lab04

November 28, 2025

[ ]:
```
%pip install ucimlrepo pyAgrum
```

```
Requirement already satisfied: ucimlrepo in /home/optert/ML-labs-
Tert/.venv/lib/python3.11/site-packages (0.0.7)
Requirement already satisfied: pyAgrum in /home/optert/ML-labs-
Tert/.venv/lib/python3.11/site-packages (2.3.0)
Requirement already satisfied: pandas>=1.0.0 in /home/optert/ML-labs-
Tert/.venv/lib/python3.11/site-packages (from ucimlrepo) (2.3.3)
Requirement already satisfied: certifi>=2020.12.5 in /home/optert/ML-labs-
Tert/.venv/lib/python3.11/site-packages (from ucimlrepo) (2025.10.5)
Requirement already satisfied: numpy in /home/optert/ML-labs-
Tert/.venv/lib/python3.11/site-packages (from pyAgrum) (1.26.4)
Requirement already satisfied: matplotlib in /home/optert/ML-labs-
Tert/.venv/lib/python3.11/site-packages (from pyAgrum) (3.10.7)
Requirement already satisfied: pydot in /home/optert/ML-labs-
Tert/.venv/lib/python3.11/site-packages (from pyAgrum) (4.0.1)
Requirement already satisfied: python-dateutil>=2.8.2 in /home/optert/ML-labs-
Tert/.venv/lib/python3.11/site-packages (from pandas>=1.0.0->ucimlrepo)
(2.9.0.post0)
Requirement already satisfied: pytz>=2020.1 in /home/optert/ML-labs-
Tert/.venv/lib/python3.11/site-packages (from pandas>=1.0.0->ucimlrepo) (2025.2)
Requirement already satisfied: tzdata>=2022.7 in /home/optert/ML-labs-
Tert/.venv/lib/python3.11/site-packages (from pandas>=1.0.0->ucimlrepo) (2025.2)
Requirement already satisfied: six>=1.5 in /home/optert/ML-labs-
Tert/.venv/lib/python3.11/site-packages (from python-
dateutil>=2.8.2->pandas>=1.0.0->ucimlrepo) (1.17.0)
Requirement already satisfied: contourpy>=1.0.1 in /home/optert/ML-labs-
Tert/.venv/lib/python3.11/site-packages (from matplotlib->pyAgrum) (1.3.3)
Requirement already satisfied: cycler>=0.10 in /home/optert/ML-labs-
Tert/.venv/lib/python3.11/site-packages (from matplotlib->pyAgrum) (0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in /home/optert/ML-labs-
Tert/.venv/lib/python3.11/site-packages (from matplotlib->pyAgrum) (4.60.1)
Requirement already satisfied: kiwisolver>=1.3.1 in /home/optert/ML-labs-
Tert/.venv/lib/python3.11/site-packages (from matplotlib->pyAgrum) (1.4.9)
Requirement already satisfied: packaging>=20.0 in /home/optert/ML-labs-
Tert/.venv/lib/python3.11/site-packages (from matplotlib->pyAgrum) (25.0)
Requirement already satisfied: pillow>=8 in /home/optert/ML-labs-
Tert/.venv/lib/python3.11/site-packages (from matplotlib->pyAgrum) (12.0.0)
```

```
Requirement already satisfied: pyparsing>=3 in /home/optert/ML-labs-
Tert/.venv/lib/python3.11/site-packages (from matplotlib->pyAgrum) (3.2.5)
Note: you may need to restart the kernel to use updated packages.
```

[3]:
```python
import pandas as pd
import pyagrum as gum
import pyagrum.lib.notebook as gnb
import numpy as np
from ucimlrepo import fetch_ucirepo
from sklearn.preprocessing import LabelEncoder, OrdinalEncoder
```

