Towards Data Visualisation based on Conceptual Modelling

P.J. McBrien and A. Poulovassilis

ER 2018

Motivating Example

continent country economy							
name	code	population	unemployment	inflation	gdp	continent	percentage
Argentina	RA	42669500	7.50	20.80	484600	America	100
Australia	AUS	23135281	5.70	2.40	1488000	Australia/Oceania	100
Belize	BZ	312971	15.50	1.30	1637	America	100
Bolivia	BOL	10027262	7.40	6.50	30790	America	100
Brazil	BR	202768562	5.70	6.20	2190000	America	100
Canada	CDN	35158304	7.10	1	1825000	America	100
Chile	RCH	16341929	6	1.70	281700	America	100
China	CN	1360720000	4.10	2.60	9330000	Asia	100
Costa Rica	CR	4773119	7.90	5.60	48510	America	100
India	IND	1210854977	8.80	9.60	1670000	Asia	100
Panama	PA	3405813	4.50	4.10	40620	America	100
Paraguay	PY	6672631	6.60	2.30	30560	America	100
Peru	PE	30135875	3.60	2.90	210300	America	100
Russia	R	143666931	5.80	6.80	2113000	Europe	25
Russia	R	143666931	5.80	6.80	2113000	Asia	75
United Kingdom	GB	64105654	7.20	2	2490000	Europe	100
United States	USA	318857056	7.30	1.50	16720000	America	100
Uruguay	ROU	3286314	6.50	8.30	57110	America	100

Current approaches require users to build visualisations from tables of data.

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Belize	BZ	312971	15.50	1.30			
Bolivia	BOL	10027262	7.40	6.50			
Brazil	BR	202768562	5.70	6.20			
Canada	CDN	35158304	7.10	1			
Chile	RCH	16341929	6	1.70			
China	CN	1360720000	4.10	2.60			
Costa Rica	CR	4773119	7.90	5.60			
India	IND	1210854977	8.80	9.60			
Panama	PA	3405813	4.50	4.10			
Paraguay	PY	6672631	6.60	2.30			
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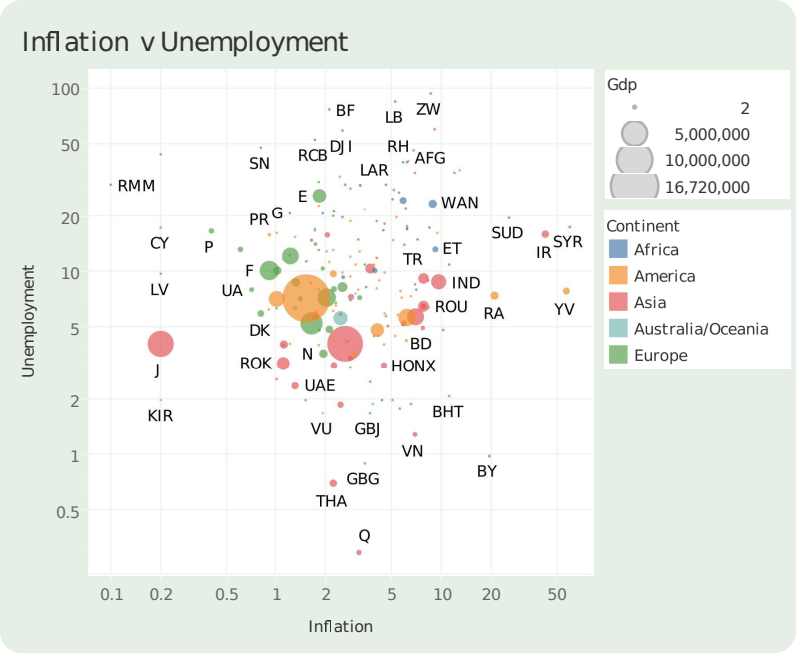
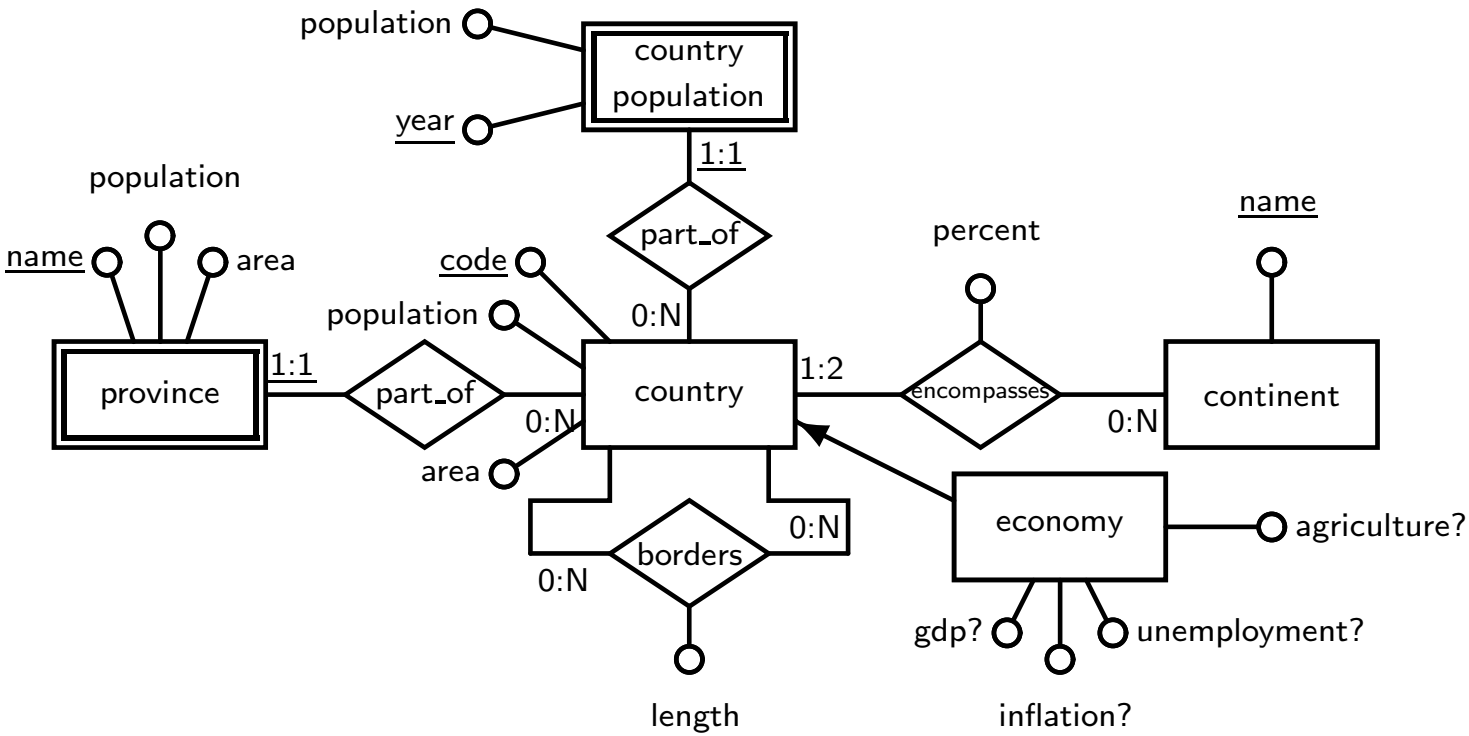


Considerable effort is needed to understand the data and decide on which visualisation.

Motivating Example



Our approach uses the conceptual model of the data to semi-automatically aid the user's choice of visualisations.

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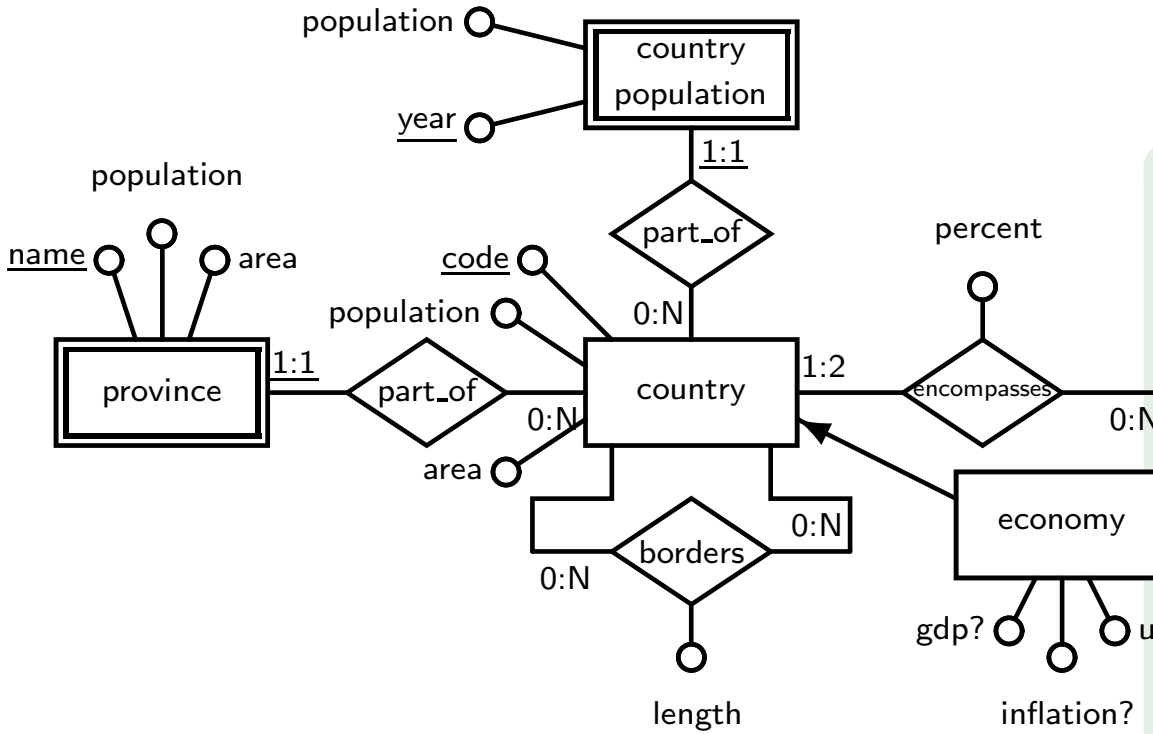

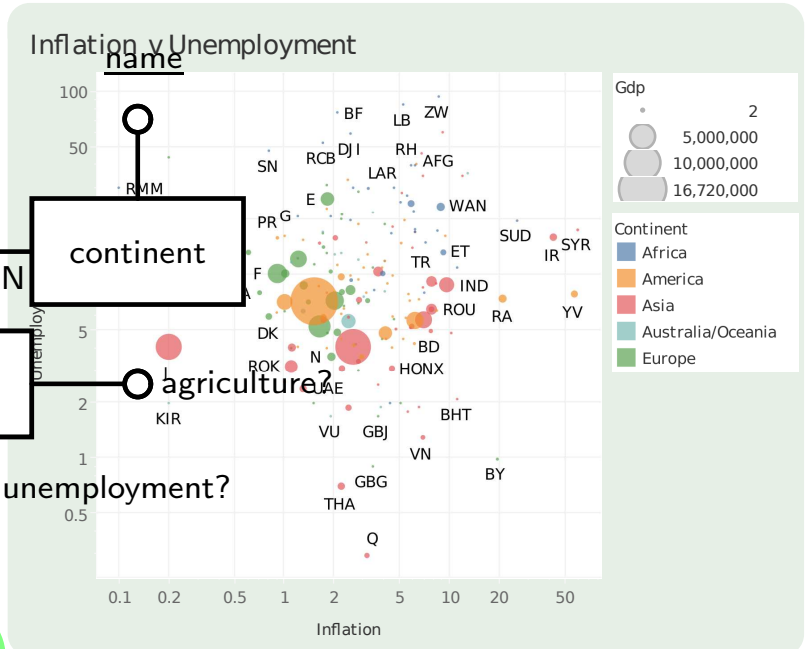

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Dimensions of a Visualisation

The elements of a visualisation are often classified in the Visualisation literature as:

- **marks** *e.g.* points, lines, areas

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In our approach, each attribute of an entity and each participation of an entity in a relationship is associated with a dimension of the visualisation. Dimensions are of two types:

- **discrete dimensions** which map to a mark or a channel

Discrete Dimension Example

continent.name={'Europe','Asia','Australia/Oceania','Africa','America'}

Dimensions of a Visualisation

The elements of a visualisation are often classified in the Visualisation literature as:

- **marks** *e.g.* points, lines, areas
- **channels** *e.g.* colour, length, shape, coordinate, texture

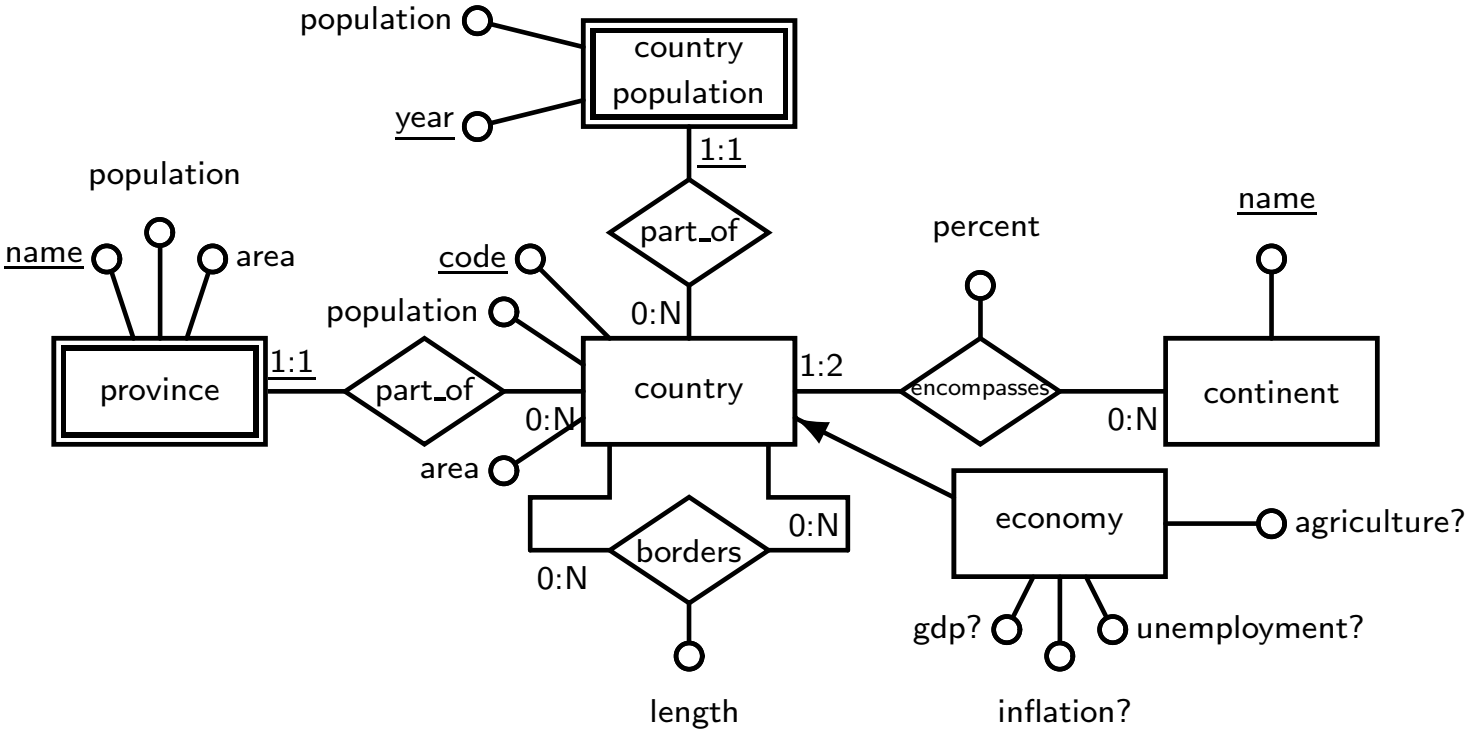
In our approach, each attribute of an entity and each participation of an entity in a relationship is associated with a dimension of the visualisation. Dimensions are of two types:

- **discrete dimensions** which map to a mark or a channel
- **scalar dimensions** which map to a channel

Scalar Dimension Example

borders.length={0.34,1.20,3.2,4.40,6.30.9.00,9.60,. . . ,5150,6846,8893}

Visualisation Schema Pattern 1: Basic Entity



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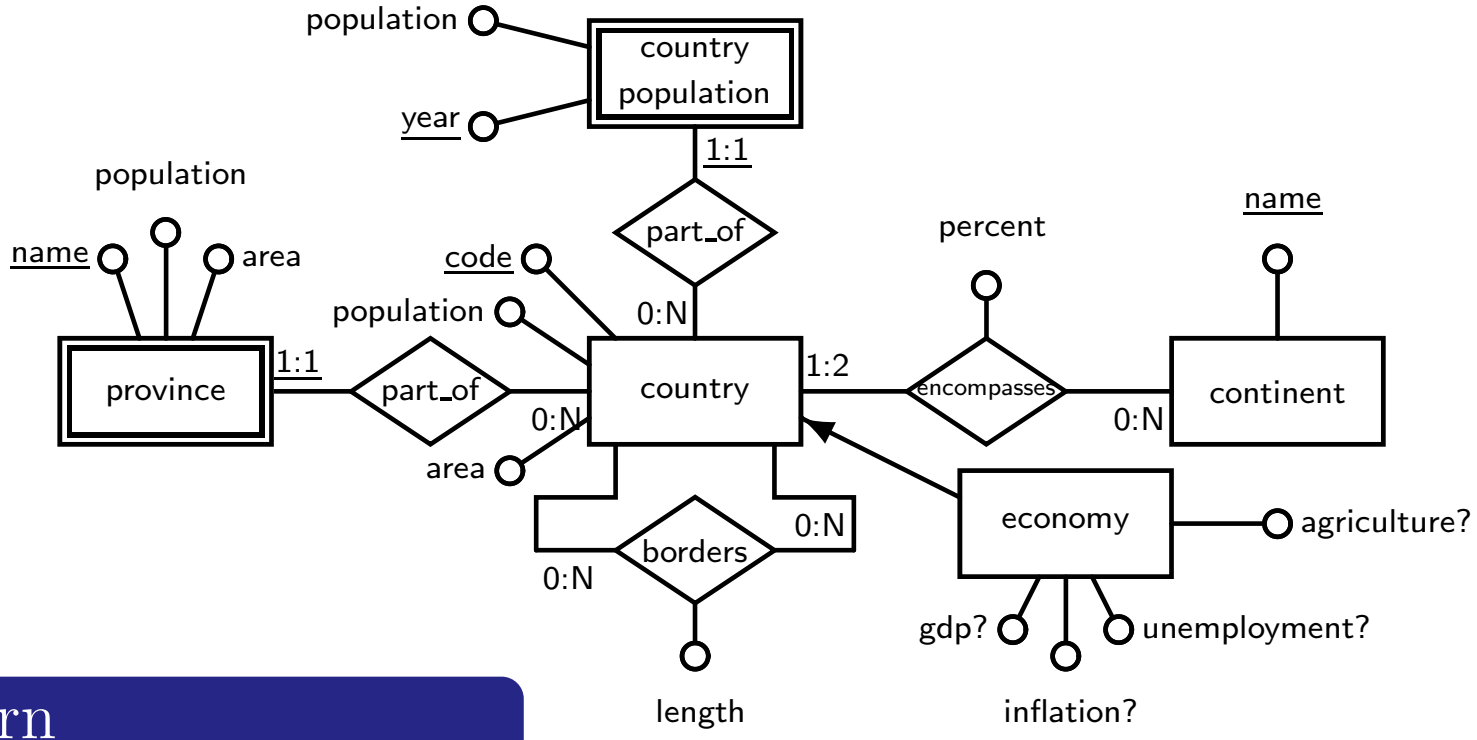
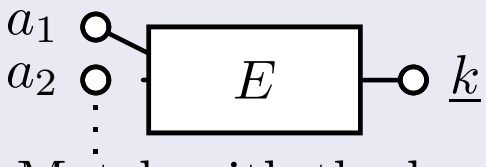


