Environnemental Sensing

Ilist

Concepts and principles

0 – Main

- **Indexed list**
  - 0 - Presentation
- **Objectives**
  - Structure optimization
    - 1 - Structure understanding
    - 2 - Structure optimization
    - 3 - Size optimization
  - Integrate process
    - 4 - Building process
    - 4 - Interface tools
- **Associated tools**
  - 5 - Data format
  - 5 - Exchange format
- **Extension**
  - 6 - Environmental sensing
  - 6 - Sensor acquisition

0 - Ilist (Indexed list)

What is Ilist ?

List of values :

\+ Age : [12, 28, 39, 58]

List of indexes :

Name : [Paul, John, Lea, Cat]

City : [Paris, Metz, Rennes, Bollène]

....

Name	city	Age
Paul	Paris	12
John	Metz	28
Lea	Rennes	39
Cat	Bollène	58

Example : csv file, measurement, log, matrix

Why Ilist ?

- The majority of work processes are underpinned by Sheets
- The main Open-data format is CSV
- Existing tools process data but not data structures

Such tool daesn't exist !

0 – Ilist structure

Red : static value n : number of indexes
Black : dynamic value m : number of values

Two levels

- **External values** *(every kind of object)*
- **Internal keys** (no duplication)

	variable	Index[0]	…	Index[n-1]	
Name (string)	**name**	**name**		**name**	*1*
External value (object)	values	values	…	values	*m*
Codec (int / ext)	**codec**	**codec**		**codec**	
Internal key (integer)	**keys**	**keys**		**keys**	*m*

Indexed values *IndexSet*

Example

variable

indexes

score
name
age
subject

name

External

10	12	15
Paul	Lea	Lea
16	15	15
math	math	english

values

codec

Structure analysis

Internal

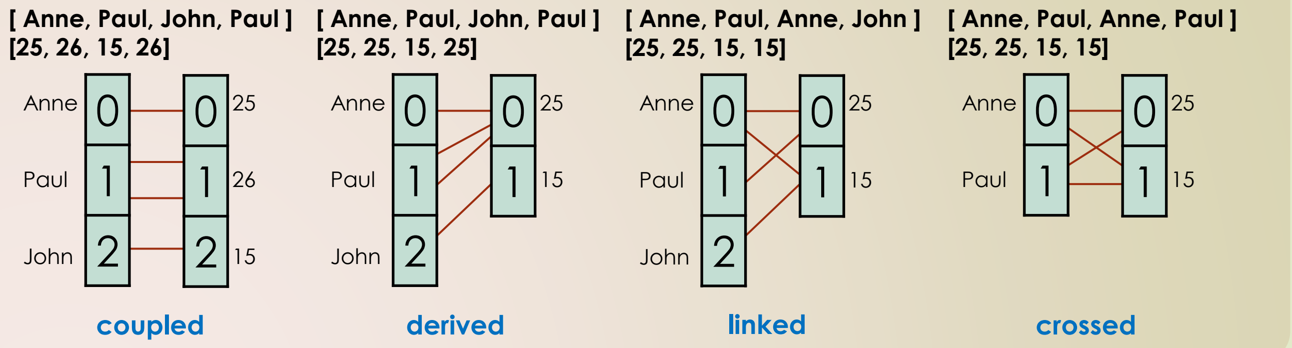
0	1	2
1	0	0
0	1	1
1	1	0

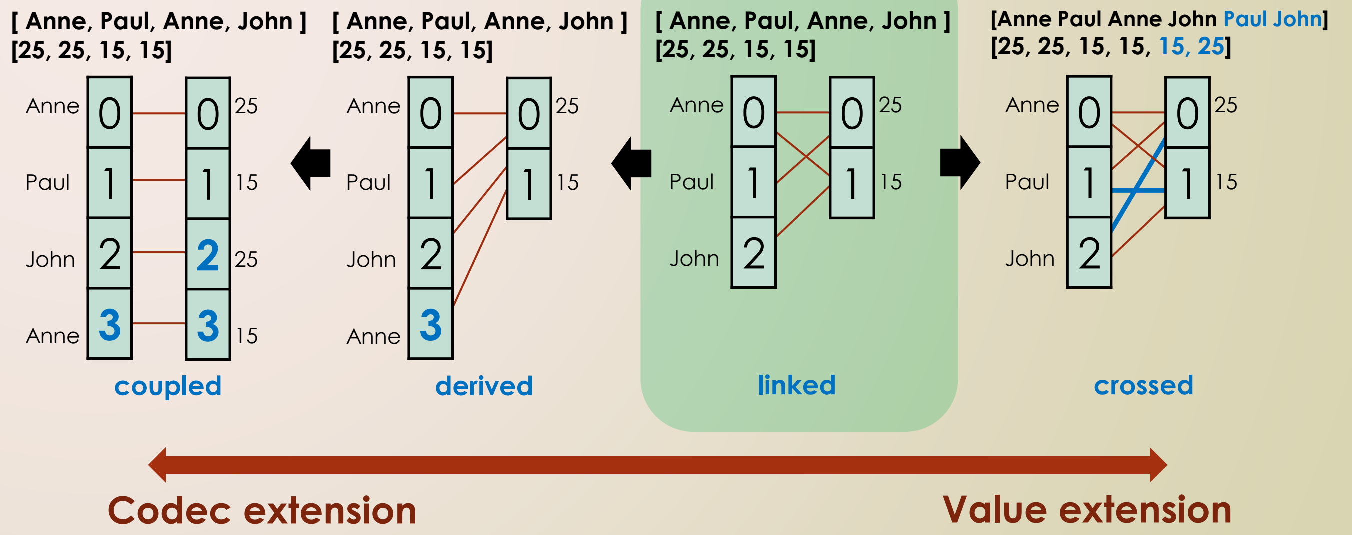
keys

1 – Structure understanding

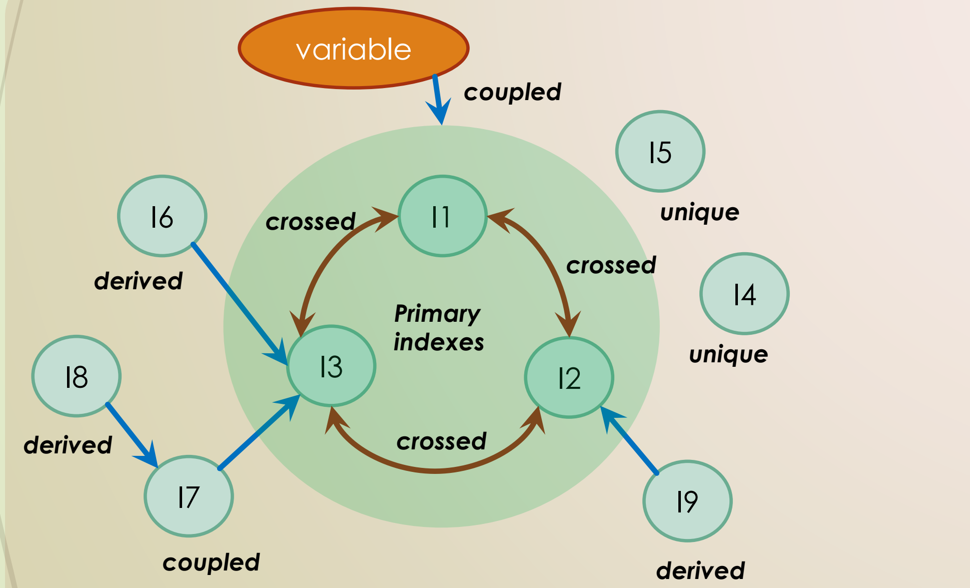
- **Relationship analysis**
  - Index qualification
  - Index relationship
- **Data structuration**
  - Canonical format
  - Convergence