[4]:
```python
# fetch dataset
student_performance = fetch_ucirepo(id=320)

# data (as pandas dataframes)
X = student_performance.data.features
y = student_performance.data.targets

# metadata
print(student_performance.metadata)

# variable information
print(student_performance.variables)
```

```
{'uci_id': 320, 'name': 'Student Performance', 'repository_url':
'https://archive.ics.uci.edu/dataset/320/student+performance', 'data_url':
'https://archive.ics.uci.edu/static/public/320/data.csv', 'abstract': 'Predict
student performance in secondary education (high school). ', 'area': 'Social
Science', 'tasks': ['Classification', 'Regression'], 'characteristics':
['Multivariate'], 'num_instances': 649, 'num_features': 30, 'feature_types':
['Integer'], 'demographics': ['Sex', 'Age', 'Other', 'Education Level',
'Occupation'], 'target_col': ['G1', 'G2', 'G3'], 'index_col': None,
'has_missing_values': 'no', 'missing_values_symbol': None,
'year_of_dataset_creation': 2008, 'last_updated': 'Fri Jan 05 2024',
'dataset_doi': '10.24432/C5TG7T', 'creators': ['Paulo Cortez'], 'intro_paper':
{'ID': 360, 'type': 'NATIVE', 'title': 'Using data mining to predict secondary
school student performance', 'authors': 'P. Cortez, A. M. G. Silva', 'venue':
'Proceedings of 5th Annual Future Business Technology Conference', 'year': 2008,
'journal': None, 'DOI': None, 'URL': 'https://www.semanticscholar.org/paper/61d4
68d5254730bbecf822c6b60d7d6595d9889c', 'sha': None, 'corpus': '16621299',
'arxiv': None, 'mag': None, 'acl': None, 'pmid': None, 'pmcid': None},
'additional_info': {'summary': 'This data approach student achievement in
secondary education of two Portuguese schools. The data attributes include
student grades, demographic, social and school related features) and it was
collected by using school reports and questionnaires. Two datasets are provided
regarding the performance in two distinct subjects: Mathematics (mat) and
Portuguese language (por). In [Cortez and Silva, 2008], the two datasets were
modeled under binary/five-level classification and regression tasks. Important
```

note: the target attribute G3 has a strong correlation with attributes G2 and G1. This occurs because G3 is the final year grade (issued at the 3rd period), while G1 and G2 correspond to the 1st and 2nd period grades. It is more difficult to predict G3 without G2 and G1, but such prediction is much more useful (see paper source for more details).', 'purpose': None, 'funded_by': None, 'instances_represent': None, 'recommended_data_splits': None, 'sensitive_data': None, 'preprocessing_description': None, 'variable_info': "# Attributes for both student-mat.csv (Math course) and student-por.csv (Portuguese language course) datasets:\r\n1 school - student's school (binary: 'GP' - Gabriel Pereira or 'MS' - Mousinho da Silveira)\r\n2 sex - student's sex (binary: 'F' - female or 'M' - male)\r\n3 age - student's age (numeric: from 15 to 22)\r\n4 address - student's home address type (binary: 'U' - urban or 'R' - rural)\r\n5 famsize - family size (binary: 'LE3' - less or equal to 3 or 'GT3' - greater than 3)\r\n6 Pstatus - parent's cohabitation status (binary: 'T' - living together or 'A' - apart)\r\n7 Medu - mother's education (numeric: 0 - none, 1 - primary education (4th grade), 2 â€" 5th to 9th grade, 3 â€" secondary education or 4 â€" higher education)\r\n8 Fedu - father's education (numeric: 0 - none, 1 - primary education (4th grade), 2 â€" 5th to 9th grade, 3 â€" secondary education or 4 â€" higher education)\r\n9 Mjob - mother's job (nominal: 'teacher', 'health' care related, civil 'services' (e.g. administrative or police), 'at_home' or 'other')\r\n10 Fjob - father's job (nominal: 'teacher', 'health' care related, civil 'services' (e.g. administrative or police), 'at_home' or 'other')\r\n11 reason - reason to choose this school (nominal: close to 'home', school 'reputation', 'course' preference or 'other')\r\n12 guardian - student's guardian (nominal: 'mother', 'father' or 'other')\r\n13 traveltime - home to school travel time (numeric: 1 - <15 min., 2 - 15 to 30 min., 3 - 30 min. to 1 hour, or 4 - >1 hour)\r\n14 studytime - weekly study time (numeric: 1 - <2 hours, 2 - 2 to 5 hours, 3 - 5 to 10 hours, or 4 - >10 hours)\r\n15 failures - number of past class failures (numeric: n if 1<=n<3, else 4)\r\n16 schoolsup - extra educational support (binary: yes or no)\r\n17 famsup - family educational support (binary: yes or no)\r\n18 paid - extra paid classes within the course subject (Math or Portuguese) (binary: yes or no)\r\n19 activities - extra-curricular activities (binary: yes or no)\r\n20 nursery - attended nursery school (binary: yes or no)\r\n21 higher - wants to take higher education (binary: yes or no)\r\n22 internet - Internet access at home (binary: yes or no)\r\n23 romantic - with a romantic relationship (binary: yes or no)\r\n24 famrel - quality of family relationships (numeric: from 1 - very bad to 5 - excellent)\r\n25 freetime - free time after school (numeric: from 1 - very low to 5 - very high)\r\n26 goout - going out with friends (numeric: from 1 - very low to 5 - very high)\r\n27 Dalc - workday alcohol consumption (numeric: from 1 - very low to 5 - very high)\r\n28 Walc - weekend alcohol consumption (numeric: from 1 - very low to 5 - very high)\r\n29 health - current health status (numeric: from 1 - very bad to 5 - very good)\r\n30 absences - number of school absences (numeric: from 0 to 93)\r\n\r\n# these grades are related with the course subject, Math or Portuguese:\r\n31 G1 - first period grade (numeric: from 0 to 20)\r\n31 G2 - second period grade (numeric: from 0 to 20)\r\n32 G3 - final grade (numeric: from 0 to 20, output target)", 'citation': None}}

```
          name     role         type      demographic  \
```