Pattern



Match with the key of an entity, plus one or more attributes

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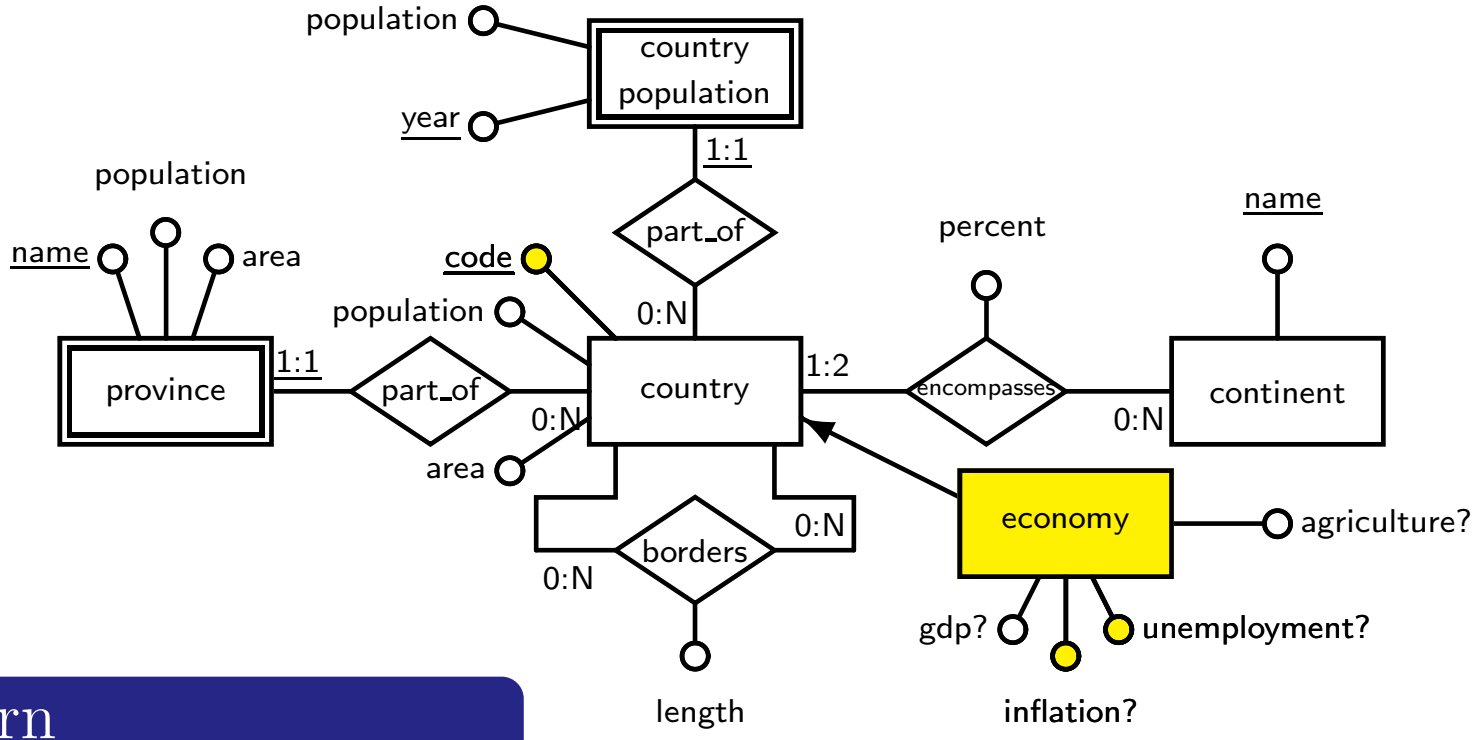

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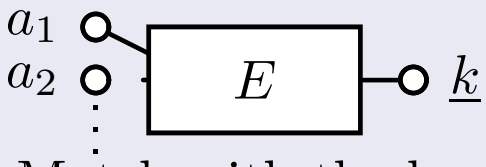

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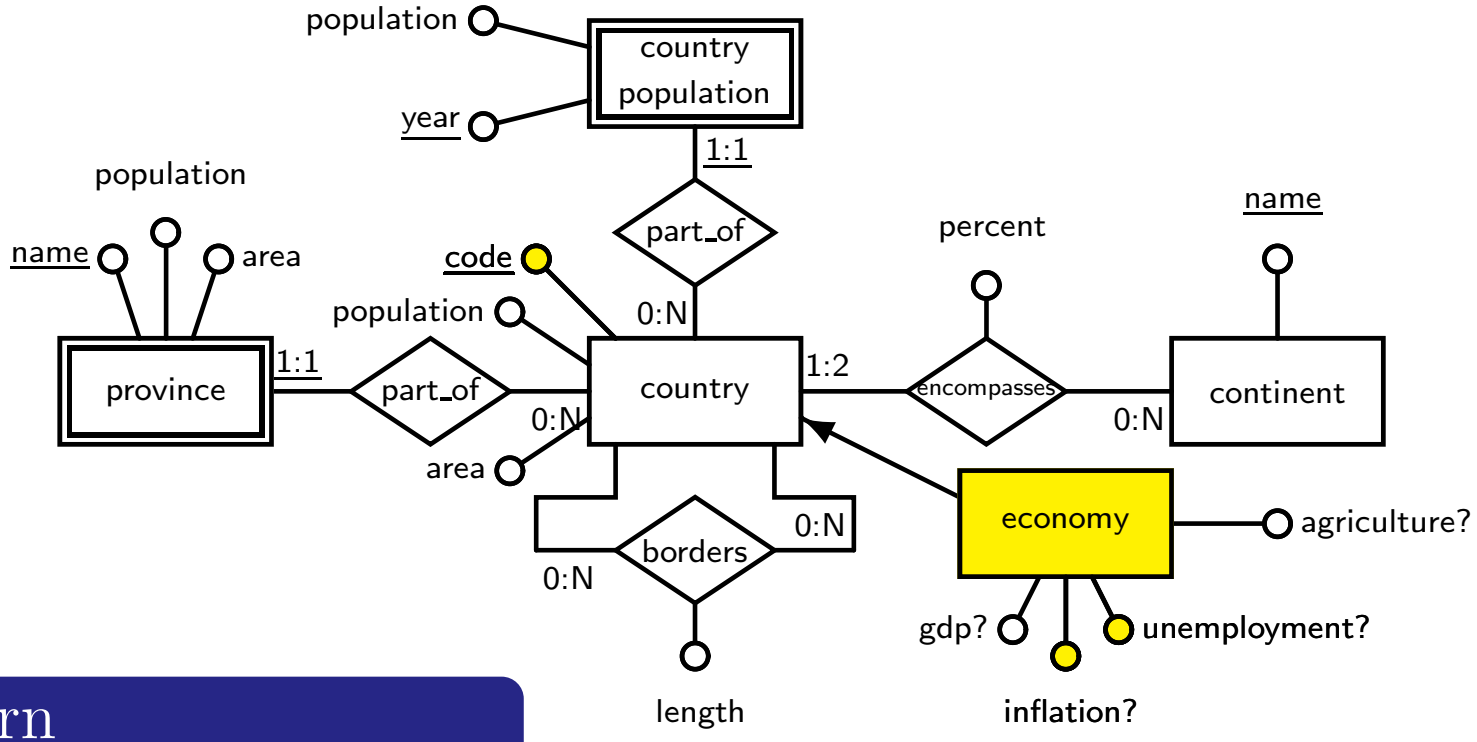

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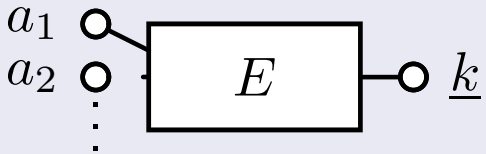

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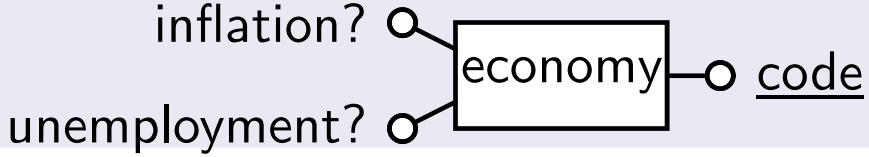

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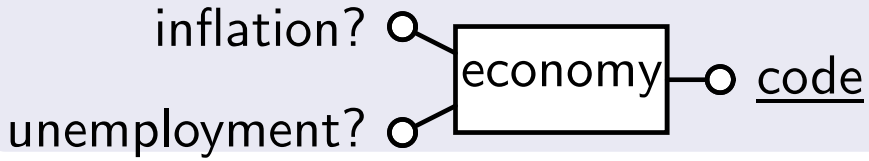
Visualisation Types

Basic Entity Visualisations			
Name	$\|k\|$	mandatory	optional
Bar Chart	1..100	a_1 scalar	-
Calendar	1..*	a_1 temporal scalar	a_2 colour
Scatter Diagrams	1..*	a_1, a_2 scalar	a_3 colour
Bubble Charts	1..*	a_1, a_2, a_3 scalar	a_4 colour
Choropleth Maps	1..*	k geographical, a_1 colour	-
Word Clouds	1..*	k lexical, a_1 scalar	a_2 colour

Instantiation



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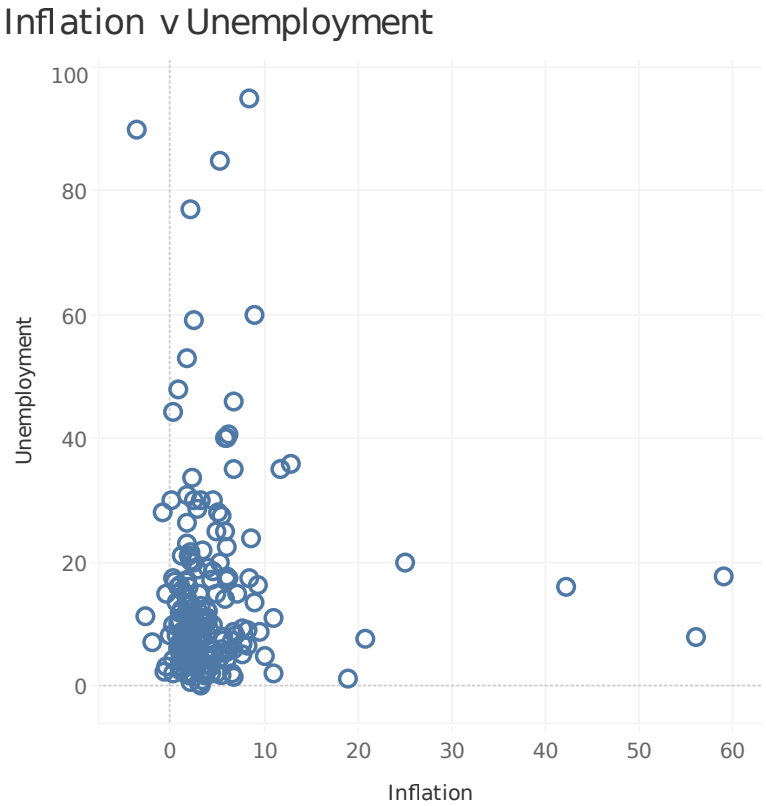

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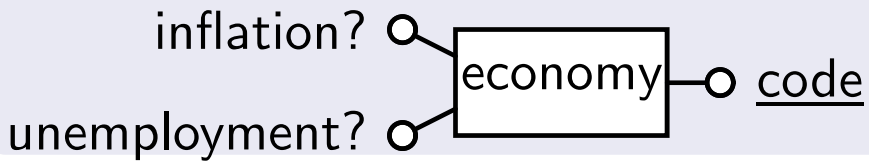
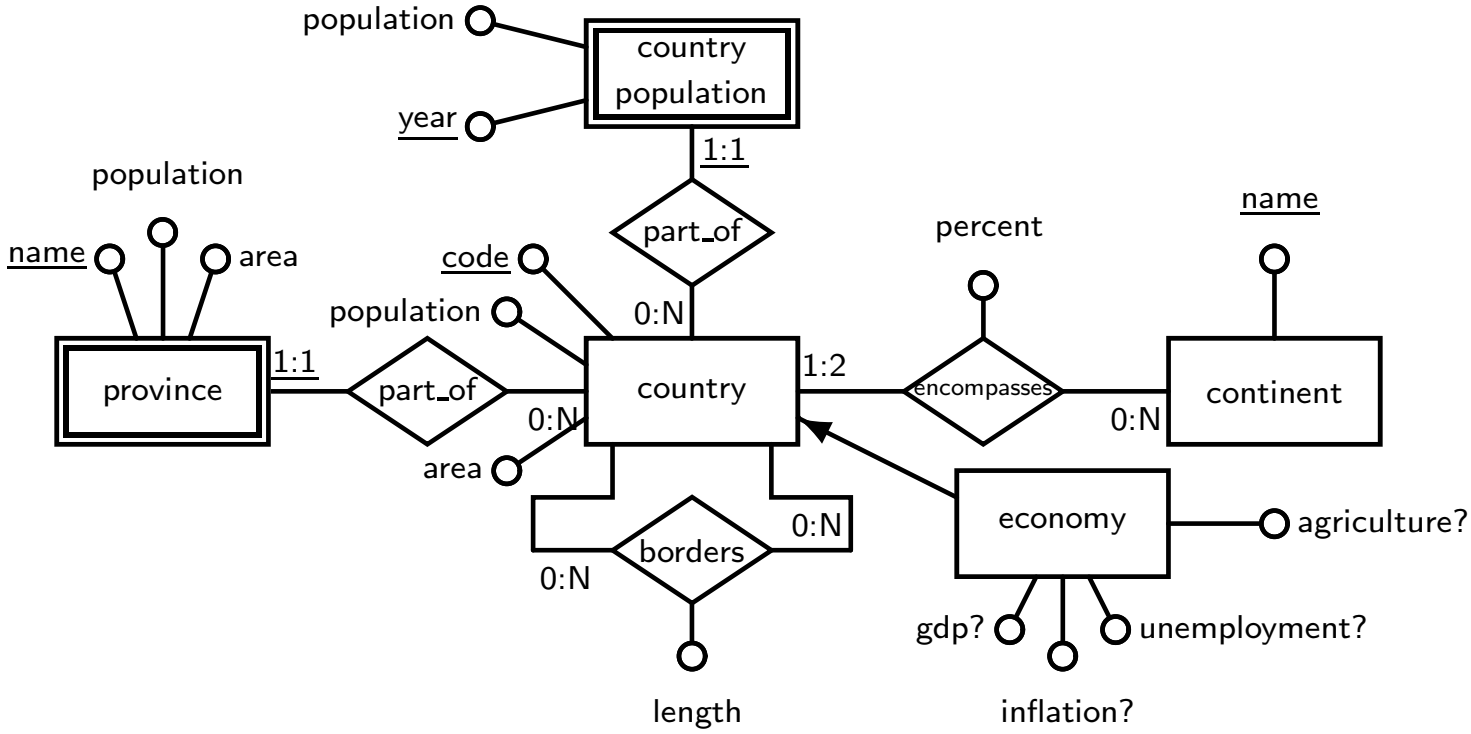


Visualisation Schema Pattern 2: Weak Entity



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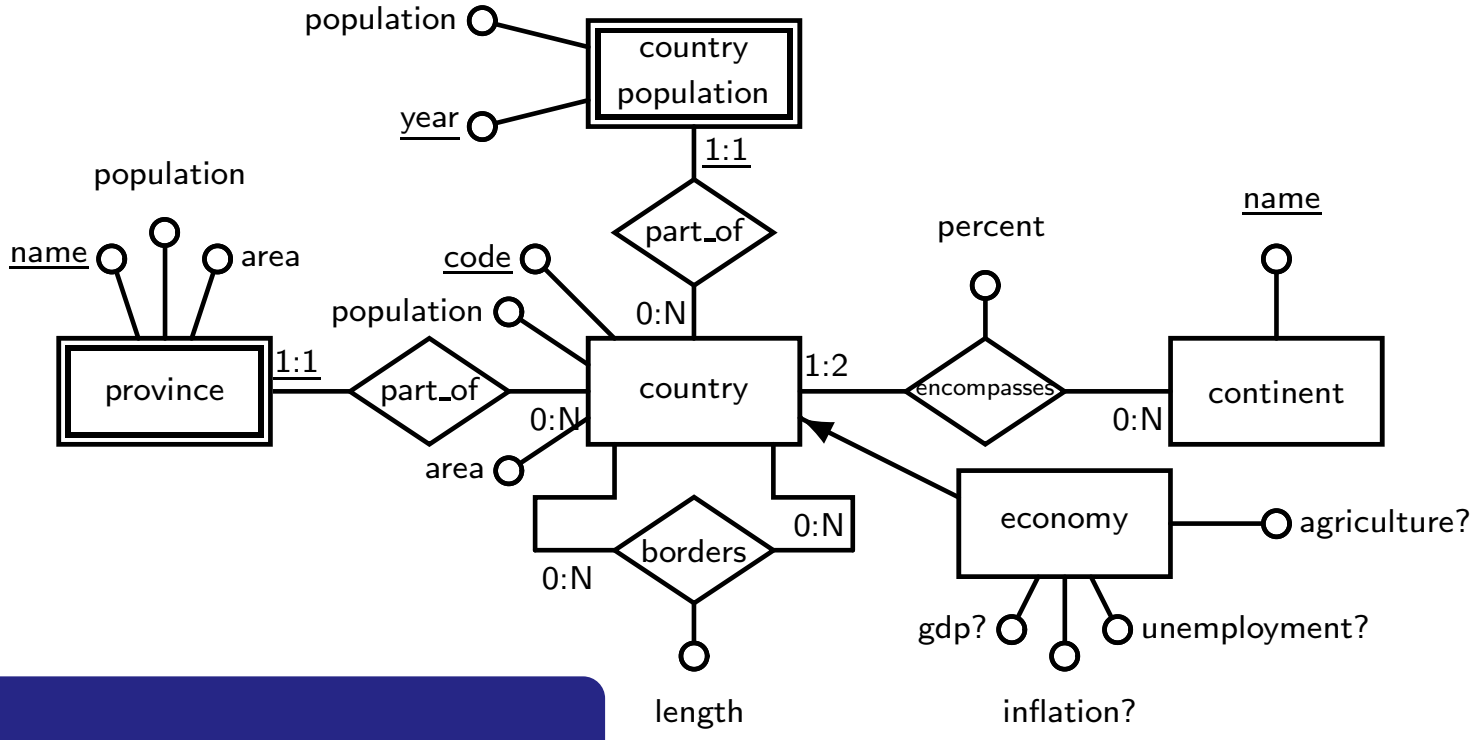
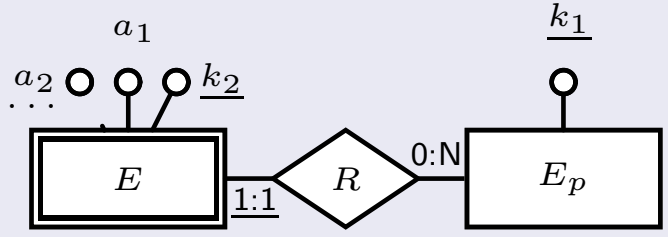


