1 and 3 have already been discussed in the main paper. For other groups it the explanations are not so clear, although interesting questions came out through IS analysis and raw data base inspection. For group 2 patients are hospitalized without an aggravated clinical condition, and their condition worse on the following days. The question here is why patients are hospitalized if they do not have an aggravated clinical condition? One possible reason may be the group age, since they are older the hospitalization decision may have been made since the doctor was already expecting a severe outcome. Here it is important to point out that this data base comes from a private hospital in the city of São Paulo where more resources were available during the pandemic.

Inside group 4 an interesting phenomenon is that some patients are hospitalized without their blood tests pointint out an aggravated condition, as in the group 2. In some days they have a significant worsening and are moved to the ICU. From the data we have access to it is impossible to guess the reason. Maybe they can receive a similar explanation of group 2 although they are younger in group 4. We also can prospect the possibility that they were hospitalized due to other health conditions, like a surgery for example, being the COVID with a consequence of the hospitalization and not its cause.

For groups 5 and 6 we could not grasp a clear patter between instances. This instances are characterized by high values of feature $N1$ meaning that they are not completely surrounded by instances on the opposite class, but are probably located in the border of the classes.