0	school	Feature	Categorical	None
1	sex	Feature	Binary	Sex
2	age	Feature	Integer	Age
3	address	Feature	Categorical	None
4	famsize	Feature	Categorical	Other
5	Pstatus	Feature	Categorical	Other
6	Medu	Feature	Integer	Education Level
7	Fedu	Feature	Integer	Education Level
8	Mjob	Feature	Categorical	Occupation
9	Fjob	Feature	Categorical	Occupation
10	reason	Feature	Categorical	None
11	guardian	Feature	Categorical	None
12	traveltime	Feature	Integer	None
13	studytime	Feature	Integer	None
14	failures	Feature	Integer	None
15	schoolsup	Feature	Binary	None
16	famsup	Feature	Binary	None
17	paid	Feature	Binary	None
18	activities	Feature	Binary	None
19	nursery	Feature	Binary	None
20	higher	Feature	Binary	None
21	internet	Feature	Binary	None
22	romantic	Feature	Binary	None
23	famrel	Feature	Integer	None
24	freetime	Feature	Integer	None
25	goout	Feature	Integer	None
26	Dalc	Feature	Integer	None
27	Walc	Feature	Integer	None
28	health	Feature	Integer	None
29	absences	Feature	Integer	None
30	G1	Target	Categorical	None
31	G2	Target	Categorical	None
32	G3	Target	Integer	None

	description	units	missing_values
0	student's school (binary: 'GP' - Gabriel Perei…	None	no
1	student's sex (binary: 'F' - female or 'M' - m…	None	no
2	student's age (numeric: from 15 to 22)	None	no
3	student's home address type (binary: 'U' - urb…	None	no
4	family size (binary: 'LE3' - less or equal to …	None	no
5	parent's cohabitation status (binary: 'T' - li…	None	no
6	mother's education (numeric: 0 - none, 1 - pr…	None	no
7	father's education (numeric: 0 - none, 1 - pr…	None	no
8	mother's job (nominal: 'teacher', 'health' car…	None	no
9	father's job (nominal: 'teacher', 'health' car…	None	no
10	reason to choose this school (nominal: close t…	None	no
11	student's guardian (nominal: 'mother', 'father…	None	no
12	home to school travel time (numeric: 1 - <15 m…	None	no

```
13  weekly study time (numeric: 1 - <2 hours, 2 - …  None            no
14  number of past class failures (numeric: n if 1…  None            no
15      extra educational support (binary: yes or no)  None            no
16     family educational support (binary: yes or no)  None            no
17  extra paid classes within the course subject (…  None            no
18    extra-curricular activities (binary: yes or no)  None            no
19        attended nursery school (binary: yes or no)  None            no
20  wants to take higher education (binary: yes or…  None            no
21        Internet access at home (binary: yes or no)  None            no
22   with a romantic relationship (binary: yes or no)  None            no
23  quality of family relationships (numeric: from…  None            no
24  free time after school (numeric: from 1 - very…  None            no
25  going out with friends (numeric: from 1 - very…  None            no
26  workday alcohol consumption (numeric: from 1 -…  None            no
27  weekend alcohol consumption (numeric: from 1 -…  None            no
28  current health status (numeric: from 1 - very …  None            no
29  number of school absences (numeric: from 0 to 93)  None            no
30         first period grade (numeric: from 0 to 20)  None            no
31        second period grade (numeric: from 0 to 20)  None            no
32  final grade (numeric: from 0 to 20, output tar…  None            no
```