Pattern



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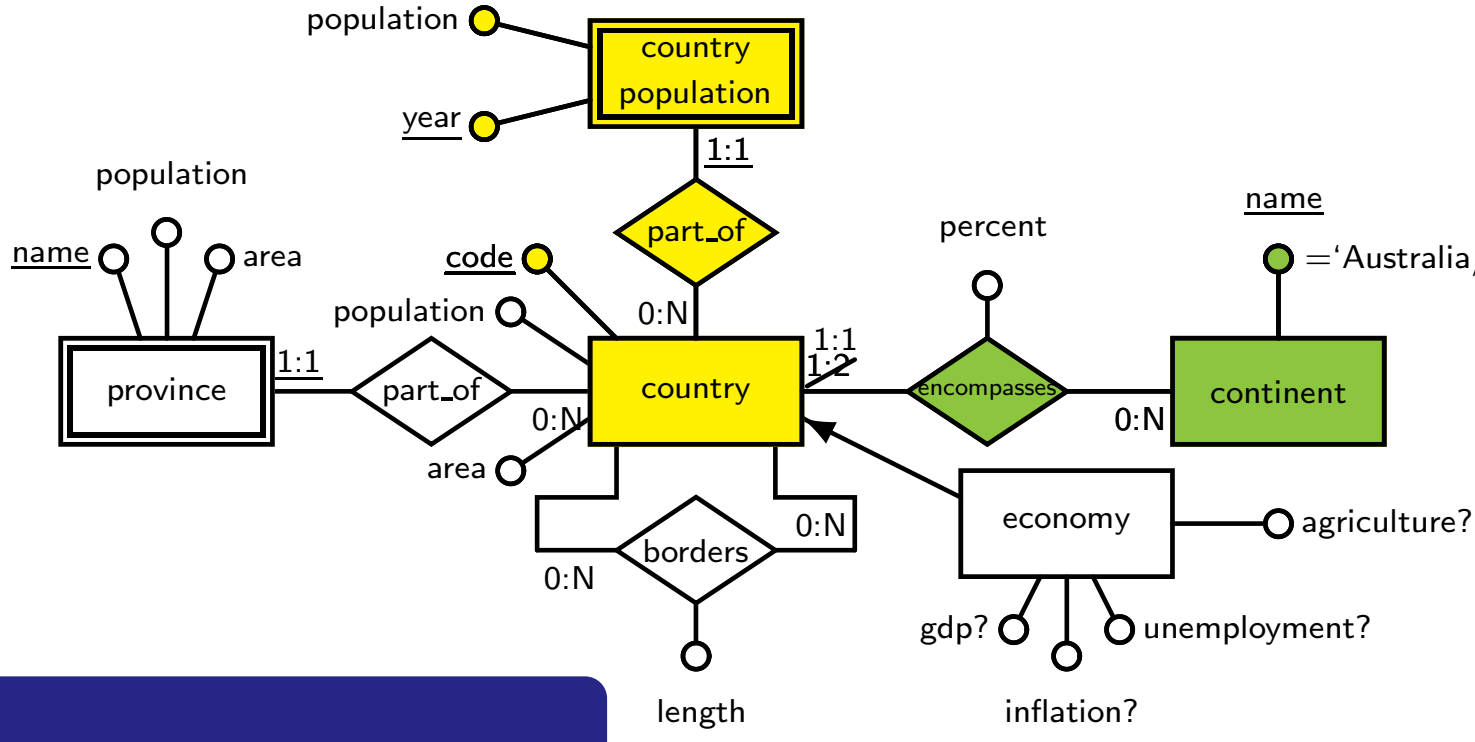

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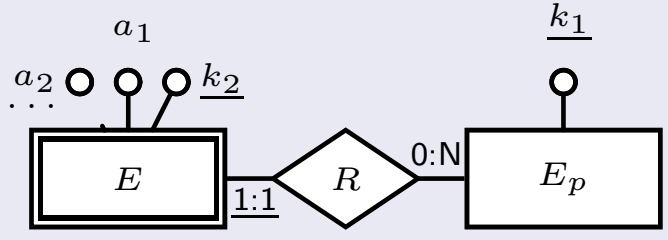

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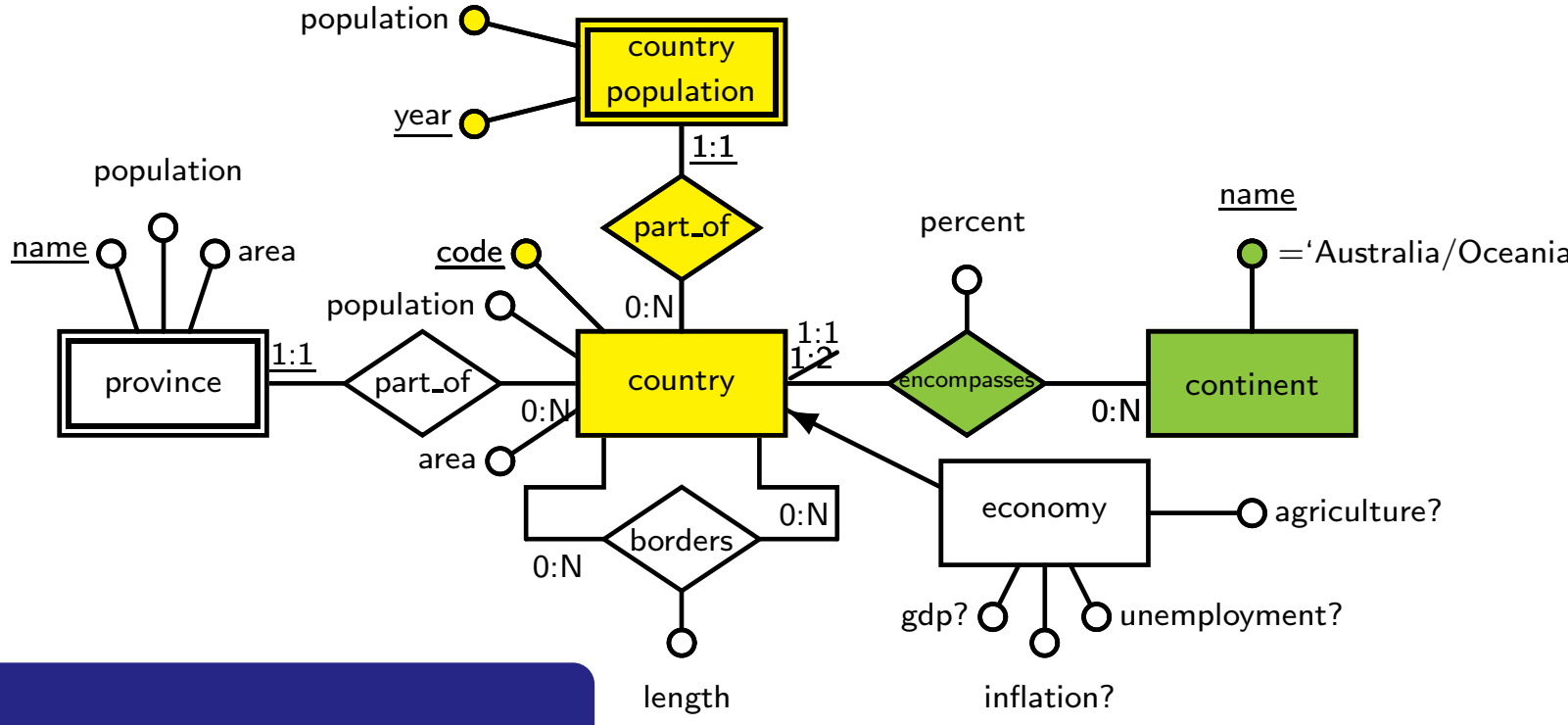

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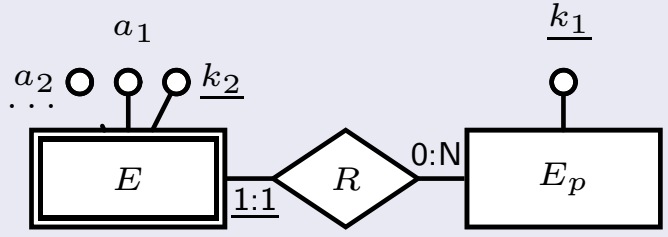

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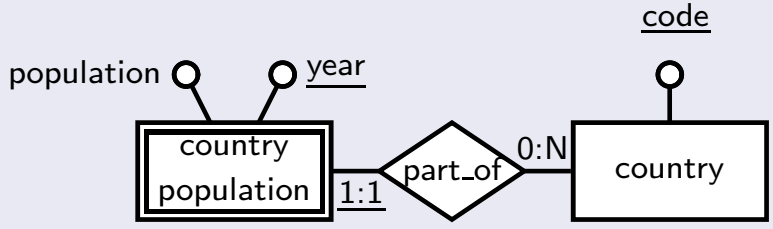
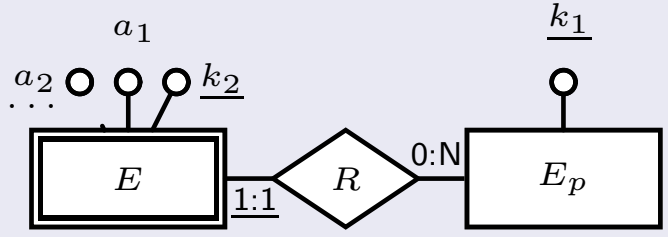


Visualisation Schema Pattern 2: Weak Entity

Visualisation Types

Weak Entity Visualisations					
Name	$\|k_1\|$	$\|k_2\|$	complete	mandatory	optiona
Line Chart	1..20	1..*	no	k_2, a_1 scalar	a_2 scal
Stacked Bar Chart	1..20	1..20	yes	a_1 scalar	-
Grouped Bar Chart	1..20	1..20	no	a_1 scalar	-
Spider Chart	3..10	1..20	yes	a_1 scalar	-

Pattern



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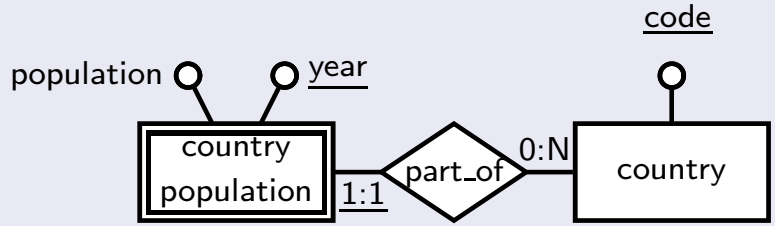

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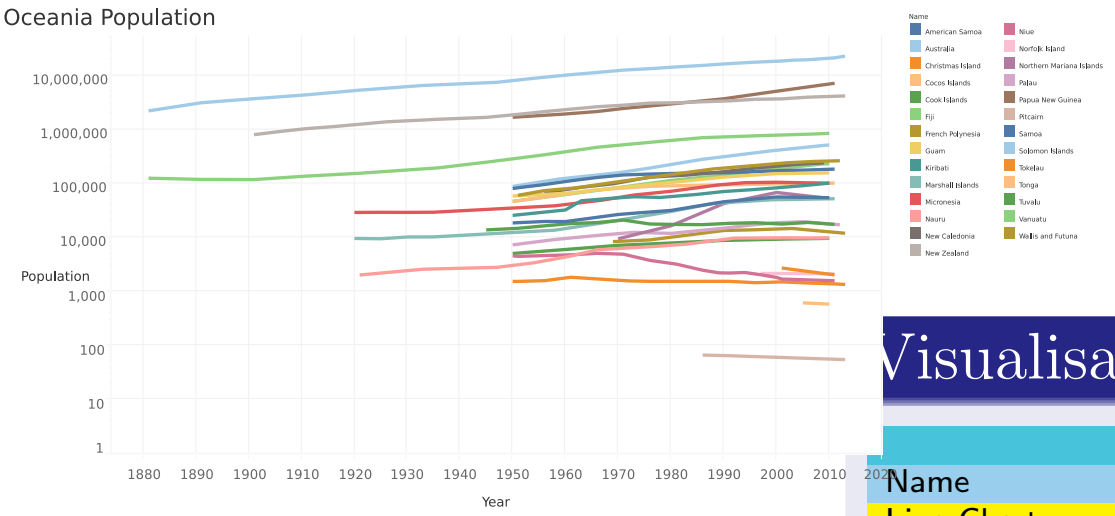

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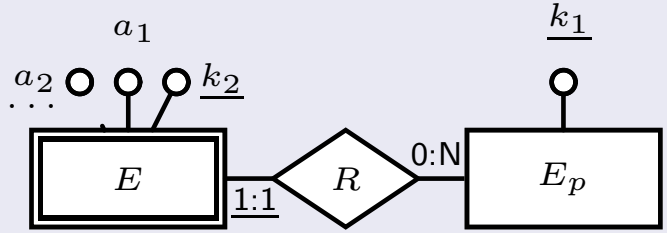

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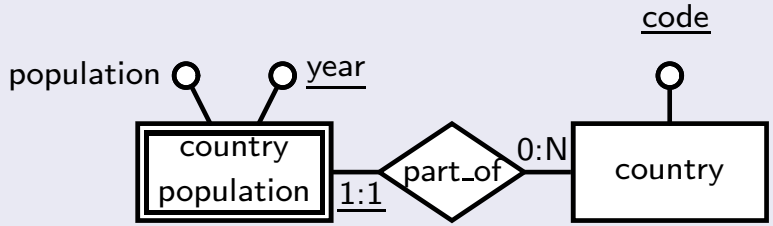
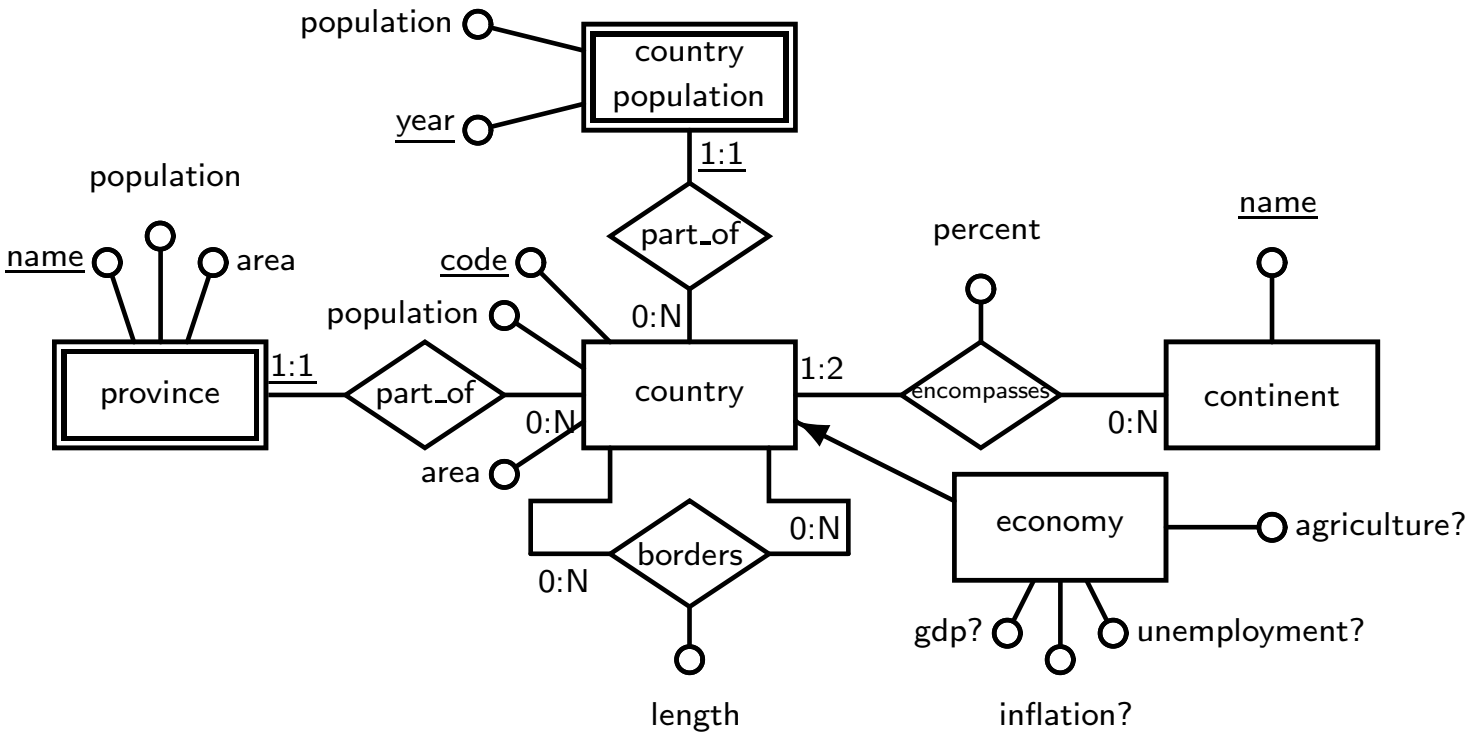