Index relationship



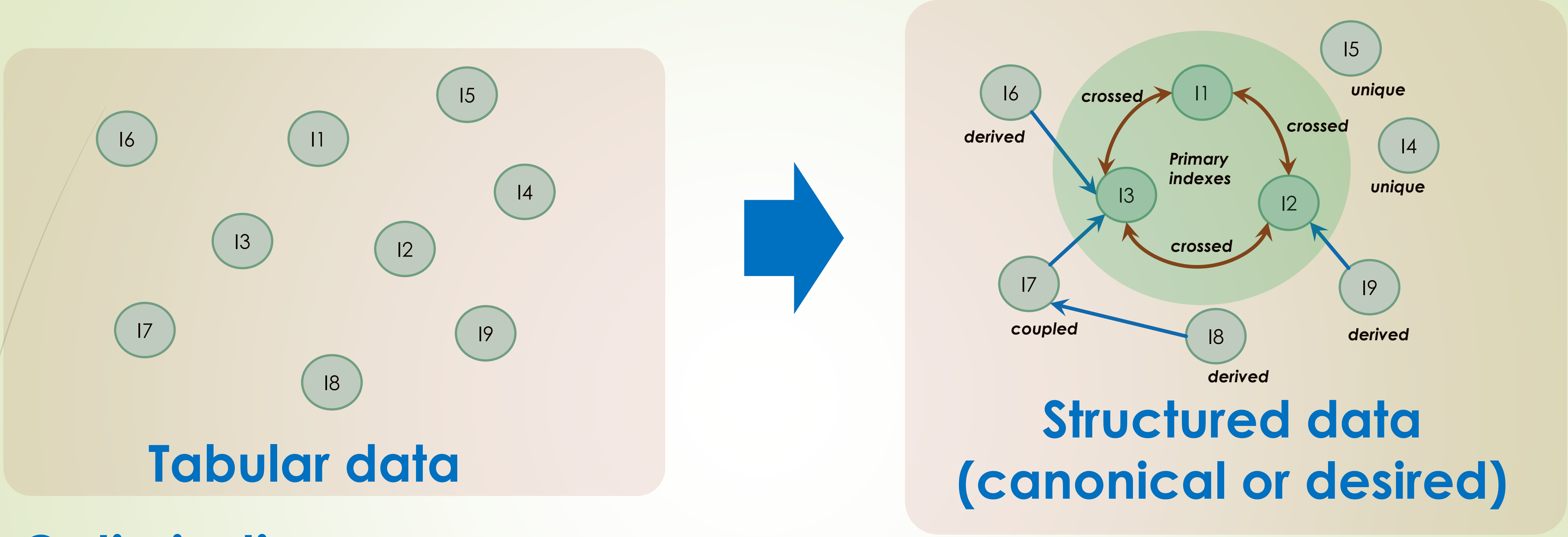


Convergence



Canonical structure

2 – Structure optimization



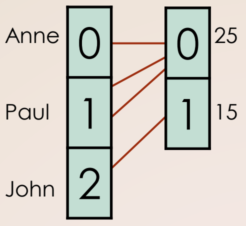
- **Optimization**
  - minimization of additional data to achieve canonical structure

- **Consistency**
  - identification of additional data to achieve the desired structure

3 – Size optimization

- **Canonical structure**
  - Minimal structure
- **Minimal size**
  - No multiple value
  - Keys optimization
- **Exchange format**
  - Text : JSON format
  - Binary : CBOR (RFC 8949)

[Anne, Paul, John, Paul]
[25, 25, 15, 25]



derived

CSV format

[Anne Paul John Paul]

[25, 25, 15, 25]

Default format

[Anne Paul John]
[0, 1, 2, 1]

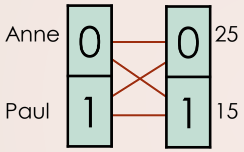
[25, 25, 15, 25]
[0, 0, 1, 0]

Optimized format

[Anne Paul John]
[0, 1, 2, 1]

[25, 25, 15, 25]
[0, 0, 1] *(relative keys to parent keys)*

[Anne, Paul, Anne, Paul]
[25, 25, 15, 15]



crossed

CSV format

[Anne Anne Paul Paul]

[25, 15, 25, 15]

Default format

[Anne Pau]
[0, 0, 1, 1]

[25, 15]
[0, 1, 0, 1]

Optimized format

[Anne Pau] *(implicit keys)*

[25, 15] *(implicit keys)*

Example : Open-data - french charging point (EVSE)

7.5 Mo – 11 000 rows – 49 columns

Analysis :

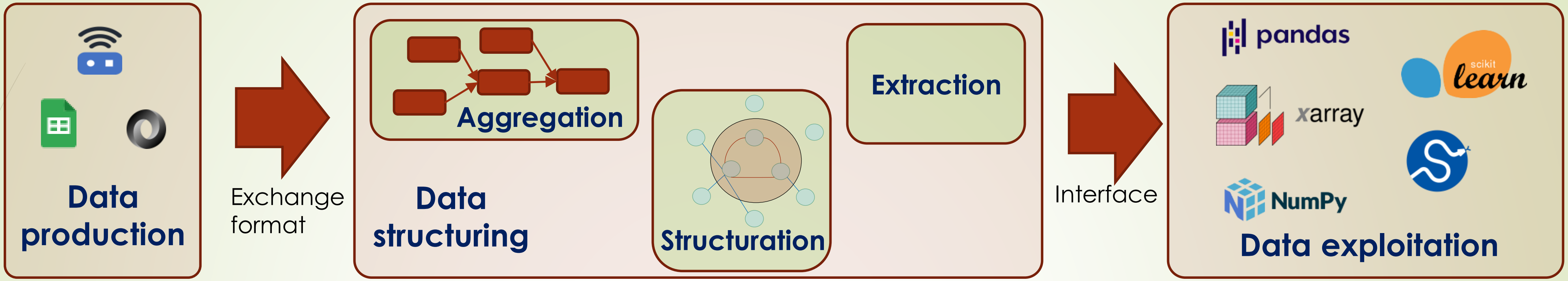
Indexes : 1 coupled, 6 derived, 1 crossed, 41 linked

Canonical format : 1 crossed, 48 derived

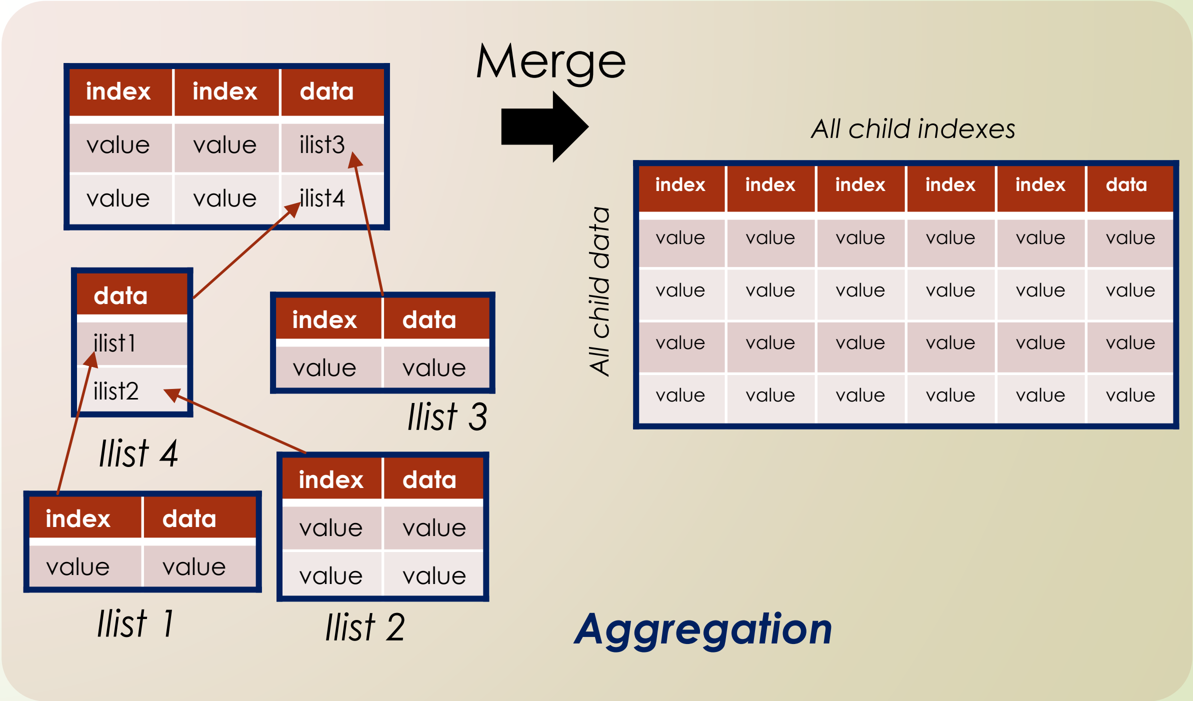
File size :