[5]:
```
X.head()
```

[5]:
```
  school sex  age address famsize Pstatus  Medu  Fedu     Mjob      Fjob  …  \
0     GP   F   18       U     GT3       A     4     4  at_home   teacher  …
1     GP   F   17       U     GT3       T     1     1  at_home     other  …
2     GP   F   15       U     LE3       T     1     1  at_home     other  …
3     GP   F   15       U     GT3       T     4     2   health  services  …
4     GP   F   16       U     GT3       T     3     3    other     other  …

  higher internet  romantic  famrel  freetime goout Dalc Walc health absences
0    yes       no        no       4         3     4    1    1      3        4
1    yes      yes        no       5         3     3    1    1      3        2
2    yes      yes        no       4         3     2    2    3      3        6
3    yes      yes       yes       3         2     2    1    1      5        0
4    yes       no        no       4         3     2    1    2      5        0

[5 rows x 30 columns]
```

[6]:
```
X.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 649 entries, 0 to 648
Data columns (total 30 columns):
 #   Column      Non-Null Count  Dtype
---  ------      --------------  -----
 0   school      649 non-null    object
 1   sex         649 non-null    object
```

```
 2   age          649 non-null    int64
 3   address      649 non-null    object
 4   famsize      649 non-null    object
 5   Pstatus      649 non-null    object
 6   Medu         649 non-null    int64
 7   Fedu         649 non-null    int64
 8   Mjob         649 non-null    object
 9   Fjob         649 non-null    object
 10  reason       649 non-null    object
 11  guardian     649 non-null    object
 12  traveltime   649 non-null    int64
 13  studytime    649 non-null    int64
 14  failures     649 non-null    int64
 15  schoolsup    649 non-null    object
 16  famsup       649 non-null    object
 17  paid         649 non-null    object
 18  activities   649 non-null    object
 19  nursery      649 non-null    object
 20  higher       649 non-null    object
 21  internet     649 non-null    object
 22  romantic     649 non-null    object
 23  famrel       649 non-null    int64
 24  freetime     649 non-null    int64
 25  goout        649 non-null    int64
 26  Dalc         649 non-null    int64
 27  Walc         649 non-null    int64
 28  health       649 non-null    int64
 29  absences     649 non-null    int64
dtypes: int64(13), object(17)
memory usage: 152.2+ KB
```

[7]:
```
X.isna().sum()
```

[7]:
```
school        0
sex           0
age           0
address       0
famsize       0
Pstatus       0
Medu          0
Fedu          0
Mjob          0
Fjob          0
reason        0
guardian      0
traveltime    0
studytime     0
```

```
failures      0
schoolsup     0
famsup        0
paid          0
activities    0
nursery       0
higher        0
internet      0
romantic      0
famrel        0
freetime      0
goout         0
Dalc          0
Walc          0
health        0
absences      0
dtype: int64
```

[8]:
```
y.head()
```

[8]:
```
   G1  G2  G3
0   0  11  11
1   9  11  11
2  12  13  12
3  14  14  14
4  11  13  13
```

FinalPass G3: 1 — , 0 — . : 549 (84.6%) 100 (15.4%).

[9]:
```
#
g3 = y['G3']

#        : 1 =         (>=10), 0 =
FinalPass = (g3 >= 10).astype(int)

#
FinalPass.value_counts(), FinalPass.value_counts(normalize=True)
```

[9]:
```
(G3
 1    549
 0    100
 Name: count, dtype: int64,
 G3
 1    0.845917
 0    0.154083
 Name: proportion, dtype: float64)
```

[11]:
```
FinalPass.sample(10)
```

[11]:
```
416    1
627    1
235    1
302    1
598    1
589    1
169    1
638    1
582    0
149    1
Name: G3, dtype: int64
```

: (G1, G2), (studytime, absences, goout, Dalc, Walc), .

[14]:
```
# ---    2 ---
#
# (   G1   G2   y,       -   X)

features = pd.DataFrame({
    "G1": y["G1"],
    "G2": y["G2"],
    "studytime": X["studytime"],
    "absences": X["absences"],
    "goout": X["goout"],
    "Dalc": X["Dalc"],
    "Walc": X["Walc"],
    "health": X["health"],
    "famsup": X["famsup"],
    "schoolsup": X["schoolsup"]
})

features.head()
```

[14]:

	G1	G2	studytime	absences	goout	Dalc	Walc	health	famsup	schoolsup
0	0	11	2	4	4	1	1	3	no	yes
1	9	11	2	2	3	1	1	3	yes	no
2	12	13	2	6	2	2	3	3	no	yes
3	14	14	3	0	2	1	1	5	yes	no
4	11	13	2	0	2	1	2	5	yes	no