Visualisation Schema Pattern 3: One-Many Relationship



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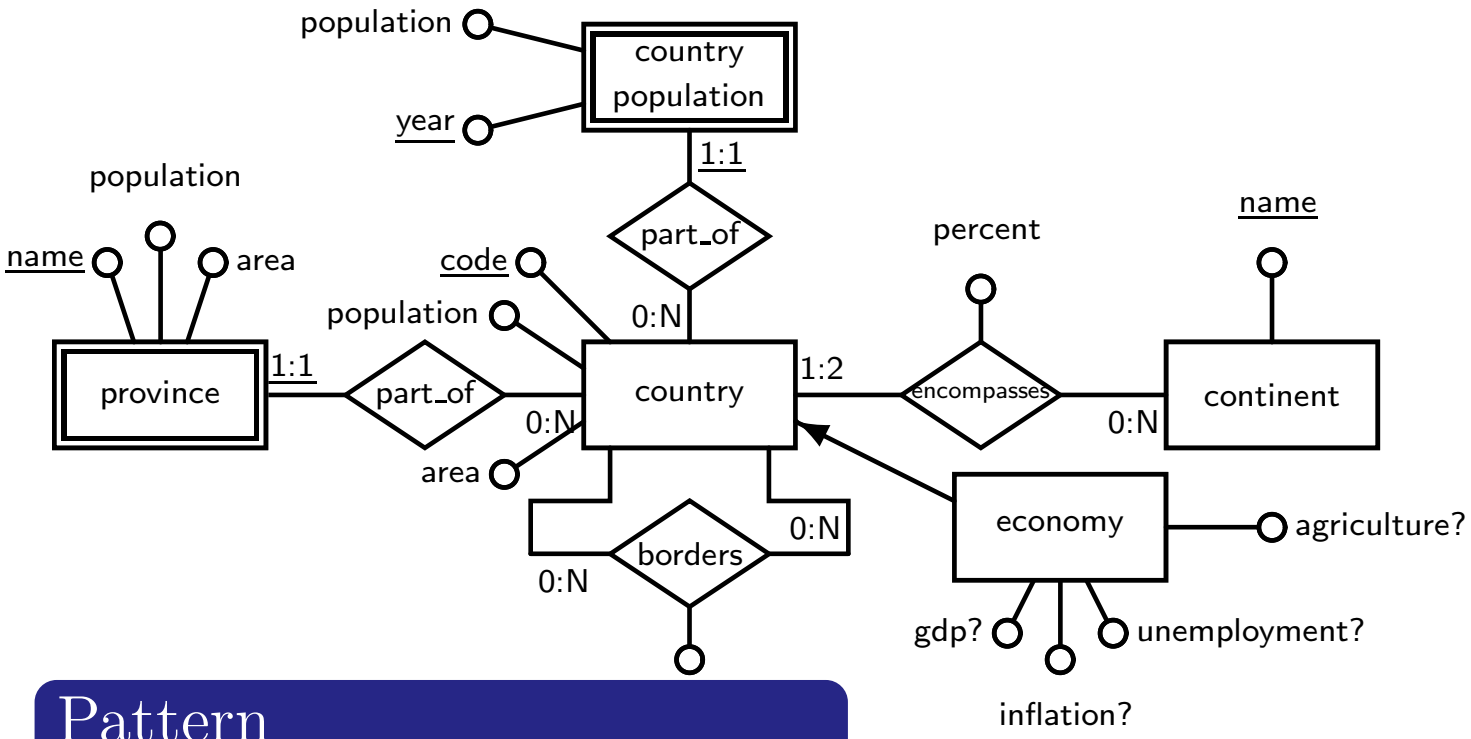
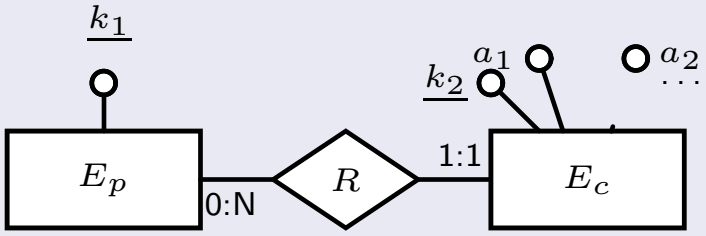


Pattern



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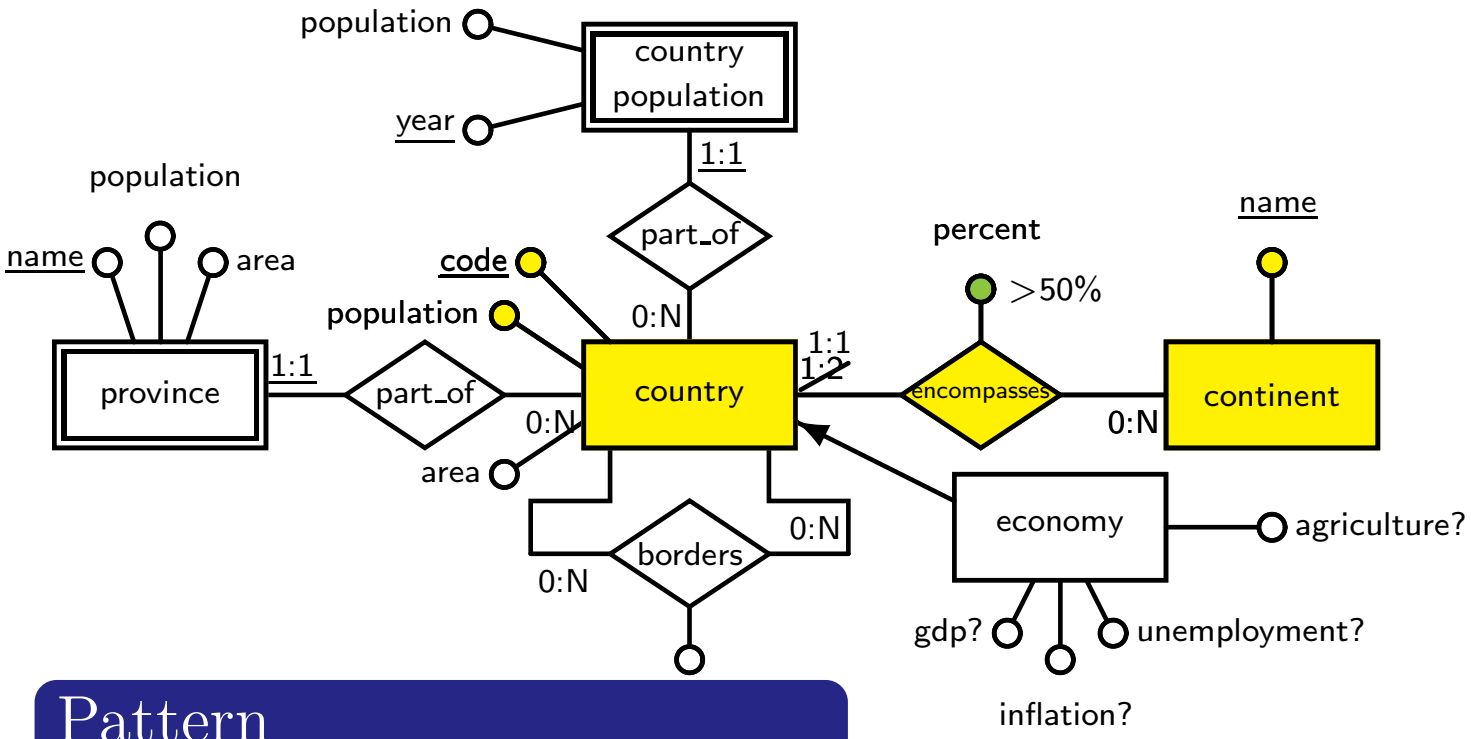

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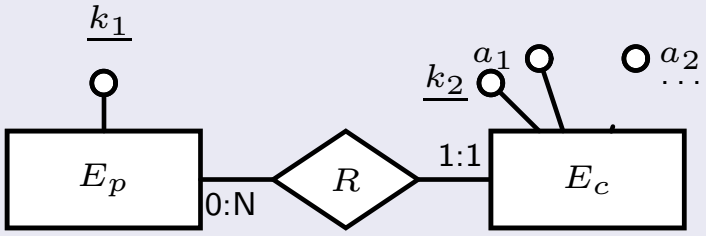

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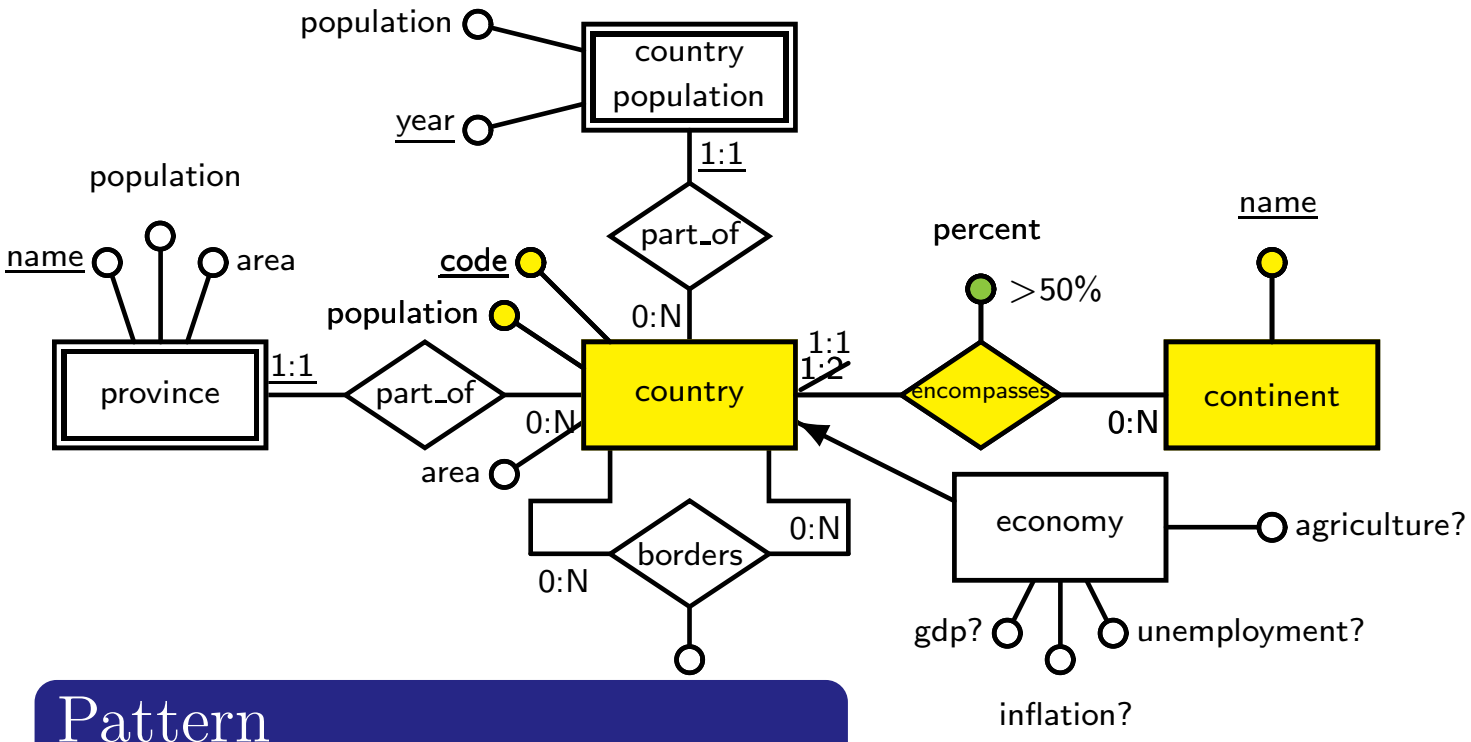

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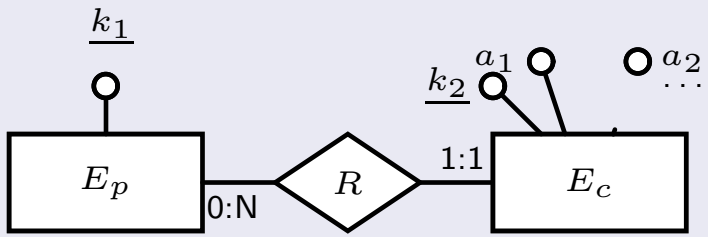

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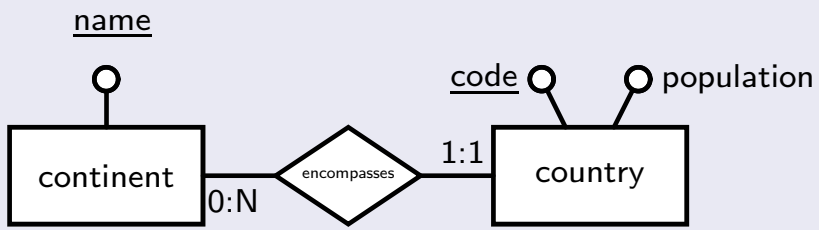
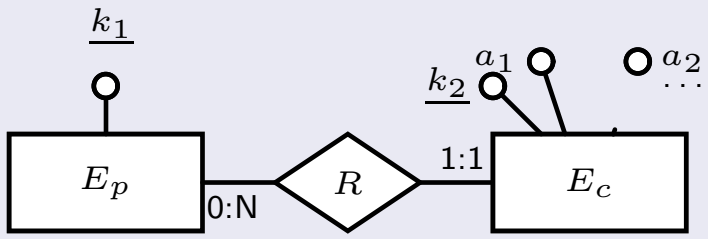


Visualisation Schema Pattern 3: One-Many Relationship

Visualisation Types

One-many relationships				
Name	$\lvert k_1 \rvert$	$\lvert k_2 \rvert$ per k_1	mandatory	optional
Tree Map	1..100	1..100	a_1 scalar	a_2 colour
Hierarchy Tree	1..100	1..100	-	a_1 colour
Circle Packing	1..100	1..100	a_1 scalar	a_2 colour

Pattern



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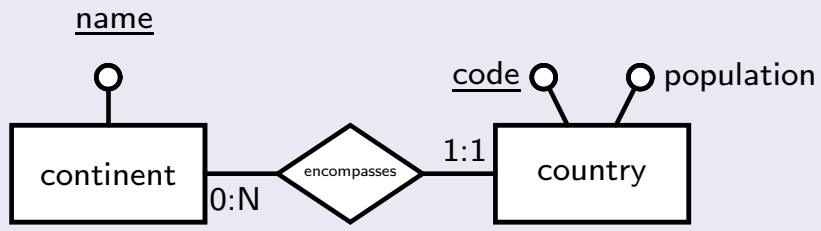

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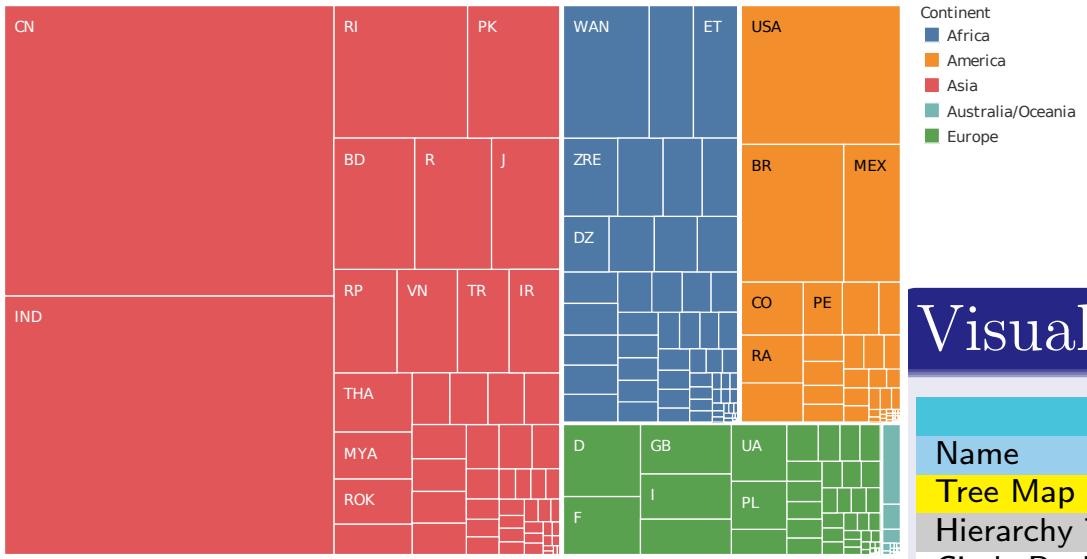

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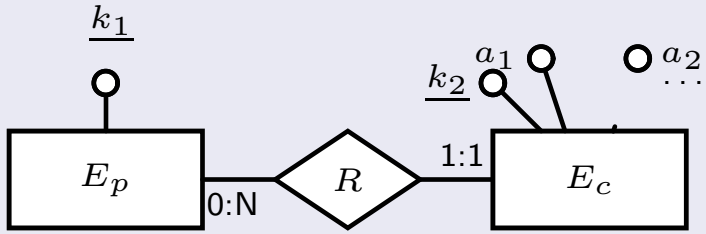
Circle Packing	1..100	1..100	a_1 scalar	a_2 colour