Default :	3.7 Mo
Optimized :	2.5 Mo
CBOR optimized :	**1.7 Mo (gain : 77% !)**

4 – Integrate process

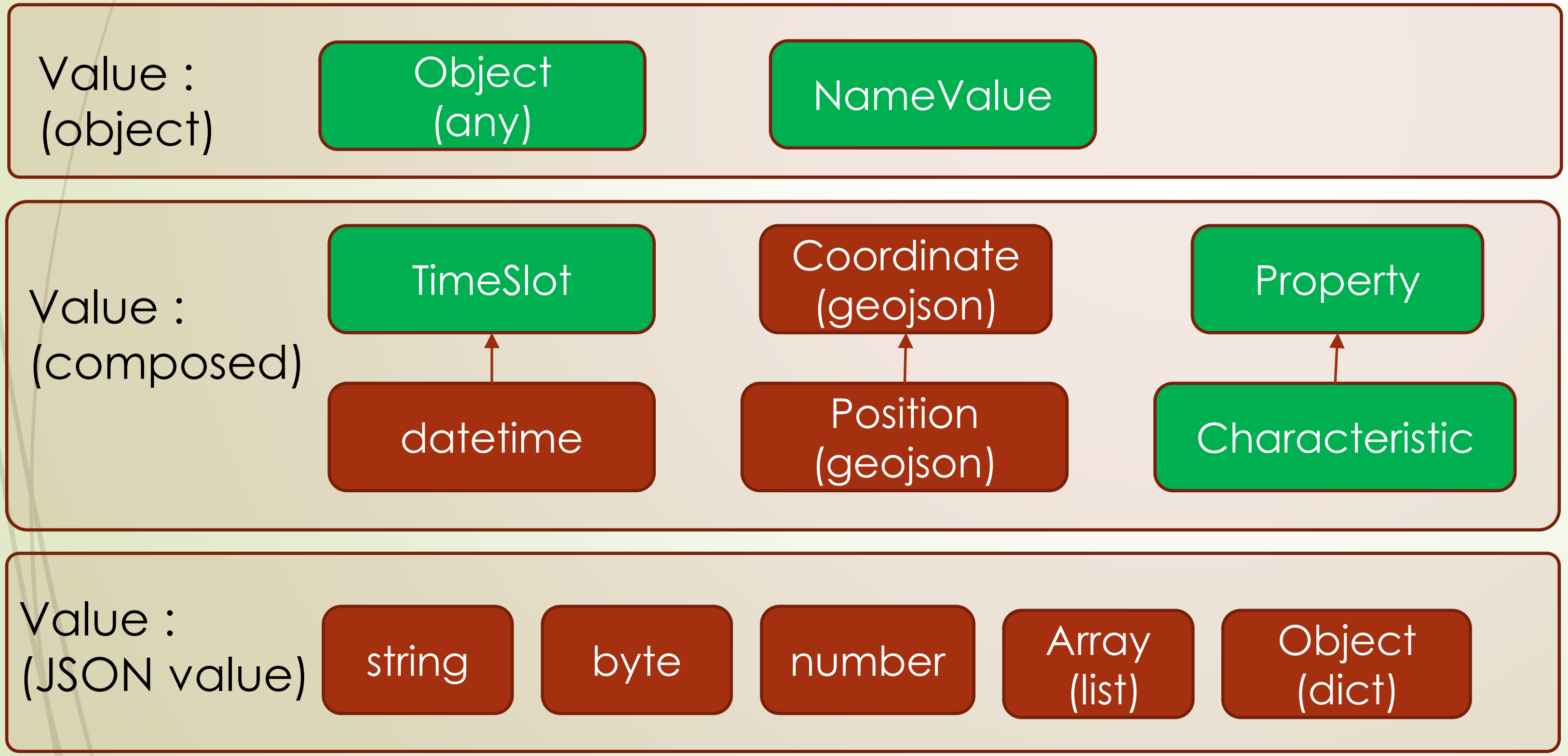


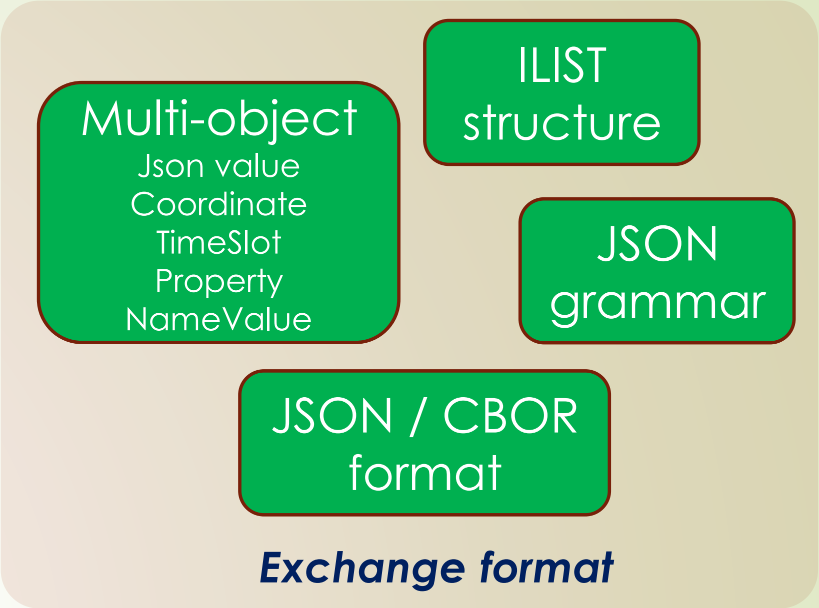
- **Data production interface**
  - Exchange format (Json, Bluetooth, CSV)
- **Aggregation / merge functions**
  - Adapted to projects / organizations
  - Add information without altering
- **Export to analysis tools**
  - Canonical structure compatibility



5 – Data format

- **Large set of objects**
  - New format (timeslot, property)
- **JSON representation**
  - Exchange format





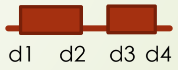
NameValue

{ 'Paris' : [2,4, 48,9] }

Object

{'object name': object value }

TimeSlot



[[[d1,d2]], [[d3,d4]]]

Property

{'char':'PM10, 'unit': 'kg/m3', …}
(Char -> i. e. BLE characteristic)

6 – Ilist extension

- **Observation**
  - Ilist specialization with three main indexes :
    - Datation index (Timeslot), Location index (coordinate), Property
  - Conformance with ISO 19156 : Observation & Measurement
- **Sensor acquisition**
  - Integration of Bluetooth Environmental Sensing Profile (extension in 2021)
  - Reduced exchange format for micro-controlers
- **Open-data**
  - Tool to define data structuring (tabular data)
  - Consistency measurement tool (tabular data)

Appendix

Concepts and principles

1 - Index analysis

2 - Matrix generation

3 - Aggregation

4 – Format, storage

1 - Index categories

Values	**[Anne, Paul, Anne]**	**[Anne, Anne, Anne]**	**[Anne, Paul, Anne]**
Length (number of values)	**3**	**3**	**3**
Codec (row)	0, 1, 2	0	0, 1
Type	*complete*	*unique*	*mixte*
Property	Rate : 1 Disttomax : 0	Rate : 0 Disttomin : 0	0 < Rate < 1 m < dist < M
Representation	**Codec :[Anne, Paul, Anne]** **Keys: implicit (full keys)**	**Codec :[Anne]** **Keys: implicit**	**Codec :[Anne, Paul]** **Keys: [0, 1, 1]**

Definition :

Default codec :
list of different values
Full codec :
list of values

Indicators :

Max = len(values)
min = 1
x = len(codec)

Rate : (M – x) / (M – m)
Dist to min : x - m
Dist to max : M - x

- **Properties**
  - An index with full codec is complete
  - Full keys is the ordered list from 0 to the length of the index
  - Any index have a default codec and a full codec
  - Default is the shortest codec, full is the longest codec

A codec defines the correspondence between values and keys (e.g.) :

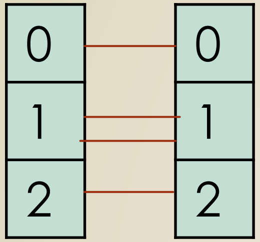
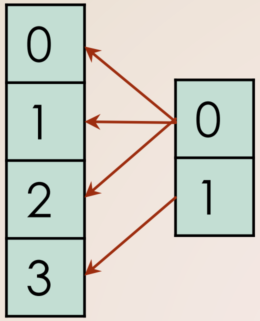
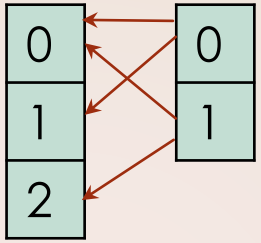
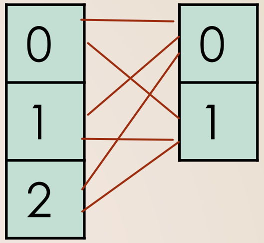
- *1 : Anne*
- *0 : Paul*
- *2 : John*

A codec may not be bijective (e.g.) :