[16]:
```
features.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 649 entries, 0 to 648
Data columns (total 10 columns):
```

```
 #   Column     Non-Null Count  Dtype
---  ------     --------------  -----
 0   G1         649 non-null    int64
 1   G2         649 non-null    int64
 2   studytime  649 non-null    int64
 3   absences   649 non-null    int64
 4   goout      649 non-null    int64
 5   Dalc       649 non-null    int64
 6   Walc       649 non-null    int64
 7   health     649 non-null    int64
 8   famsup     649 non-null    object
 9   schoolsup  649 non-null    object
dtypes: int64(8), object(2)
memory usage: 50.8+ KB
```

[ ]:
```
['famsup'].unique()
```

[ ]:
```
array(['no', 'yes'], dtype=object)
```

[17]:
```
#
disc = features.copy()

disc["G1_cat"] = pd.cut(disc["G1"], bins=[-1, 9, 14, 20],
                        labels=["low", "mid", "high"])
disc["G2_cat"] = pd.cut(disc["G2"], bins=[-1, 9, 14, 20],
                        labels=["low", "mid", "high"])

disc["abs_cat"] = pd.cut(disc["absences"], bins=[-1, 2, 7, 100],
                         labels=["low", "mid", "high"])

disc["famsup_cat"] = disc["famsup"].map({"no": 0, "yes": 1})
disc["schoolsup_cat"] = disc["schoolsup"].map({"no": 0, "yes": 1})

disc[["G1_cat", "G2_cat", "abs_cat", "famsup_cat", "schoolsup_cat"]].head()
```

[17]:

	G1_cat	G2_cat	abs_cat	famsup_cat	schoolsup_cat
0	low	mid	mid	0	1
1	low	mid	low	1	0
2	mid	mid	mid	0	1
3	mid	mid	low	1	0
4	mid	mid	low	1	0

[18]:
```
#
#                                   FinalPass

bn_data = pd.DataFrame({
    "G1_cat": disc["G1_cat"].astype(str),
```

```
    "G2_cat": disc["G2_cat"].astype(str),
    "abs_cat": disc["abs_cat"].astype(str),
    "studytime": disc["studytime"].astype(str),
    "goout": disc["goout"].astype(str),
    "Dalc": disc["Dalc"].astype(str),
    "Walc": disc["Walc"].astype(str),
    "health": disc["health"].astype(str),
    "famsup_cat": disc["famsup_cat"].astype(str),
    "schoolsup_cat": disc["schoolsup_cat"].astype(str),
    "FinalPass": FinalPass.astype(str)
})

bn_data.head()
```

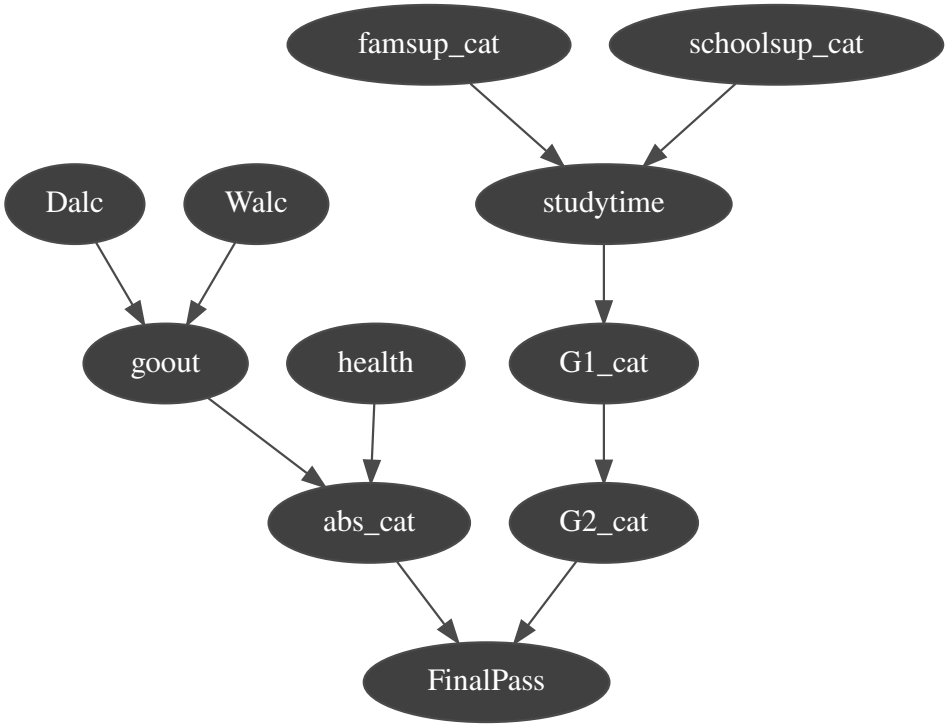
[18]:

	G1_cat	G2_cat	abs_cat	studytime	goout	Dalc	Walc	health	famsup_cat	schoolsup_cat	FinalPass
0	low	mid	mid	2	4	1	1	3	0	1	1
1	low	mid	low	2	3	1	1	3	1	0	1
2	mid	mid	mid	2	2	2	3	3	0	1	1
3	mid	mid	low	3	2	1	1	5	1	0	1
4	mid	mid	low	2	2	1	2	5	1	0	1

[21]:
```
# ---        DAG (                  ) ---

bn = gum.BayesNet('StudentPerformance_New')

#                          bn_data
card = {c: int(bn_data[c].nunique()) for c in bn_data.columns}

#
for var in bn_data.columns:
    lv = gum.LabelizedVariable(var, var, card[var])
    bn.add(lv)

#                    (               )
arcs = [
    #
    ("studytime", "G1_cat"),
    ("G1_cat", "G2_cat"),
    ("G2_cat", "FinalPass"),
```

```
    #
    ("goout", "abs_cat"),
    ("health", "abs_cat"),
    ("abs_cat", "FinalPass"),

    #      →
    ("Dalc", "goout"),
    ("Walc", "goout"),

    #          /    →
    ("famsup_cat", "studytime"),
    ("schoolsup_cat", "studytime"),
]

#
for u, v in arcs:
    bn.addArc(u, v)

print("Nodes in DAG:", bn.names())
print("Arcs in DAG:", bn.arcs())

#
gnb.showBN(bn)
```

```
Nodes in DAG: {'studytime', 'abs_cat', 'Dalc', 'G2_cat', 'Walc', 'FinalPass',
'famsup_cat', 'goout', 'health', 'G1_cat', 'schoolsup_cat'}
Arcs in DAG: {(0, 1), (9, 3), (2, 10), (5, 4), (6, 4), (4, 2), (3, 0), (8, 3),
(1, 10), (7, 2)}
```



[24]:
```
# ---                          bn_data    pyAgrum ---

from sklearn.preprocessing import LabelEncoder

bn_data = disc.copy()
bn_data["FinalPass"] = FinalPass

#                  (          )
for col in bn_data.columns:
    bn_data[col] = bn_data[col].astype(str)

#                    LabelEncoder
for col in bn_data.columns:
    le = LabelEncoder()
    bn_data[col] = le.fit_transform(bn_data[col])

#       ,
bn_data = bn_data.astype(int)

bn_data.head()
```

[24]:

	G1	G2	studytime	absences	goout	Dalc	Walc	health	famsup	schoolsup	\
0	0	2	1	18	3	0	0	2	0	1	

```
1  16   2          1        10      2     0     0       2       1          0
2   3   4          1        20      1     1     2       2       0          1
3   5   5          2         0      1     0     0       4       1          0
4   2   4          1         0      1     0     1       4       1          0
```

```
   G1_cat  G2_cat  abs_cat  famsup_cat  schoolsup_cat  FinalPass
0       1       2        2           0              1          1
1       1       2        1           1              0          1
2       2       2        2           0              1          1
3       2       2        1           1              0          1
4       2       2        1           1              0          1
```

[25]:
```
learner = gum.BNLearner(bn_data, bn)
learner.useSmoothingPrior(1)
params = learner.learnParameters(bn.dag())
```

[26]:
```
#
for node in params.names():
    print(f"CPD of {node}:\n{params.cpt(node)}\n")
```

```
CPD of studytime:

             ||  studytime                          |
famsup|school||0        |1        |2        |3        |
------|------||---------|---------|---------|---------|
0     |0     || 0.4407  | 0.3898  | 0.1314  | 0.0381  |
1     |0     || 0.2776  | 0.4958  | 0.1643  | 0.0623  |
0     |1     || 0.1304  | 0.6522  | 0.1304  | 0.0870  |
1     |1     || 0.2075  | 0.5094  | 0.1698  | 0.1132  |


CPD of abs_cat:

             ||  abs_cat                   |
goout |health||0        |1        |2        |
------|------||---------|---------|---------|
0     |0     || 0.1250  | 0.5000  | 0.3750  |
1     |0     || 0.2381  | 0.5238  | 0.2381  |
2     |0     || 0.1852  | 0.5556  | 0.2593  |
3     |0     || 0.2581  | 0.4516  | 0.2903  |
4     |0     || 0.3889  | 0.3333  | 0.2778  |
0     |1     || 0.2000  | 0.5000  | 0.3000  |
[…13 more line(s) …]
4     |3     || 0.2222  | 0.5000  | 0.2778  |
0     |4     || 0.2174  | 0.5217  | 0.2609  |
1     |4     || 0.2000  | 0.5538  | 0.2462  |
2     |4     || 0.1324  | 0.5882  | 0.2794  |
```

```
3     |4     || 0.1964  | 0.5357  | 0.2679  |
4     |4     || 0.2500  | 0.5385  | 0.2115  |
```