Pattern



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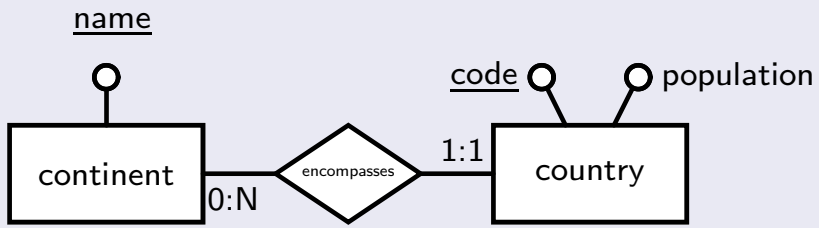
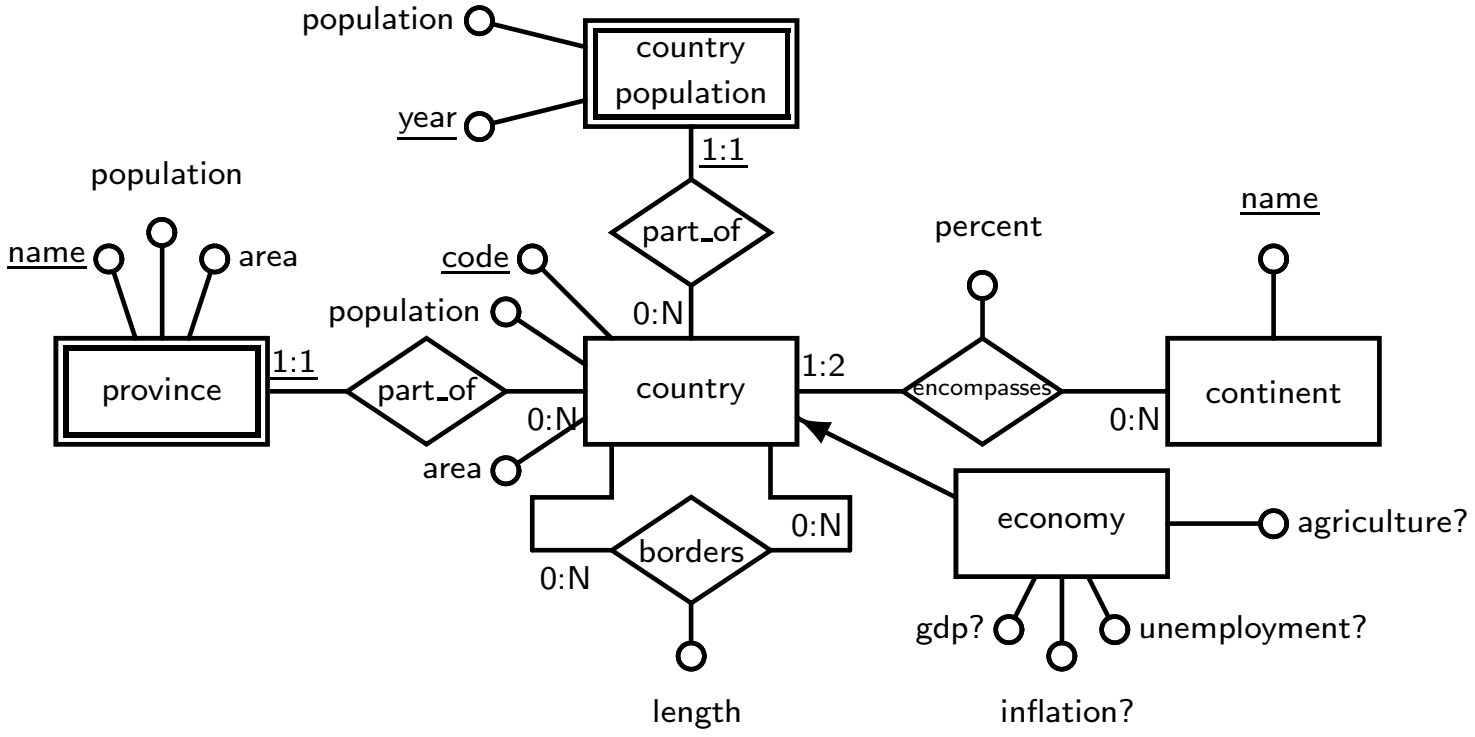


Visualisation Schema Pattern 4: Many-Many Relationship



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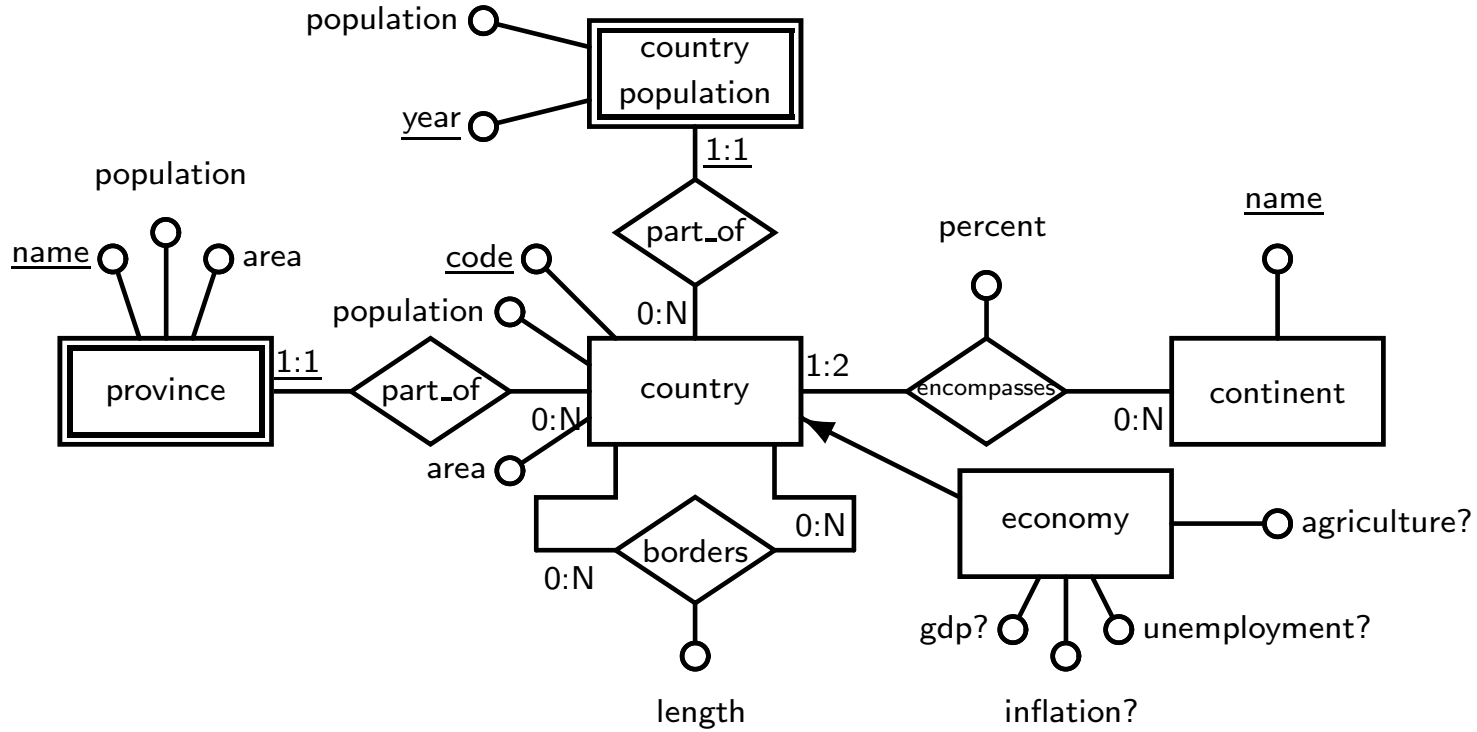
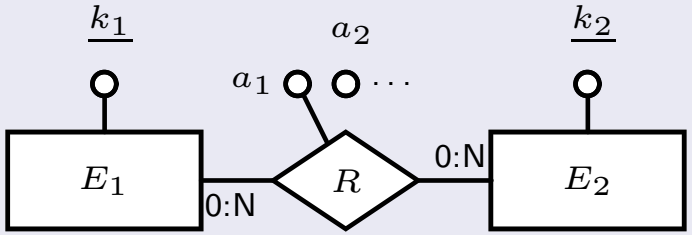
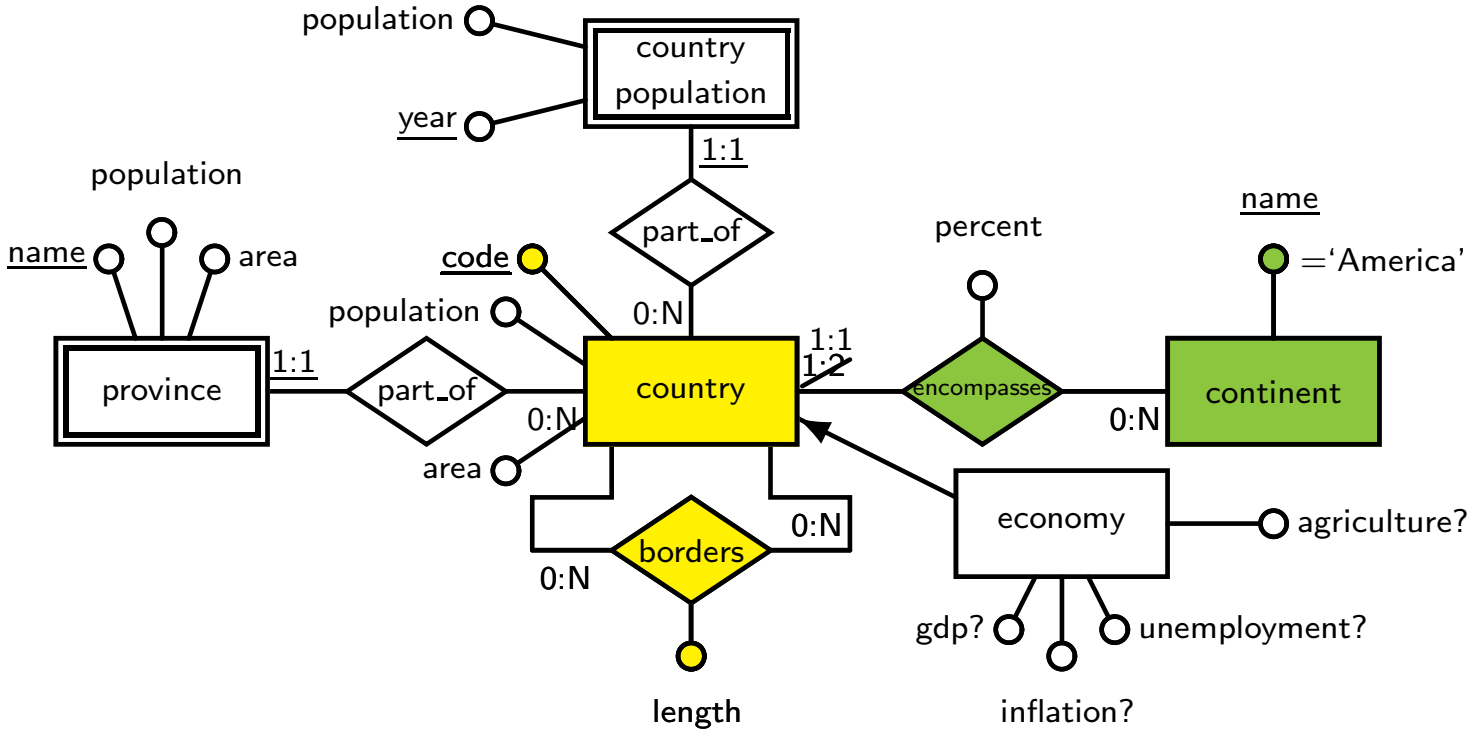


Pattern

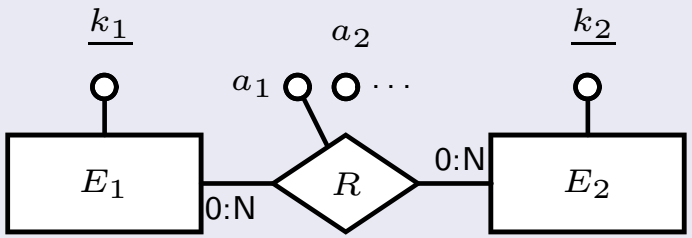


Match a (possibly reflexive) many-many relationship

Visualisation Schema Pattern 4: Many-Many Relationship



Pattern



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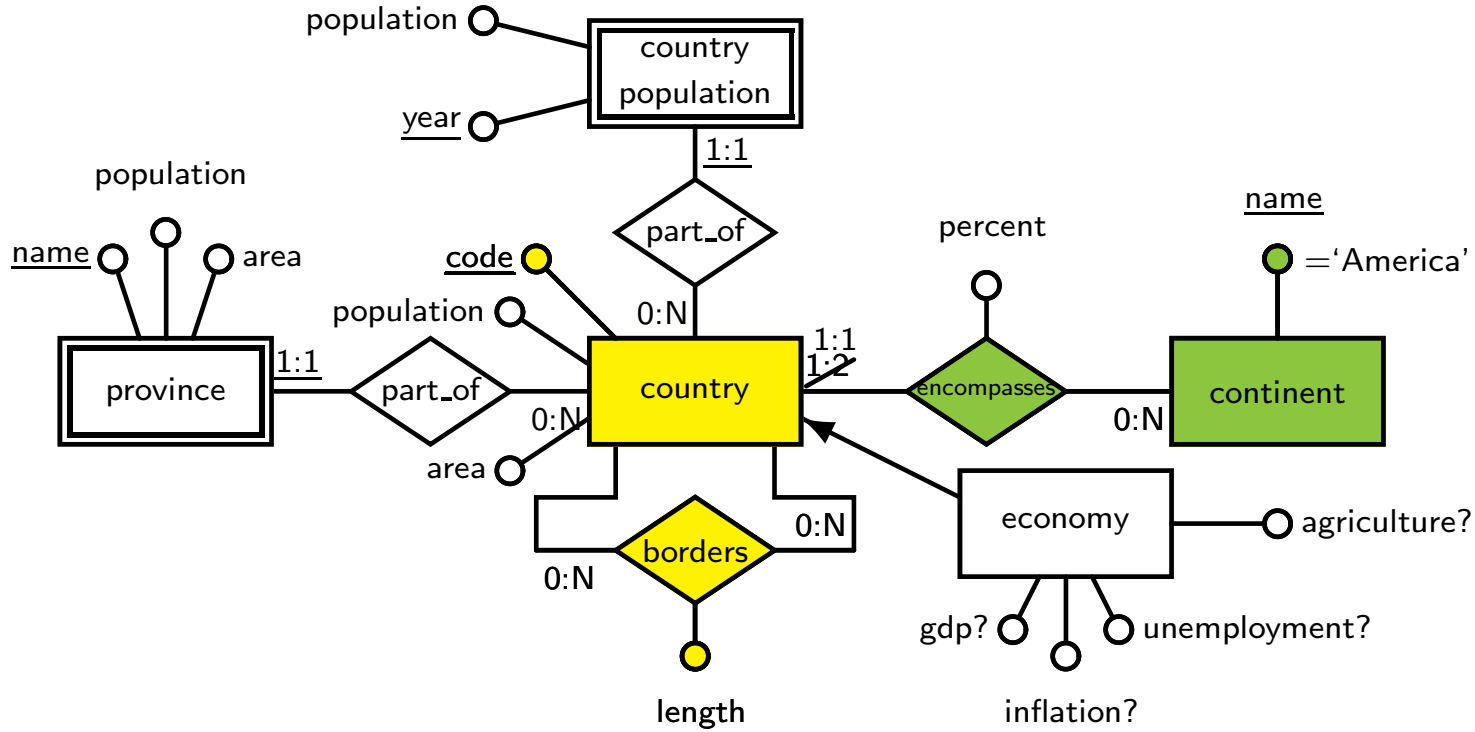
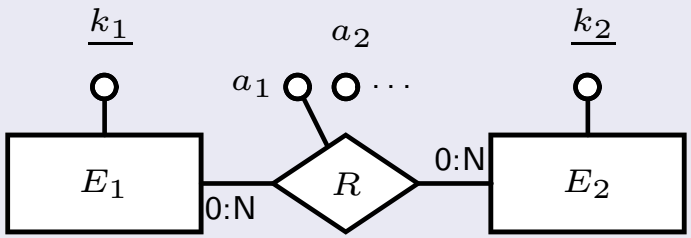
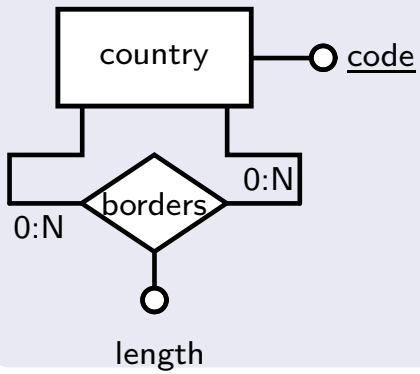


Pattern



Match a (possibly reflexive) many-many relationship

Instantiation

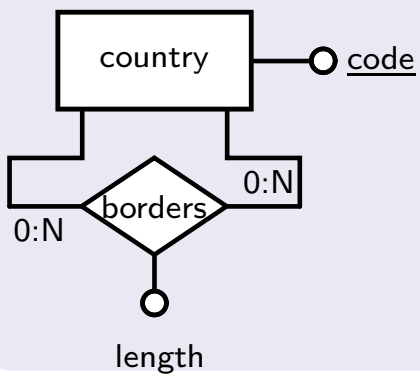


Visualisation Schema Pattern 4: Many-Many Relationship

Visualisation Types

Many-many relationships					
Name	$\|k_1\|$	$\|k_2\|$	reflexive	mandatory	optional
Sankey	1..20	1..20	no	a_1 scalar	a_2 colour
Chord	1..100	1..100	yes	a_1 scalar	a_2 colour

Instantiation



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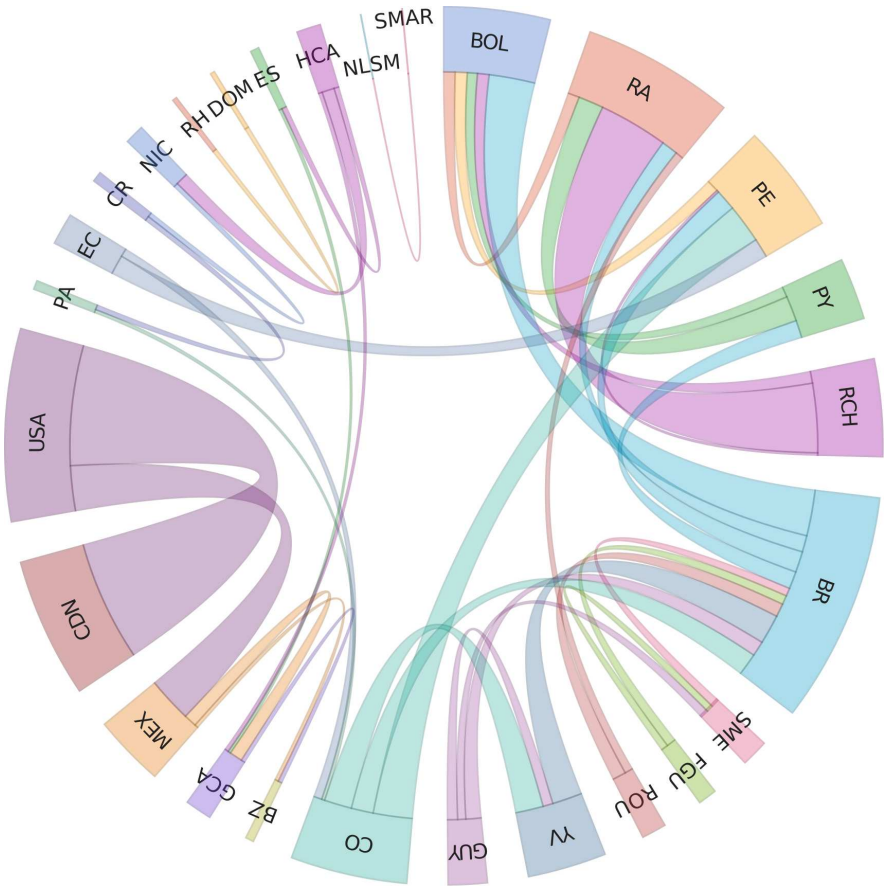