- *0 : Anne*
- *1 : Paul*
- *2 : Anne*

c

1 - Relationship categories

Values	**A** [Anne, Paul, John, Paul] **B** [25, 26, 15, 26]	[Anne, Paul, John, Lea] [25, 25, 25, 12]	[Anne, Paul, Anne, Lea] [25, 25, 12, 12]	[Anne, Anne, Anne, Paul, Paul, Paul] [25, 12, 25, 12, 25, 12]
Codec (row)	 A B	 B derived from A A derive B	 B linked from A A link B	 A B
Type	coupled	derived (asymmetrical)	linked (asymmetrical)	crossed
Property	Rate : 0 Disttomin : 0 diff : 0	Rate : 0 Disttomin : 0 0 < diff < min	0 < Rate < 1 min < dist < Max 0 <= diff < min	Rate : 1 Disttomax : 0 0 <= diff < min
Keys B	Relative (equal Keys A) **Codec :[25, 26, 15, 35]** **Keys: implicit**	Relative to keys A **Codec :[25, 12]** **Keys: relative [0,0,0,1]**	Absolute **Codec :[25, 12]** **Keys: absolute [0,0,1,1]**	Matrix order **Codec :[25, 12]** **Keys: implicit *([0,1,0,1,0,1])***

Indicators :

Max = len(i1) * len(i2)
min = max(len(i1), len(i2)
diff = abs(len(i1) – len(i2))
x = len(index(v1, v2))

Rate : (x – m) / (M – m)
Dist to min : x – m
Dist to coup : 2x - 2m + diff
Dist to max : M - x

Relative derived keys :

Length:

- *length(parent.codec)*

Values:

- Keyder(parent.key(i)) = key(i)

1 - relationship properties

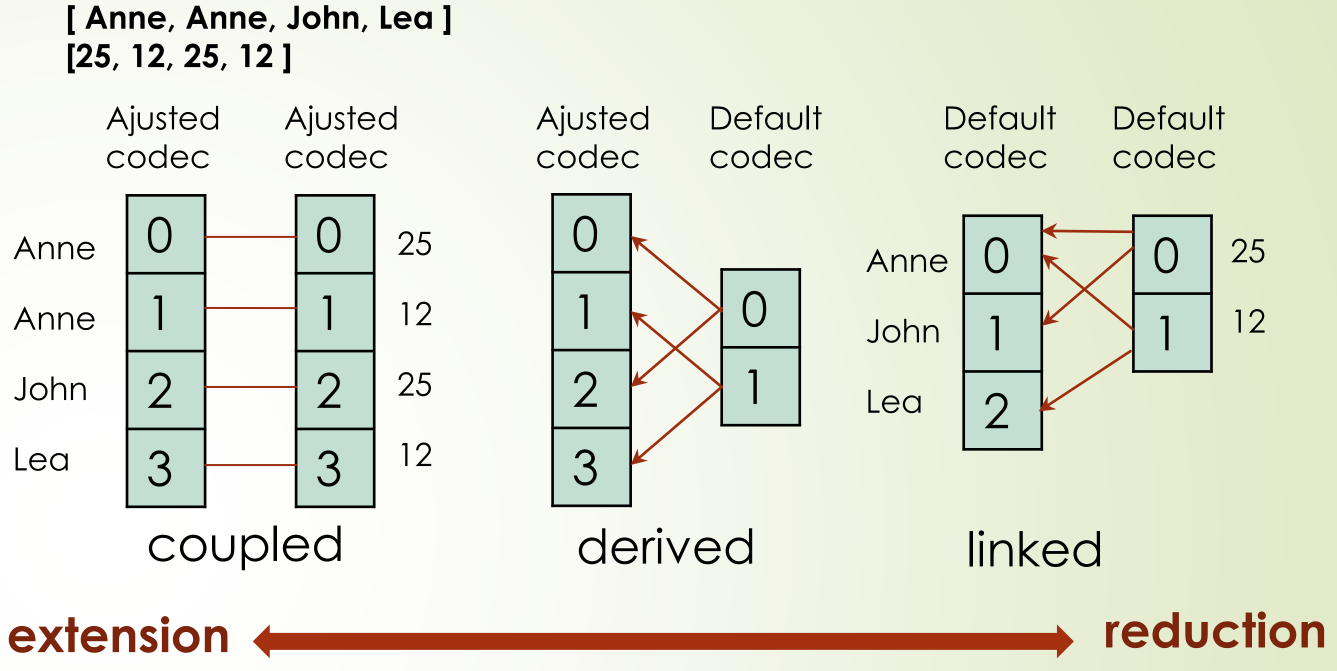
- Type and Indicators are independant of Values (order or value) and dependant of Codec and Keys
- If one index is complete, all the indexes are derived or coupled from it
- If one index is unique, it is derived from all other indexes
- If A is derived (coupled) from B and B is derived (coupled) from C, A is derived (coupled) from C
- If A is coupled to B, all the relationships with other indexes are identical
- **Keys can be deduced with coupled or crossed relationship**

1 – Relationship adjustement

- **Codec reduction / extension**
  - Codec changed
  - Values unchanged

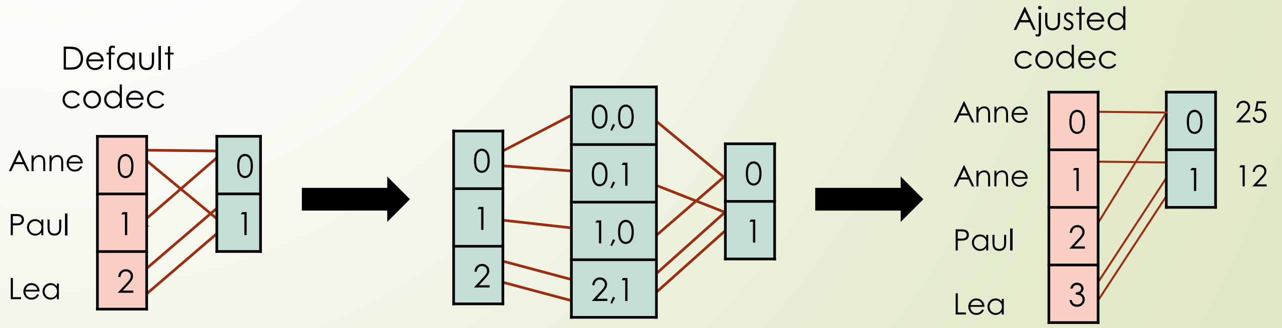
Reduction is usefull to minimize codec size

Extension is usefull to increase values readibility (like csv data)



- **Codec adjustement**
  - Codec is ajusted to the other codec
  - Other index is derived or coupled to the ajusted index
  - If A is derived from B and if B is adjusted to C, A is still derived from B

Keys can be deduced from keys parent

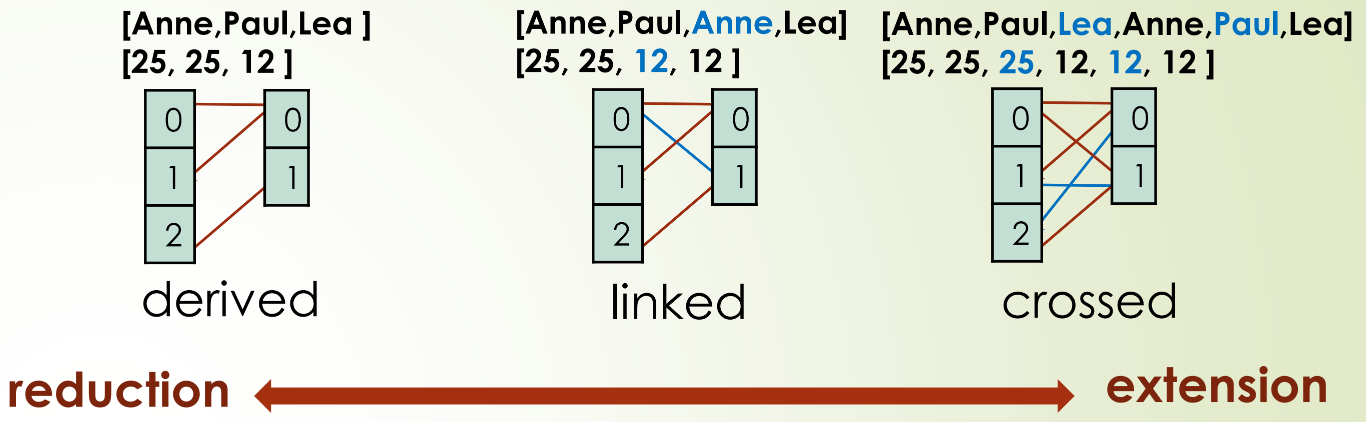


1 – Relationship adjustement

- **Values reduction / extension**
  - Codec unchanged
  - Values changed

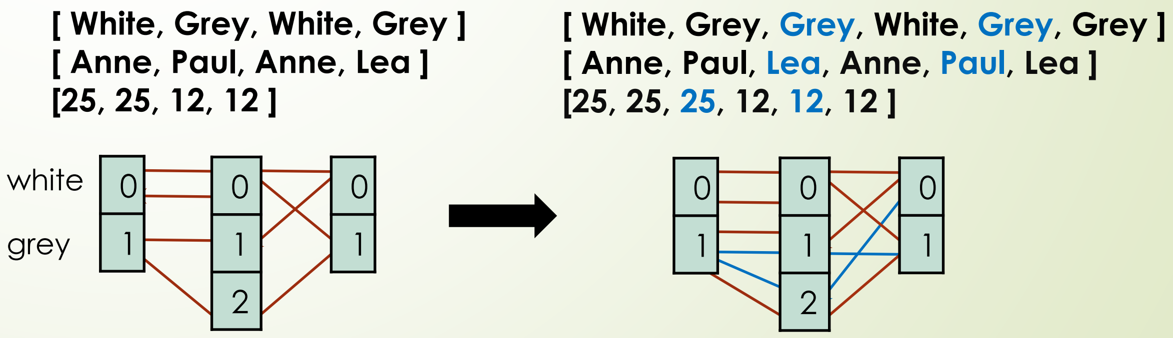
Extension is usefull to generate matrix

Reduction is usefull to increase codec readibility



- **Propagation**
  - Values reduction / extension can be propagated to derived ou coupled indexes