CPD of Dalc:

```
  Dalc                                          |
0        |1        |2        |3        |4        |
---------|---------|---------|---------|---------|
 0.6911  | 0.1865  | 0.0673  | 0.0275  | 0.0275  |
```

CPD of G2_cat:

```
      ||  G2_cat                    |
G1_cat||0        |1        |2        |
------||---------|---------|---------|
0     || 0.7976  | 0.0119  | 0.1905  |
1     || 0.0063  | 0.6750  | 0.3187  |
2     || 0.0797  | 0.0942  | 0.8261  |
```

CPD of Walc:

```
  Walc                                          |
0        |1        |2        |3        |4        |
---------|---------|---------|---------|---------|
 0.3792  | 0.2309  | 0.1850  | 0.1346  | 0.0703  |
```

CPD of FinalPass:

```
             ||  FinalPass        |
G2_cat|abs_ca||0        |1        |
------|------||---------|---------|
0     |0     || 0.0714  | 0.9286  |
1     |0     || 0.6341  | 0.3659  |
2     |0     || 0.0429  | 0.9571  |
0     |1     || 0.0145  | 0.9855  |
1     |1     || 0.6377  | 0.3623  |
2     |1     || 0.0342  | 0.9658  |
0     |2     || 0.0476  | 0.9524  |
1     |2     || 0.5366  | 0.4634  |
2     |2     || 0.0278  | 0.9722  |
```

CPD of famsup_cat:

```
  famsup_cat       |
0        |1        |
---------|---------|
 0.3871  | 0.6129  |
```

CPD of goout:

```
             ||  goout                                          |
Dalc  |Walc  ||0        |1        |2        |3        |4        |
------|------||---------|---------|---------|---------|---------|
0     |0     || 0.1382  | 0.3008  | 0.3008  | 0.1748  | 0.0854  |
1     |0     || 0.1250  | 0.3750  | 0.2500  | 0.1250  | 0.1250  |
2     |0     || 0.1667  | 0.1667  | 0.3333  | 0.1667  | 0.1667  |
3     |0     || 0.1667  | 0.1667  | 0.1667  | 0.3333  | 0.1667  |
4     |0     || 0.1667  | 0.1667  | 0.3333  | 0.1667  | 0.1667  |
0     |1     || 0.0508  | 0.2542  | 0.3898  | 0.1610  | 0.1441  |
[…13 more line(s) …]
4     |3     || 0.2000  | 0.2000  | 0.2000  | 0.2000  | 0.2000  |
0     |4     || 0.1000  | 0.1000  | 0.2000  | 0.1000  | 0.5000  |
1     |4     || 0.0833  | 0.1667  | 0.0833  | 0.1667  | 0.5000  |
2     |4     || 0.1176  | 0.0588  | 0.1176  | 0.3529  | 0.3529  |
3     |4     || 0.0909  | 0.1818  | 0.1818  | 0.2727  | 0.2727  |
4     |4     || 0.0500  | 0.1000  | 0.1500  | 0.1500  | 0.5500  |
```

CPD of health:

```
  health                                          |
0        |1        |2        |3        |4        |
---------|---------|---------|---------|---------|
 0.1391  | 0.1208  | 0.1911  | 0.1667  | 0.3823  |
```

CPD of G1_cat:

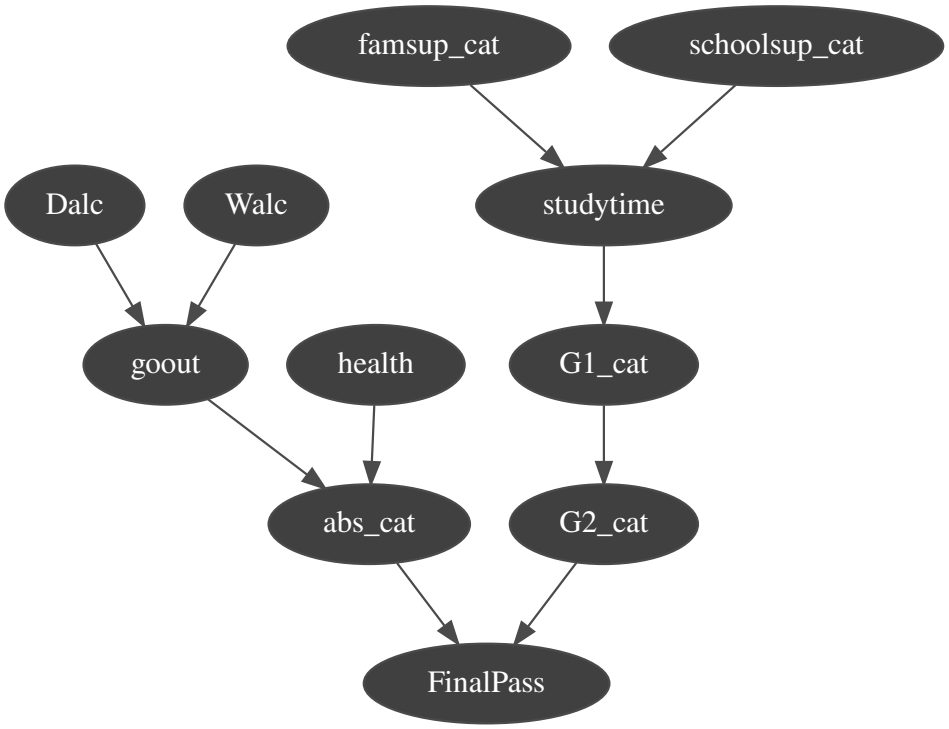
```
      ||  G1_cat                    |
studyt||0        |1        |2        |
------||---------|---------|---------|
0     || 0.0512  | 0.3721  | 0.5767  |
1     || 0.1396  | 0.2208  | 0.6396  |
2     || 0.2200  | 0.1000  | 0.6800  |
3     || 0.2368  | 0.0789  | 0.6842  |
```

CPD of schoolsup_cat:

```
  schoolsup_cat    |
```

```
0         |1         |
----------|----------|
 0.8940   | 0.1060   |
```

[27]:
```
gnb.showBN(bn)
```



0.0.1

.

:

1. – , , .
   `FinalPass`.
2. – , , .
   `FinalPass` .
3. – , .
   , .

,

.

[31]:
```
# ---        (                      ) ---

ie = gum.LazyPropagation(params)

# 3          ,

evidences = [
    # 1)                    +           +
    {
        "G1_cat": 2,          #           1
        "G2_cat": 2,          #            2
        "health": 4,          #
        "abs_cat": 0,         #
        "Dalc": 0,            #
        "Walc": 1             #
    },

    # 2)          -    :        ,    ,
    {
        "goout": 4,           #
        "Walc": 4,            #
        "Dalc": 3,            #
        "studytime": 1,       #
        "abs_cat": 2          #
    },

    # 3)              :               ,
    #
    {
        "famsup_cat": 1,      #
        "schoolsup_cat": 1,   #
        "health": 1,          #
        "G2_cat": 0,          #
        "abs_cat": 1          #
    }
]

for evidence in evidences:
    ie.setEvidence(evidence)
    ie.makeInference()
    print(f"Posterior of FinalPass with evidence: {evidence}")
    print(ie.posterior("FinalPass"))
    print("----------------------------------------\n")
```

```
Posterior of FinalPass with evidence: {'G1_cat': 2, 'G2_cat': 2, 'health': 4,
'abs_cat': 0, 'Dalc': 0, 'Walc': 1}
```

```
  FinalPass        |
0        |1        |
---------|---------|
 0.0429  | 0.9571  |

--------------------------------------

Posterior of FinalPass with evidence: {'goout': 4, 'Walc': 4, 'Dalc': 3,
'studytime': 1, 'abs_cat': 2}

  FinalPass        |
0        |1        |
---------|---------|
 0.1384  | 0.8616  |

--------------------------------------

Posterior of FinalPass with evidence: {'famsup_cat': 1, 'schoolsup_cat': 1,
'health': 1, 'G2_cat': 0, 'abs_cat': 1}

  FinalPass        |
0        |1        |
---------|---------|
 0.0145  | 0.9855  |

--------------------------------------
```