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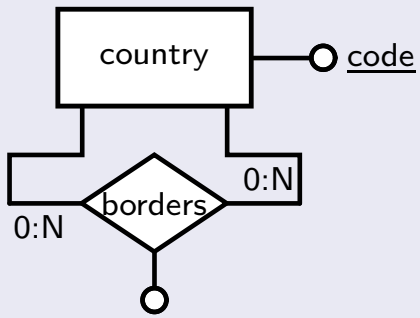
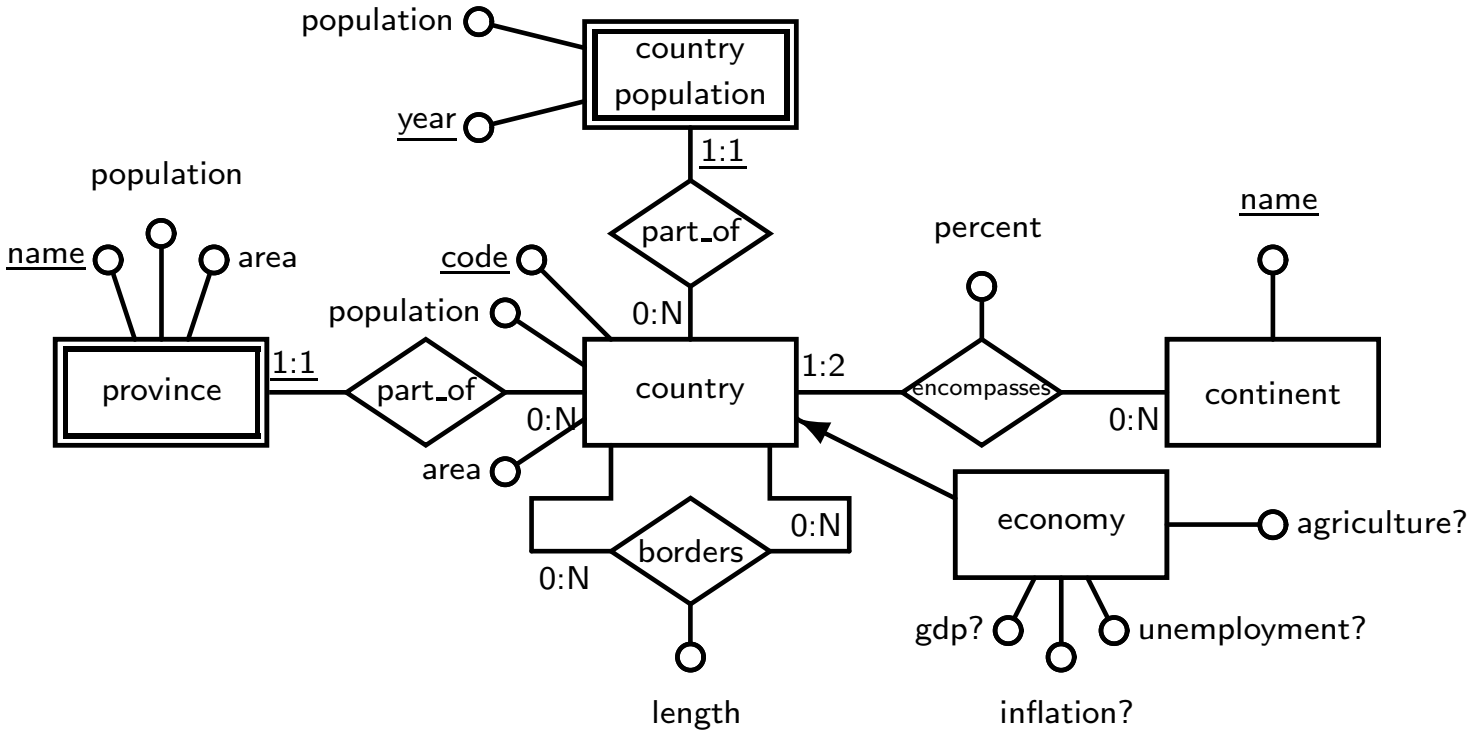


Transformations: Pivot



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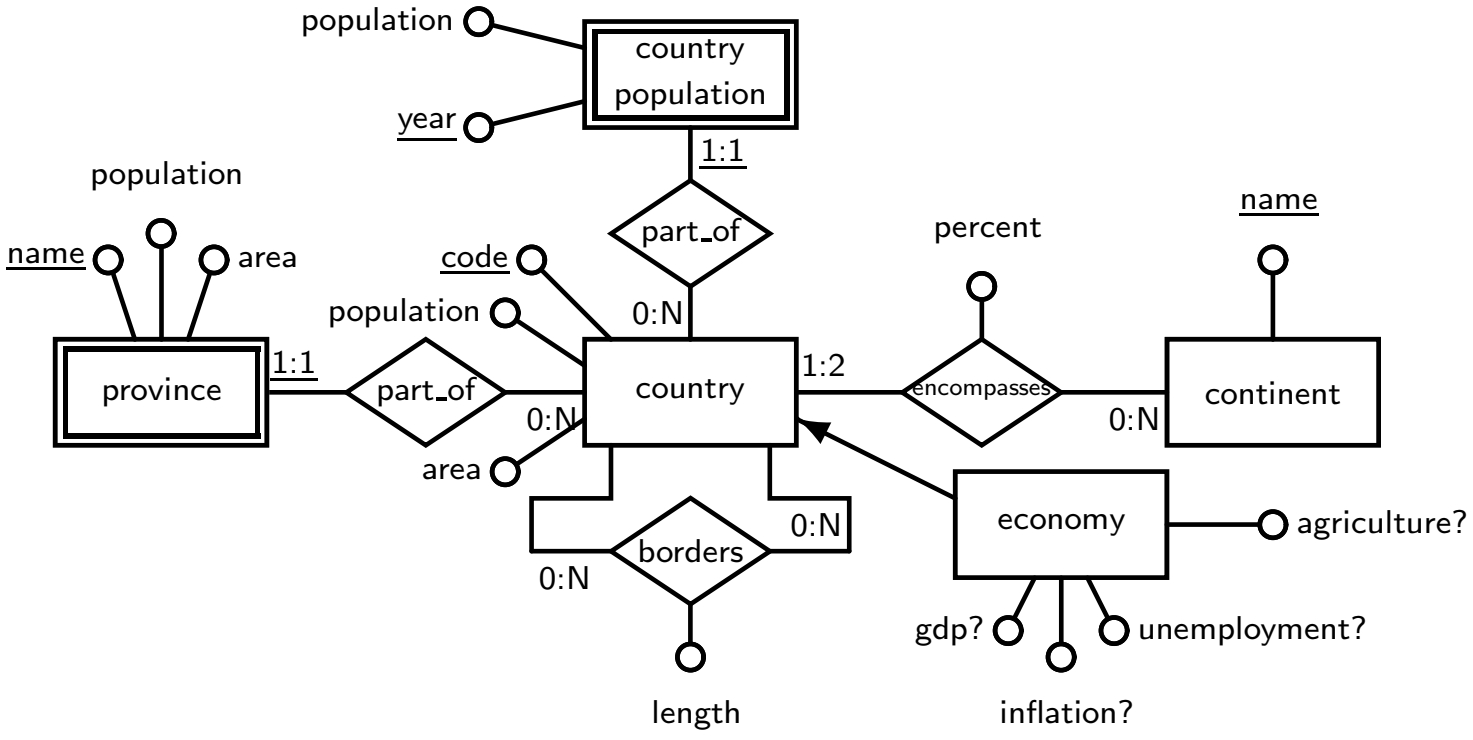
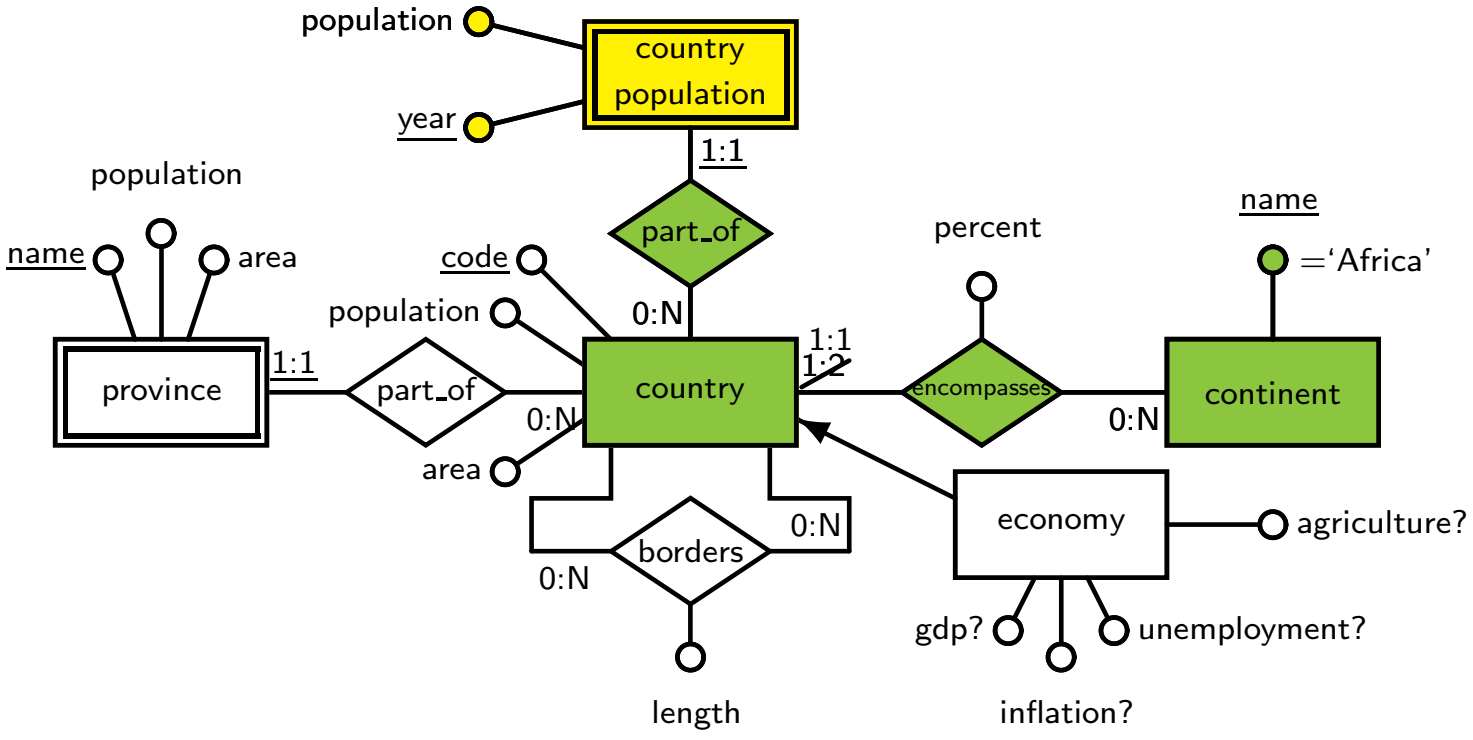


Transformation

Pivot $E(a, b)$ $\{v_1, \ldots, v_n\} \rightarrow$
$E_p(a\_v_1, \ldots, a\_v_n)$:-
$E(v_1, a\_v_1)$,
$\ldots$,
$E(v_n, a\_v_n)$.
Not information preserving

Transformations: Pivot



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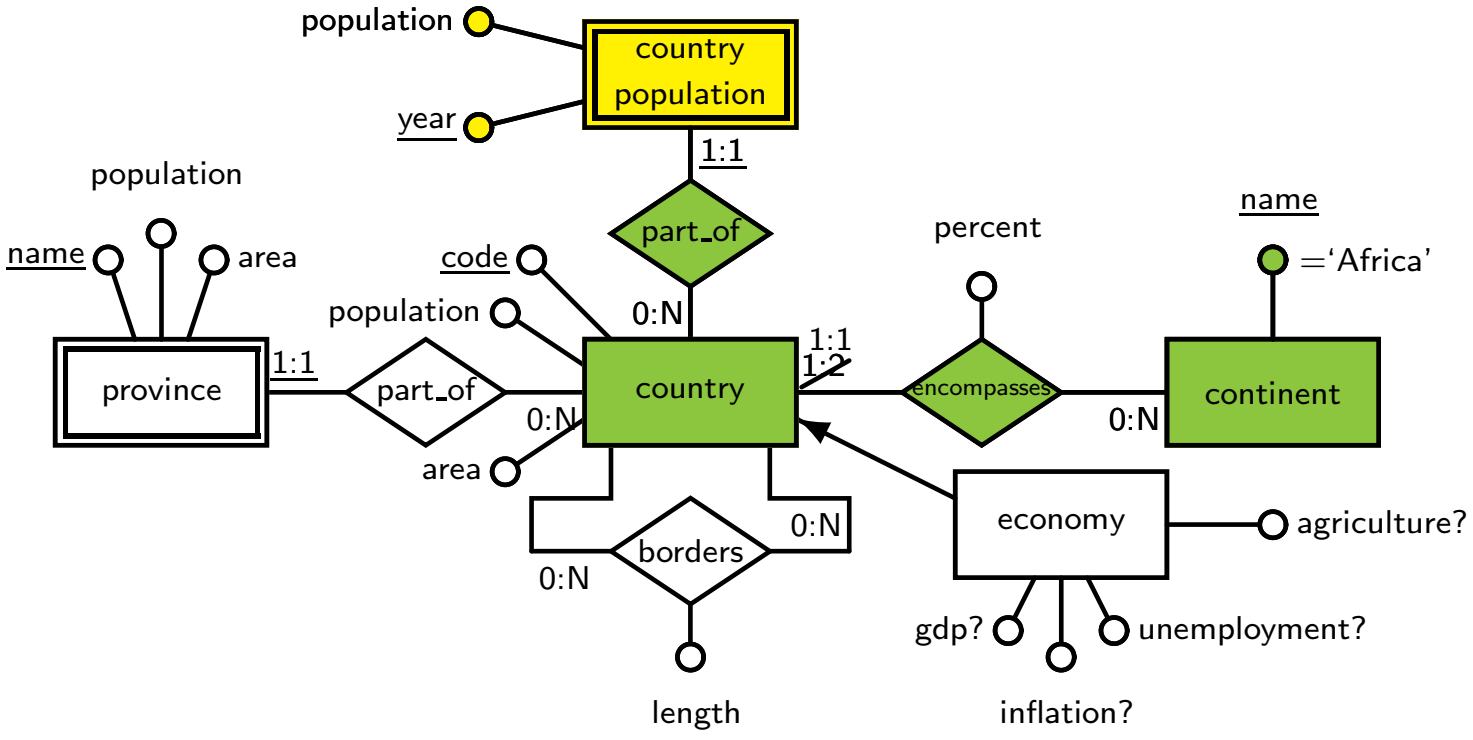

Transformation

Pivot $E(a, b)$ $\{v_1, \ldots, v_n\} \rightarrow$
$E_p(a\_v_1, \ldots, a\_v_n)$:-
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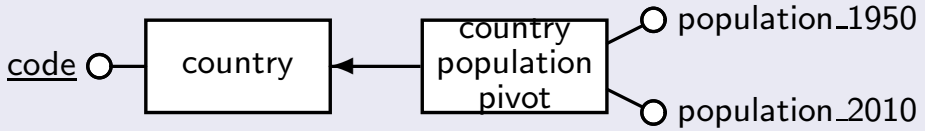
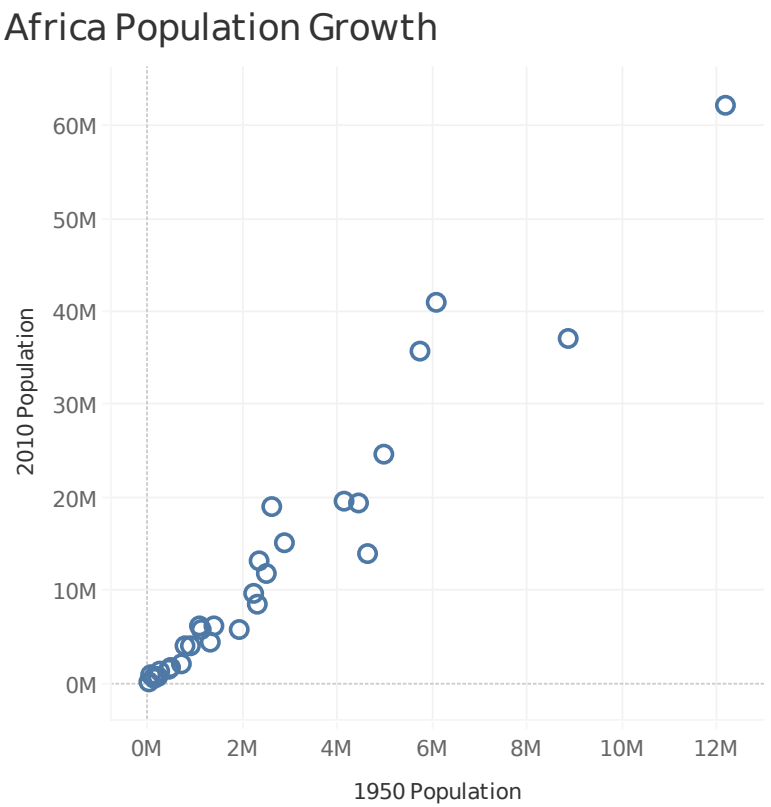
$\ldots$,
$E(v_n, a\_v_n)$.
Not information preserving

Application to Schema

Pivot country_population(year, population) {1950, 2010}



Transformations: Pivot



Transformation

Pivot $E(a, b)$ $\{v_1, \ldots, v_n\} \rightarrow$
$E_p(a\_v_1, \ldots, a\_v_n)$:-
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Not information preserving