Extension can't be propagated to crossed or linked Indexes.



1 – Representation

- **Codec representation**
  - List of values (or dict key/value)
  - List of unique value + list of keys
- **Keys representation**
  - Absolute : List of integer (index of codec value)
  - Relative : List of integer (index of other keys)
  - Implicit : Automatic list (i.e. with full codec)
- **Iindex /variable Formats**
  - Simple format (codec)
  - Complete format (codec + keys)
  - Coupled format (codec + parent)
  - Derived format (codec + parent + keys)
    - Keys = index of parent keys

Json Example

['Anne', 'Anne', 'John', 'Paul']

[['Anne', 'John', 'Paul'], [0, 0, 1, 2]]

[2, 2, 3] ➡ **['John', 'John', 'Paul']**

[0, 1, 2, 3] ⬅ **if full codec**

['Anne', 'Anne', 'John', 'Paul', 'John'] *(full)*

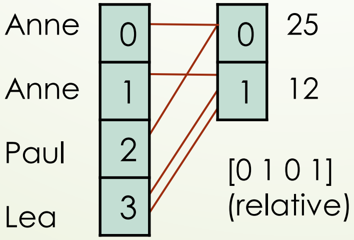
['Anne', 'John', 'Paul'] *(default)*

[['Anne', 'John', 'Paul'], [0, 0, 1, 2, 1]]

[['Anne', 'John', 'Paul'], parent]

[['Anne', 'John', 'Paul'], parent, [0, 0, 1, 2, 1]]

[Anne,Anne, Lea, Paul, Lea]
[12, 25, 12, 25, 12]



Derived Iindex : [[25, 12], parent, [0, 1, 0, 1]] *(derived)*
Parent index : [Anne, Anne, Paul, Lea], [0, 1, 3, 2, 3]] *(complete)*

or

Parent index : [[Anne, Paul, Lea], [0,0,1,2]], [0, 1, 3, 2, 3]] *(complete)*

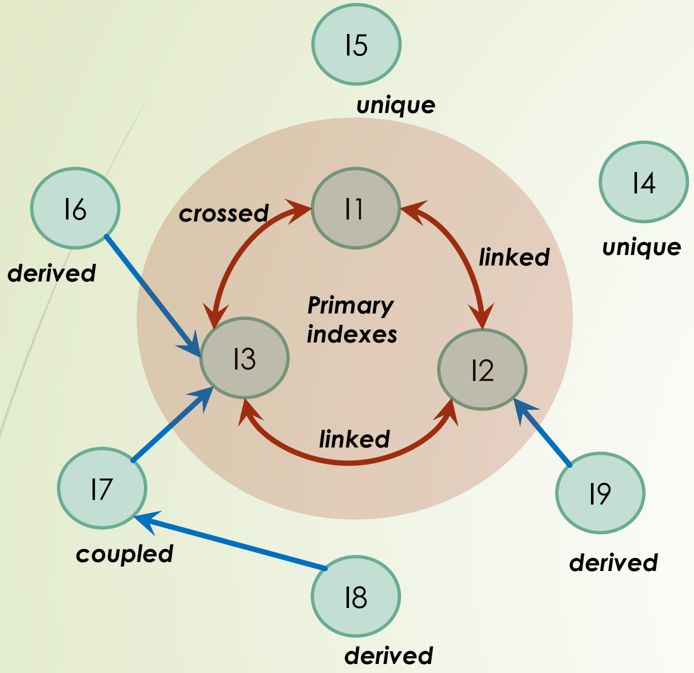
2 – IndexSet (list of indexes with same length)

- **Index definition**
  - An index is **secondary** if it's derived or coupled from at least one other index
  - An Index is **primary** if it's not secondary
  - If the index is secondary, the **parent** index is the first index with the lowest disttomin in the list of coupling or derivating indexes
  - If the index is primary, the **parent** index is the first index with the lowest disttomin in the list of primary indexes (or itself if the index is the first crossed primary)
  - The **precursor** index is the first Primary index in the indexing tree

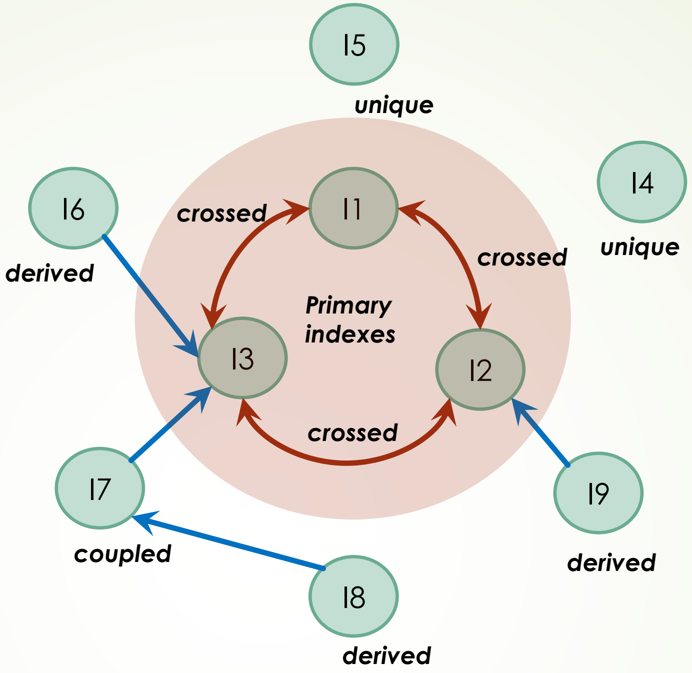
- **IndexSet definition**
  - **Dimension** : number of primary indexes
  - **Complete** : An indexSet is complete if all the primary indexes are crossed with each other primary index

- **Properties**
  - **The number of values of a full indexset is the product of the primary indexes length**
  - **A complete IndexSet can be transformed in a Matrix with the dimension of the indexset**
  - **Keys data is unnecessary in a complete indexset whithout derived codec**
  - **Dimension can be reduced by codec extension**
  - **Dimension can be increased by values extension**

2 – Structure

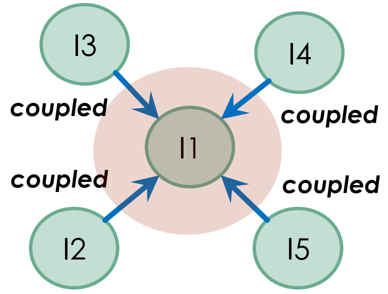


Canonical structure
(default codec)



Complete structure
(adjusted codec and values)

In a complete format, Keys are:
- **Implicit for Primary, Unique and Coupled indexes**
- **Relative for Derived indexes**



CSV format

- **Properties**
  - Each indexset has a **canonical structure** (at least one primary index)
  - **Complete data** is obtained by crossing all the primary indexes (values extension)
  - Complete indexset can be transformed in **Matrix** (full codec for secondary indexes)
  - **CSV format** is a canonical structure with one primary index and any coupled indexes, all indexes have full codec

2 - Example

3 columns are linked
- Full name
- Course
- Examen

3 columns are derived
- First name
- Last name
- Group

1 column is coupled
- Surname

1 column is unique
- Year

ratio
- Name – Course : 37,5 %
- Name – Examen : 62,5 %
- Course – Examen : 83,7 %