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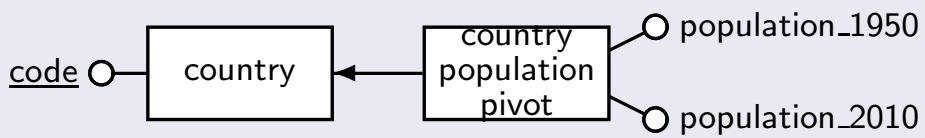
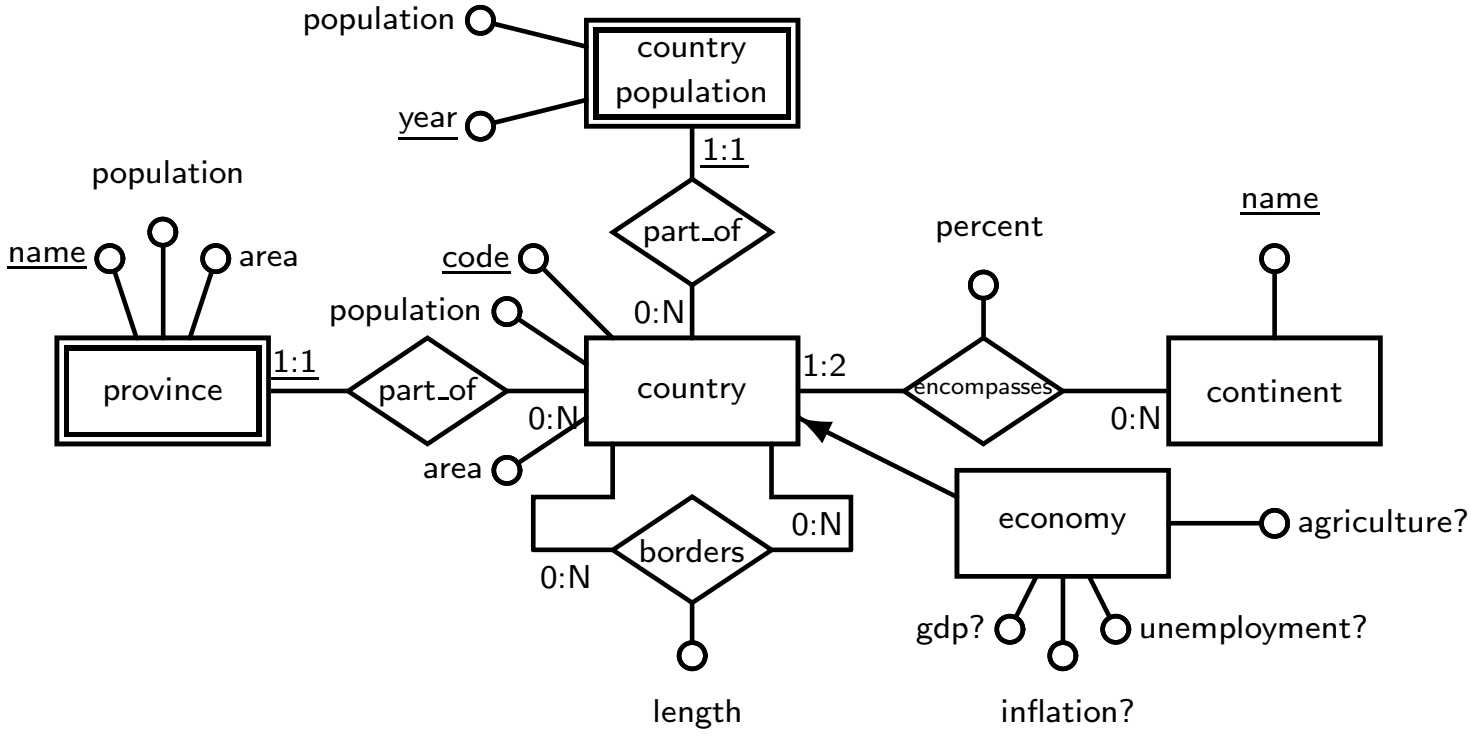
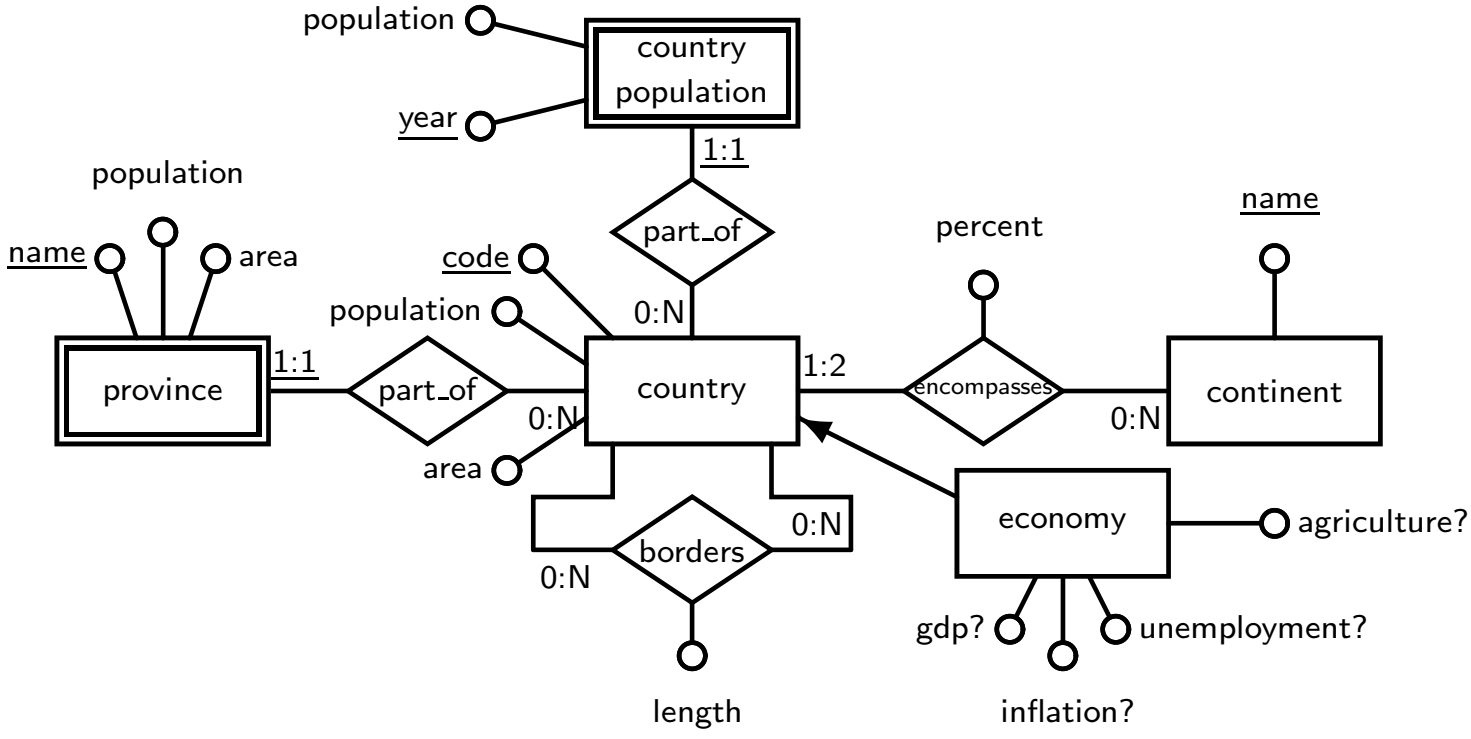


Transformations: Denormalisation



Transformations: Denormalisation

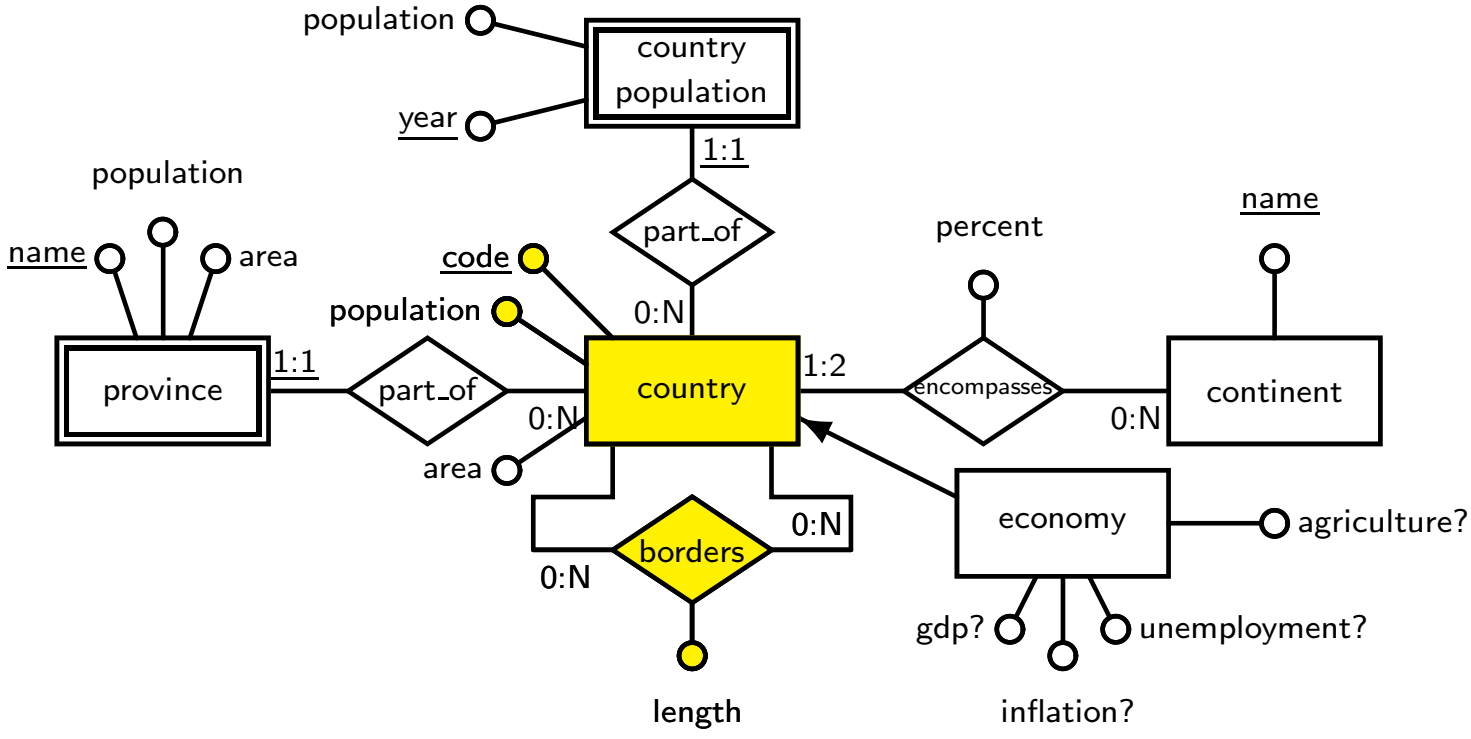


Transformation

Denormalise $E_2(k_2, x, \ldots)$
$R(k_1, k_2, a, \ldots) \rightarrow$
$ED_2(k_1, k_2, x, \ldots, a, \ldots)$:-
$E_2(k_2, x, \ldots)$,
$R(k_1, k_2, a, \ldots)$.

Information preserving

Transformations: Denormalisation



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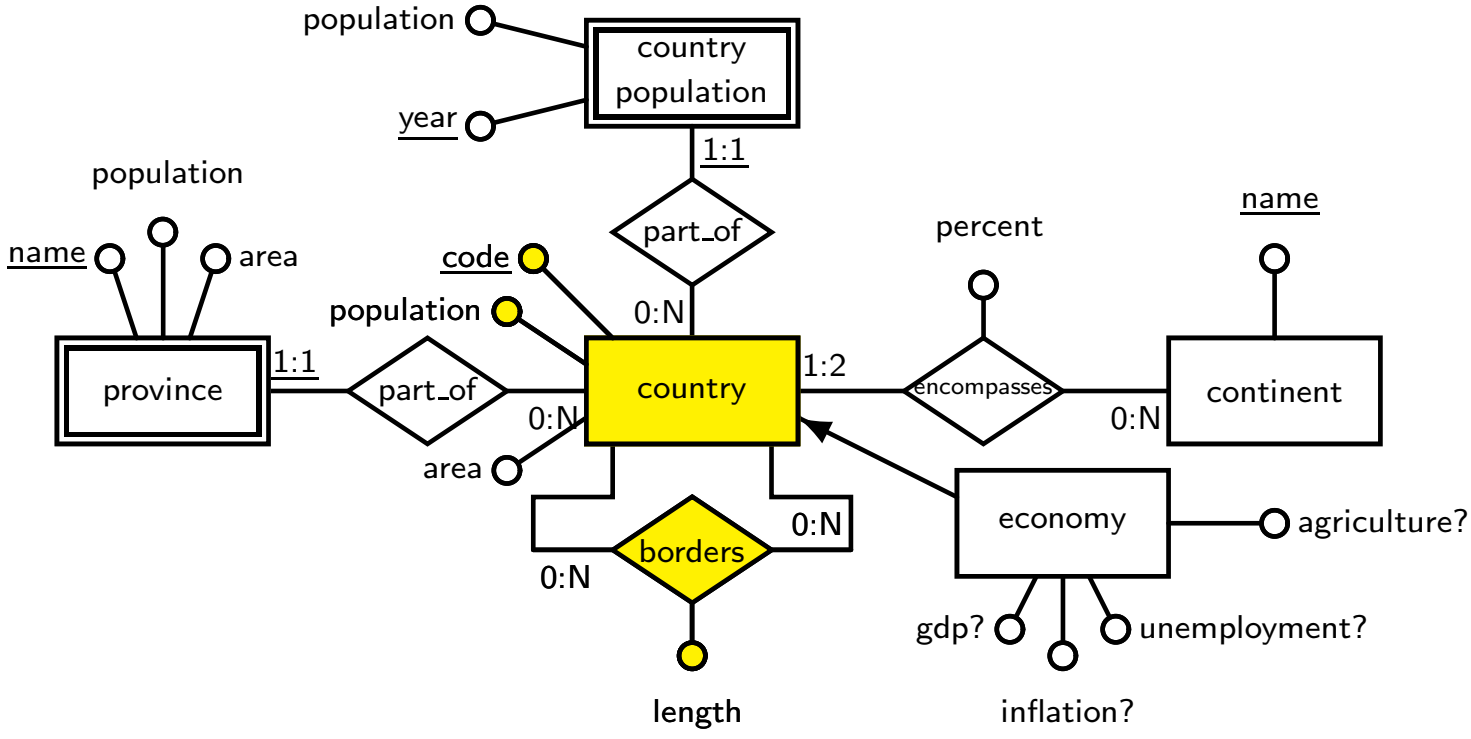

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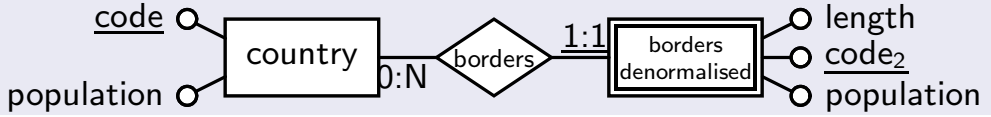
Information preserving

Application to Schema

Denormalise country(code, population) borders($code_1$, $code_2$, length)



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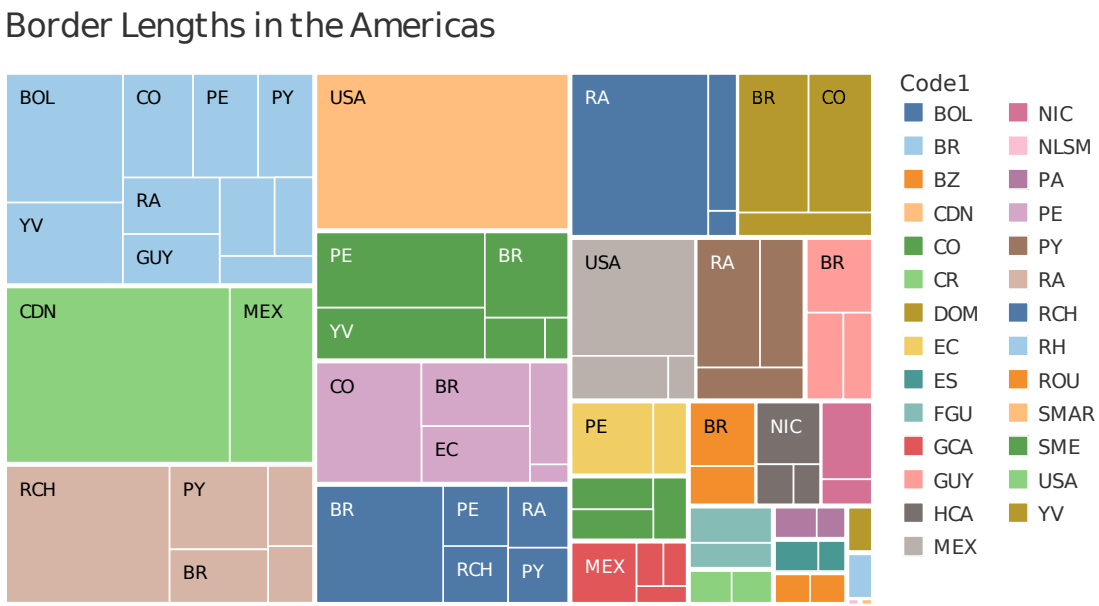

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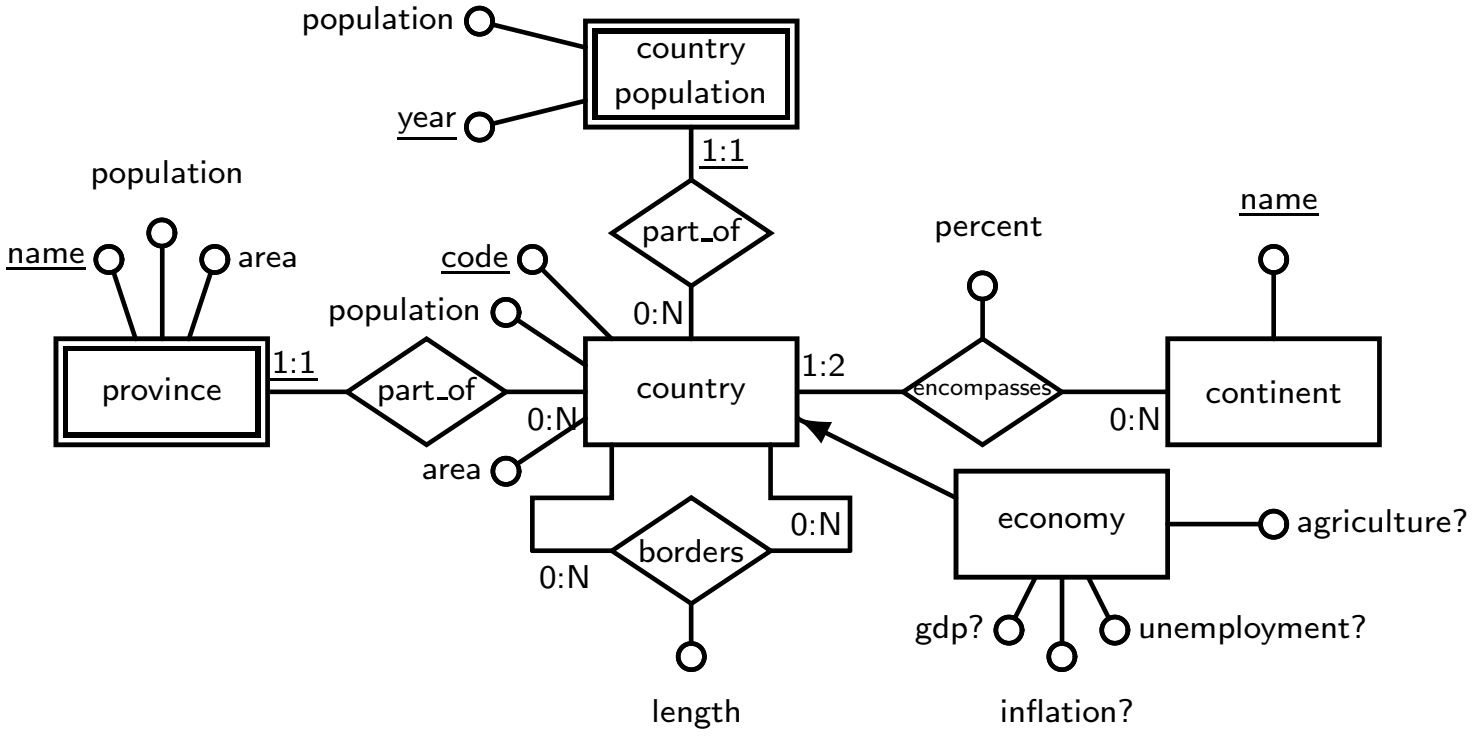
Information preserving

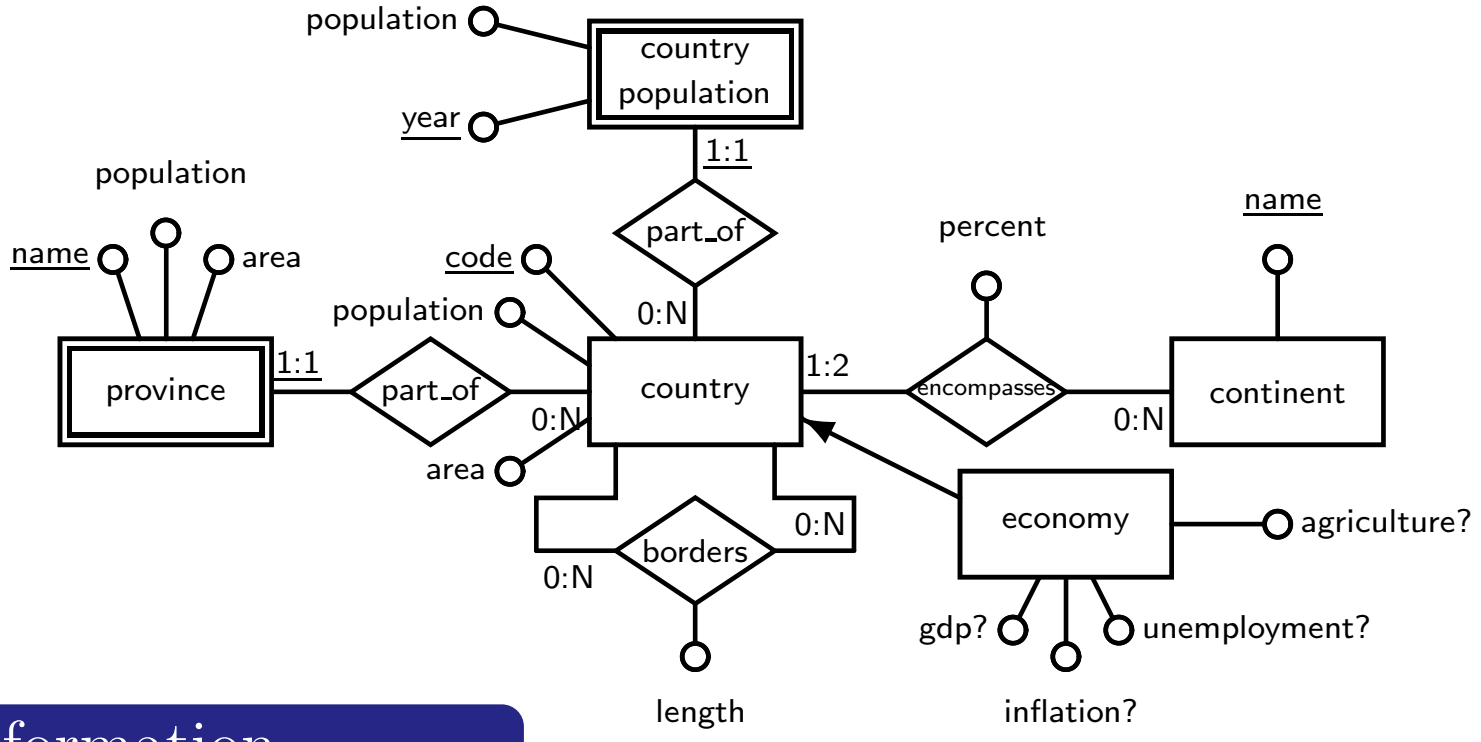
Application to Schema

Denormalise country(code, population) borders($code_1$, $code_2$, length)

Transformations: Attribute Specialisation



Transformations: Attribute Specialisation



Transformation

Mandatory $E(k, a_1, \ldots, a_n) \rightarrow$
$EM(k, a_1, \ldots, a_n)$:-
$E(k, a_1, \ldots, a_n)$,
$IsNotNull(a_1)$,
$\ldots$,
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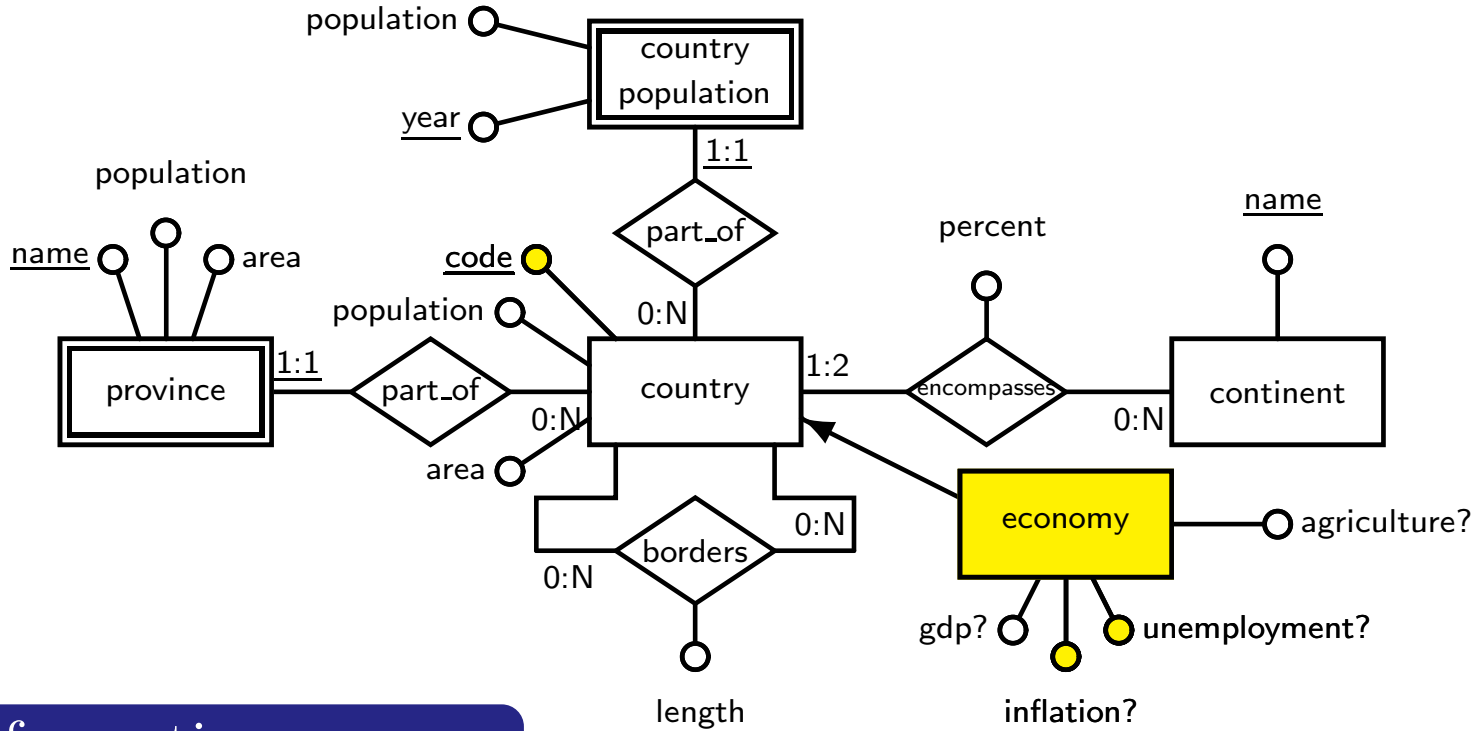
Not information preserving

Transformations: Attribute Specialisation



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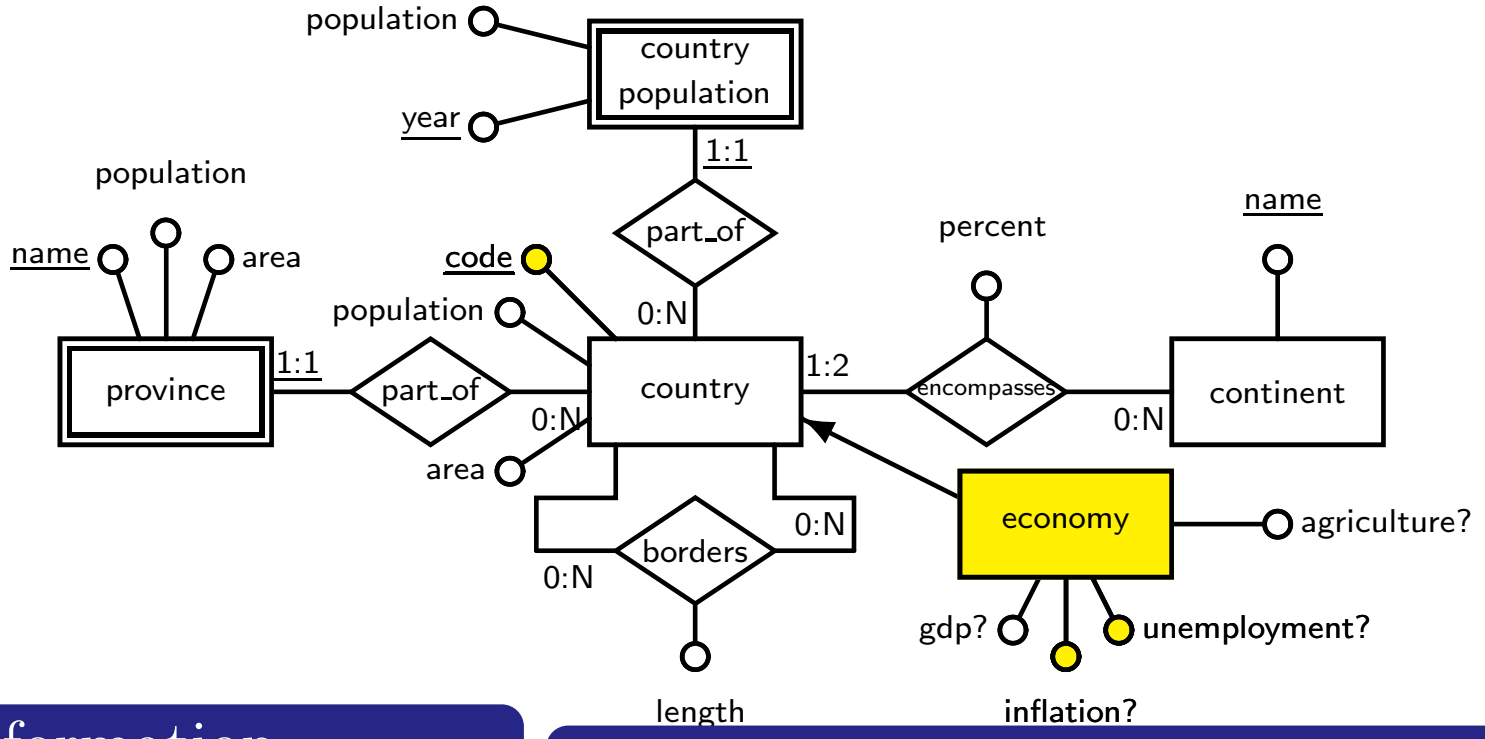

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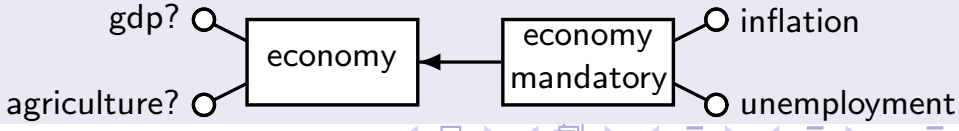
Not information preserving

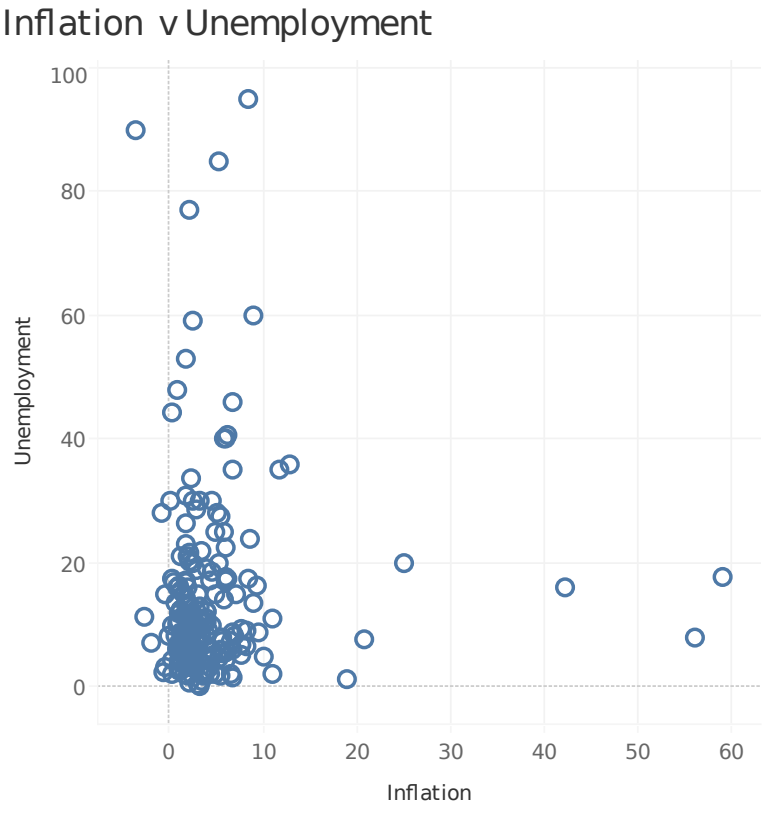
Application to Schema (1)

Mandatory economy(code, inflation, unemployment)



Transformations: Attribute Specialisation

Formalises dropping of null attributes performed in Basic Entity example earlier.



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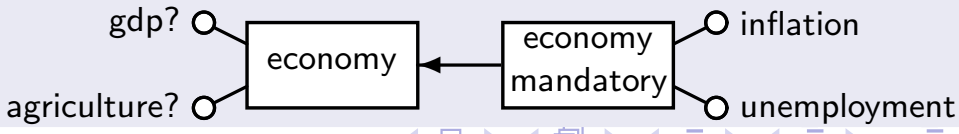

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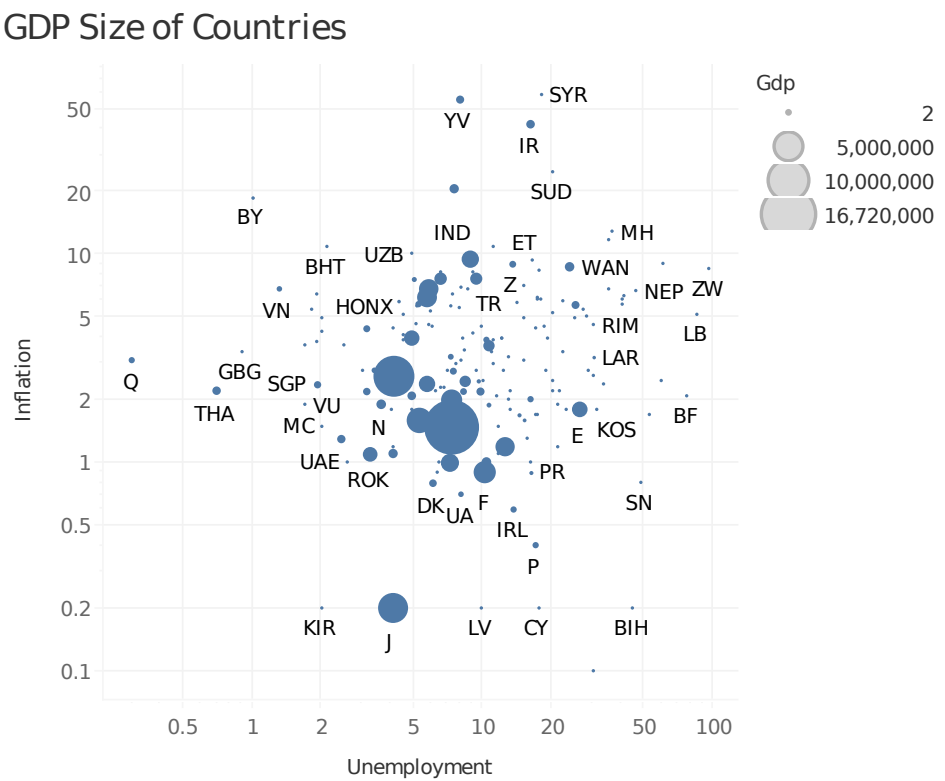

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Mandatory $E(k, a_1, \ldots, a_n) \rightarrow$
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$\ldots$,
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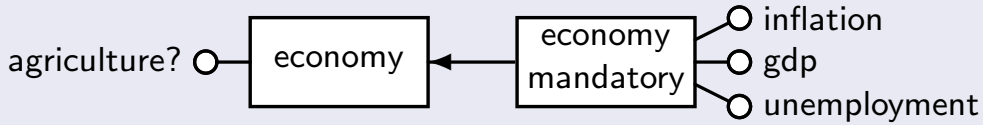
Not information preserving

Application to Schema (2)

Mandatory economy(code, inflation, unemployment, gdp)



Conclusions

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Ongoing work includes implementation of the approach, to be followed by user evaluation