IndexSet

37% almost derived or coupled

83% almost crossed

Data

first name	last name	full name	surname	group	course	year	examen	score
Anne	White	Anne White	skyler	gr1	math	2021	t1	11
Anne	White	Anne White	skyler	gr1	math	2021	t2	13
Anne	White	Anne White	skyler	gr1	math	2021	t3	15
Anne	White	Anne White	skyler	gr1	english	2021	t2	10
Anne	White	Anne White	skyler	gr1	english	2021	t3	12
Philippe	White	Philippe White	heisenberg	gr2	math	2021	t1	15
Philippe	White	Philippe White	heisenberg	gr2	english	2021	t2	8
Camille	Red	Camille Red	saul	gr3	software	2021	t3	17
Camille	Red	Camille Red	saul	gr3	software	2021	t2	18
Camille	Red	Camille Red	saul	gr3	english	2021	t1	2
Camille	Red	Camille Red	saul	gr3	english	2021	t2	4
Philippe	Black	Philippe Black	gus	gr3	software	2021	t3	18
Philippe	Black	Philippe Black	gus	gr3	english	2021	t1	6

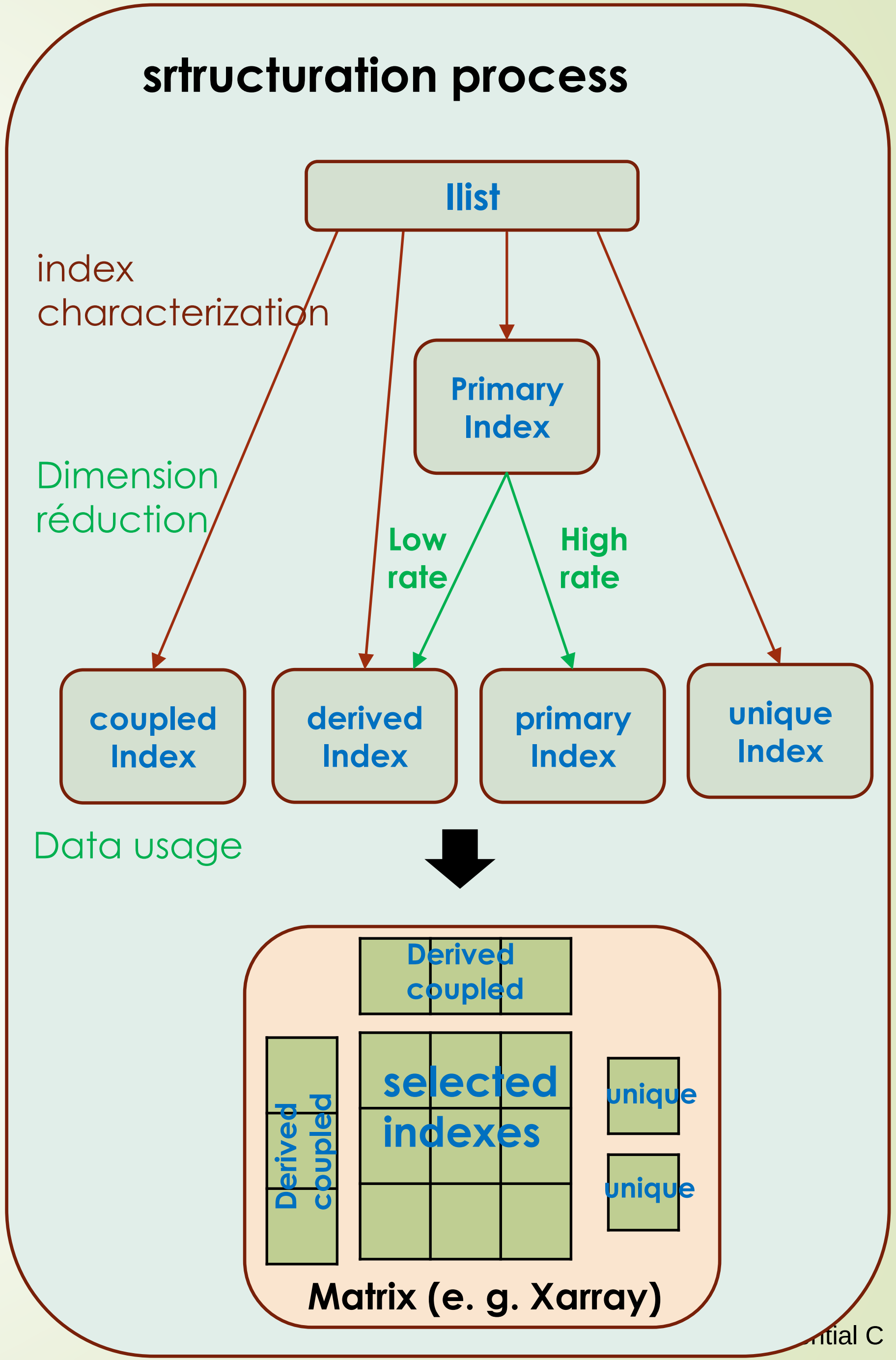
coupled

derived

unique

2 – Structuration process

- **Objectives**
  - Data understanding
  - Unconsistent data identification
  - Size reduction
  - Tranfer to analysis tools (e.g. Pandas, Xarray)
- **Analysis**
  - **Index characterization**
    - Identification of primary indexes
    - Association of secondary indexes to primary indexes
  - **Linked indexes analysis**
    - Low rate (i.e. < 0,1) = almost derived index
      -> transform to derived index (codec extension)
      -> or values correction
    - High rate (i.e. > 0,9) = almost crossed index
      -> transform to crossed index
      -> or values correction
- **Data usage**
  - **Dimension reduction (if necessary)**
    - Primary index merging (rather low rate)
  - **Export**
    - Matrix generation
    - Storage



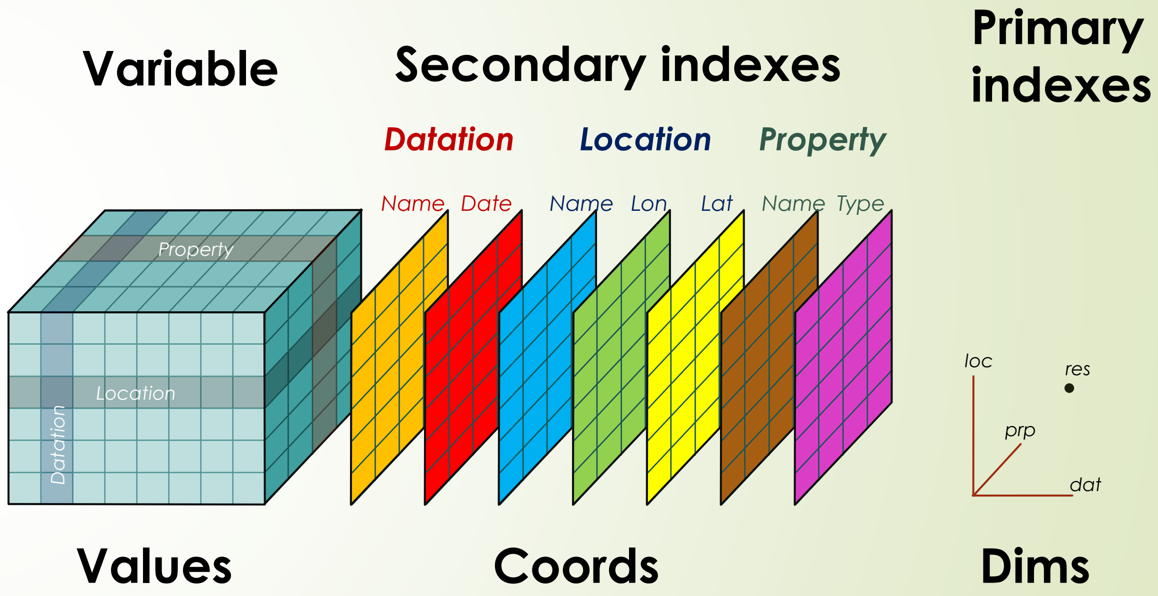
Example : Xarray – mapping

> Xarray

- Values : data matrix(ex. numpy ndarray)
- Coords : list of indexes: (dims, data, attrs)
- Dims : names of dimensions
- Attrs : attribut dictionnary (data or coord)
- Name

> Ilist Mapping

- Dims : Primary indexes
- Values : Variable values
- Coords : Secondary indexes
- Attrs : Unique indexes
- Name : Ilist name



2 - Example

to_xarray function :
- Primary crossed (values extension)
- Secondary coupled (full codec)

first name	last name	full name	surname	group	course	year	examen	score
Anne	White	Anne White	skyler	gr1	english	2021	t1	-
Anne	White	Anne White	skyler	gr1	english	2021	t2	10
Anne	White	Anne White	skyler	gr1	english	2021	t3	12
Anne	White	Anne White	skyler	gr1	math	2021	t1	11
Anne	White	Anne White	skyler	gr1	math	2021	t2	13
Anne	White	Anne White	skyler	gr1	math	2021	t3	15
Anne	***White***	***Anne White***	***skyler***	***gr1***	***software***	***2021***	***t1***	-
Anne	***White***	***Anne White***	***skyler***	***gr1***	***software***	***2021***	***t2***	-
Anne	***White***	***Anne White***	***skyler***	***gr1***	***software***	***2021***	***t3***	-

completed

derived

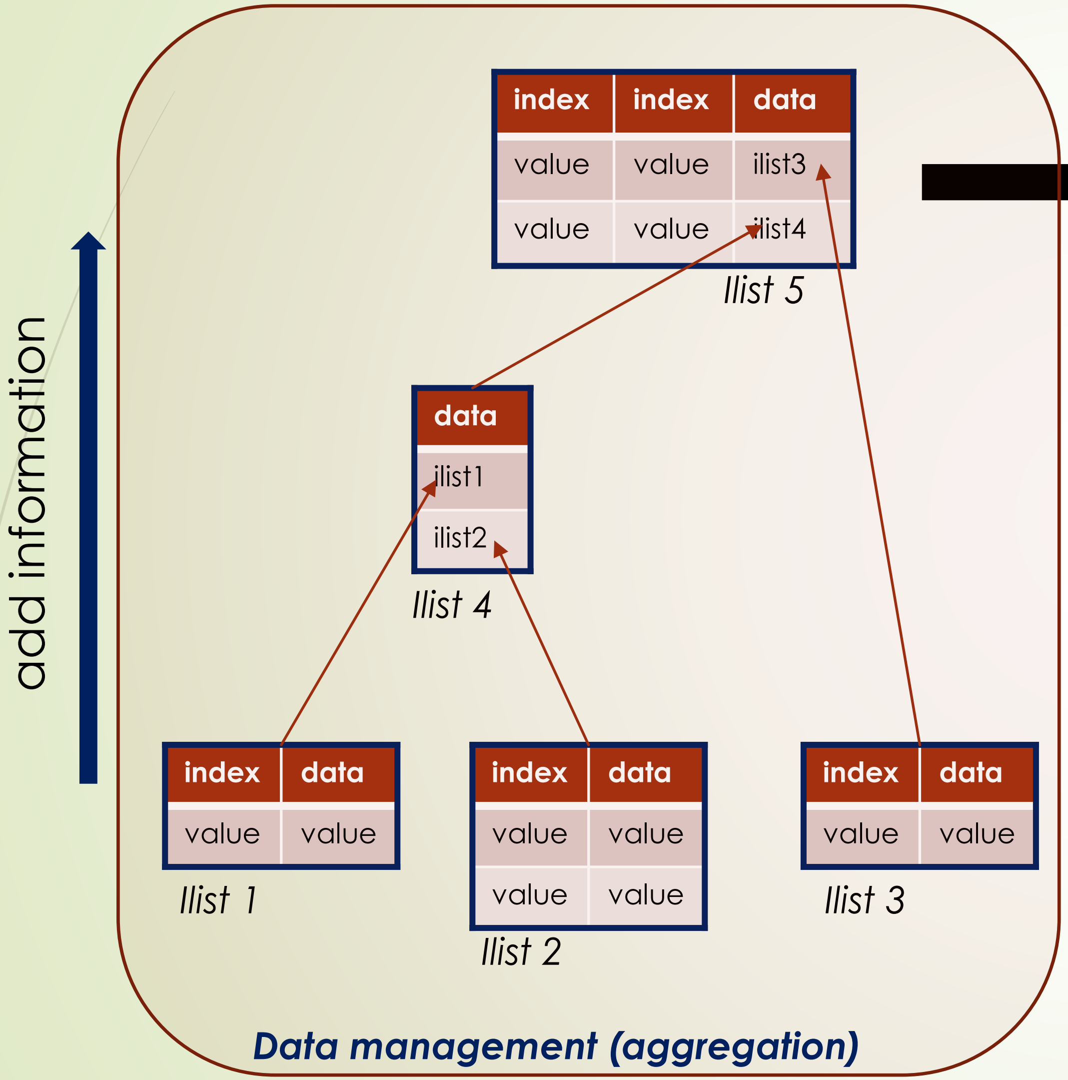
coupled

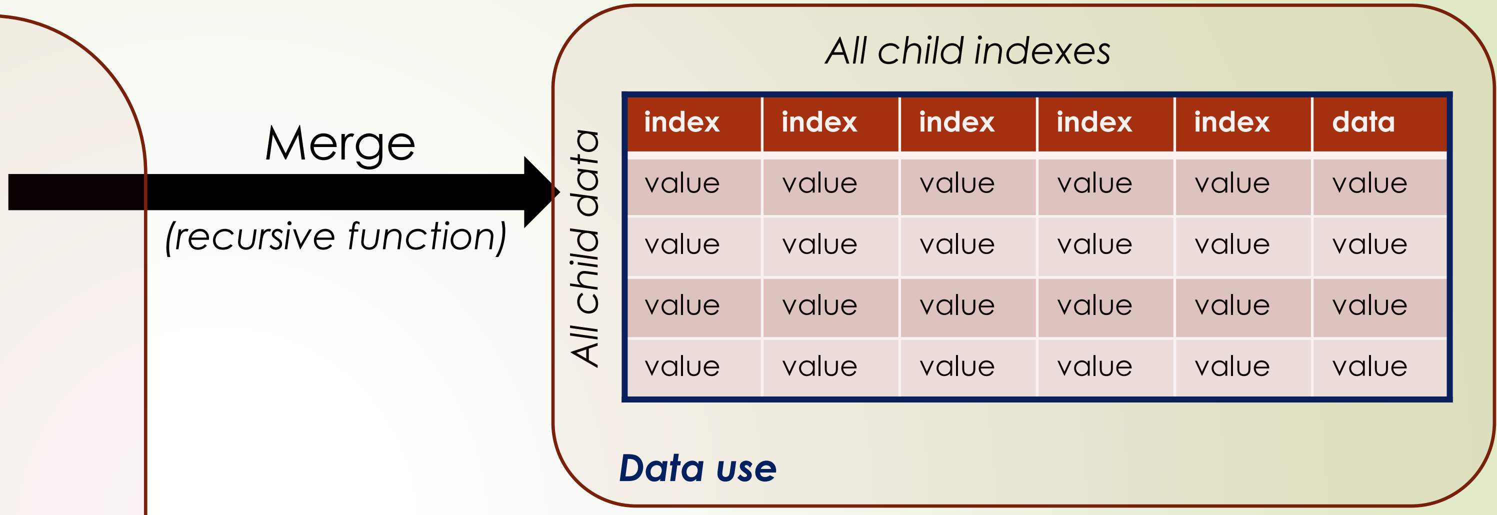
unique

```
In [367]: cours.to_xarray(axes=cours.axesmin)
Out[367]:
<xarray.DataArray 'Ilist' (full name: 4, course: 3, examen: 3)>
array([[['?', '10', '12'],
        ['11', '13', '15'],
        ['?', '?', '?']],

       [['2', '4', '?'],
        ['?', '?', '?'],
        ['?', '18', '17']],

       [['6', '?', '?'],
        ['?', '?', '?'],
        ['?', '?', '18']],

       [['?', '8', '?'],
        ['15', '?', '?'],
        ['?', '?', '?']]], dtype='<U2')
```

```
Coordinates:
    ï»¿first name   (full name) <U8 'Anne' 'Camille' 'Philippe' 'Philippe'
    last name        (full name) <U5 'White' 'Red' 'Black' 'White'
  * full name        (full name) <U14 'Anne White' ... 'Philippe White'
    surname          (full name) <U10 'gus' 'heisenberg' 'saul' 'skyler'
    group            (full name) <U3 'gr1' 'gr3' 'gr3' 'gr2'
  * course           (course) <U8 'english' 'math' 'software'
  * examen           (examen) <U2 't1' 't2' 't3'
```

3 - Building process





- **Process adapted to organizations**
- **Add information without altering**
- **Separation of management and use**

3 - Example

IndexSet | Data

aw

course	year	examen	score
math	2021	t1	11
math	2021	t2	13
math	2021	t3	15
english	2021	t2	10
english	2021	t3	12

pw

course	year	examen	score
math	2021	t1	15
english	2021	t2	8

cr

course	year	examen	score
software	2021	t3	17
software	2021	t2	18
english	2021	t1	2
english	2021	t2	4

pb

course	year	examen	score
software	2021	t3	18
english	2021	t1	6

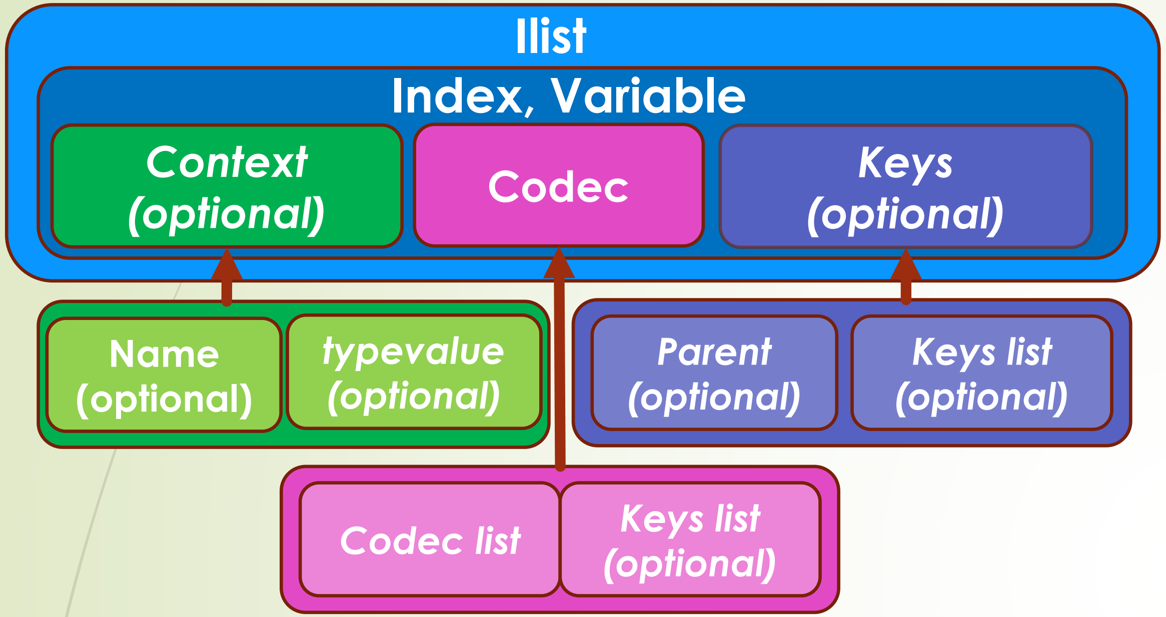
total

first name	last name	full name	surname	group	file
Anne	White	Anne White	skyler	gr1	aw
Philippe	White	Philippe White	heisenberg	gr2	pw
Camille	Red	Camille Red	saul	gr3	cr
Philippe	Black	Philippe Black	gus	gr3	pb

total.merge()

first name	last name	full name	surname	group	course	year	examen	score
Anne	White	Anne White	skyler	gr1	math	2021	t1	11
Anne	White	Anne White	skyler	gr1	math	2021	t2	13
Anne	White	Anne White	skyler	gr1	math	2021	t3	15
Anne	White	Anne White	skyler	gr1	english	2021	t2	10
Anne	White	Anne White	skyler	gr1	english	2021	t3	12
Philippe	White	Philippe White	heisenberg	gr2	math	2021	t1	15
Philippe	White	Philippe White	heisenberg	gr2	english	2021	t2	8
Camille	Red	Camille Red	saul	gr3	software	2021	t3	17
Camille	Red	Camille Red	saul	gr3	software	2021	t2	18
Camille	Red	Camille Red	saul	gr3	english	2021	t1	2
Camille	Red	Camille Red	saul	gr3	english	2021	t2	4
Philippe	Black	Philippe Black	gus	gr3	software	2021	t3	18
Philippe	Black	Philippe Black	gus	gr3	english	2021	t1	6

4 – JSON Representation



Ilist: JSON Array (or JSON value if only one value)
Index: JSON Array (or JSON value if only one value)

Context: JSON Object (or JSON string if only one value)
Codec: JSON Array (or JSON value if only one value)
Keys: JSON Array (or JSON value if only one value)

Name, Typevalue: string
Codec list: JSON Array
keys list: JSON Array
Parent: Integer

Format

Text (JSON text), Binary (CBOR)

Example Index : Name : 'team1'
Values : ['Anne', 'Anne', 'John', 'Paul', 'John']

- **Simple format (without name)**
  ['Anne', 'Anne' 'John', 'Paul', 'John']
  -> Full codec (e.g. csv format)
- **Simple format (with name)**
  ['team1', ['Anne', 'John', 'Paul']]
  -> Default codec (e.g. crossed index)
- **Complete format (with name)**
  ['team1', ['Anne', 'John', 'Paul'], [0,0,1,2,1]]
  -> Default codec, name, absolute keys
- **Coupled format (with name)**
  ['team1', ['Anne', 'John', 'Paul', 'John'], 2]
  -> Adjusted codec, parent id
- **Derived format (with name)**
  ['team1', ['Anne', 'John', 'Paul'], [2, [0,1,2,1]]]
  -> Default codec, parent id, relative keys
- **Unique format**
  ['team1', ['Anne']] (with name) ['Anne'] (without name)
  -> Default codec (= full codec)

4 – format

- **llist format**
  - Dict + Array

- **Tabular format (csv)**
  - Easy to read, duplication data, text only
- **Json format**
  - Easy to read, text only
  - Not duplication data
  - Compatible with NoSQL Database
- **Bson format**
  - Compatible with json format
  - Binary, structured data (eg datetime)
- **Binary format**
  - CBOR (Concise Binary Object Representation)
  - Compatible with json format
  - Binary, numerical, text, structured (eg datetime, coordinates)

4 – Ilist size and indicators

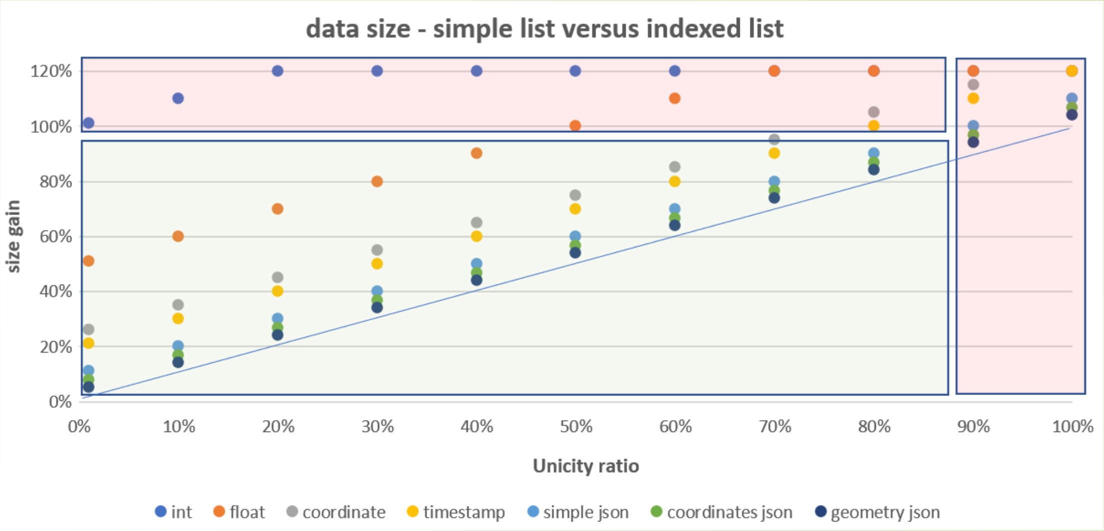
- **Simple list size** **= nv * sv**
  - nv : number of values
  - sv : mean value size = sizesimple / nv

- **Indexed list size** **= (nv – nc) * sc + nc * sv**
  - nc : number of different values
  - sc: mean coding size = (size – nc * sv) / (nv – nc)

- **Gain = (Simple size - indexed size) / simple size** **= (1 – ul) * (1 – ol)**
  - **OL = sc / sv (object lightness)** **[0, 1] (data complexity)**
  - **UL = nc / nv (unicity level)** **[0, 1] (data quality)**

- **Properties**
  - If object lightness and unicity level are low, the indexed list size is lower than simple list size
    - e.g. : OL = 0.1 , UL = 0.2 => **Gain = 72 %**

- **In a Ilist with data more complex than numerical data, the json (or binary) format has a smaller size than a tabular format**



Object lightness	l	OL
int	2	1,00
float, int32	4	0,50
coordinate	8	0,25
string(10) (eg. timestamp)	10	0,20
simple json element (eg key/value)	20	0,10
structured json element (eg coordinates)	30	0,07
complex json element (eg geometry)	50	0,04

E.g. previous example :
- csv : 2 418 bytes
- json : 1 496 bytes
- binary (CBOR) : 697 bytes