

Towards Data Visualisation based on Conceptual Modelling

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ER 2018

Motivating Example

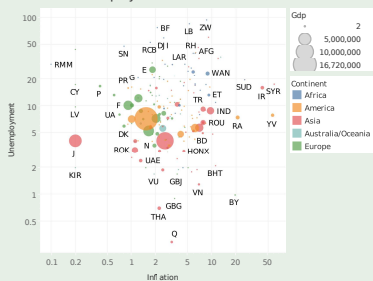
continent country economy							
name	code	population	unemployment	inflation	gdp	continent	percentage
Argentina	RA	42669500	7.50	20.80	484600	America	100
Australia	AUS	23135281	5.70	2.40	1488000	Australia/Oceania	100
Belize	BZ	312971	15.50	1.30	1637	America	100
Bolivia	BOL	10027262	7.40	6.50	30790	America	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.

Motivating Example

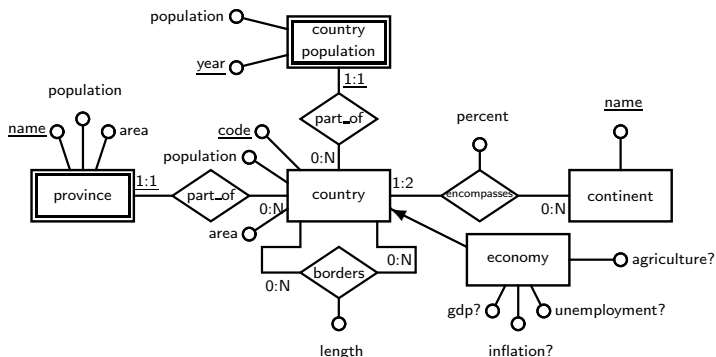
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Bolivia	BOL	10027262	7.40	6.50	10000	America	100
Brazil	BR	202768562	5.70	6.20	10000	America	100
Canada	CDN	35158304	7.10	1.00	10000	America	100
Chile	RCH	16341929	6.00	1.70	10000	America	100
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United States	USA	318857056	7.30	1.50	10000	America	100
Uruguay	ROU	3286314	6.50	8.30	10000	America	100

Inflation v Unemployment



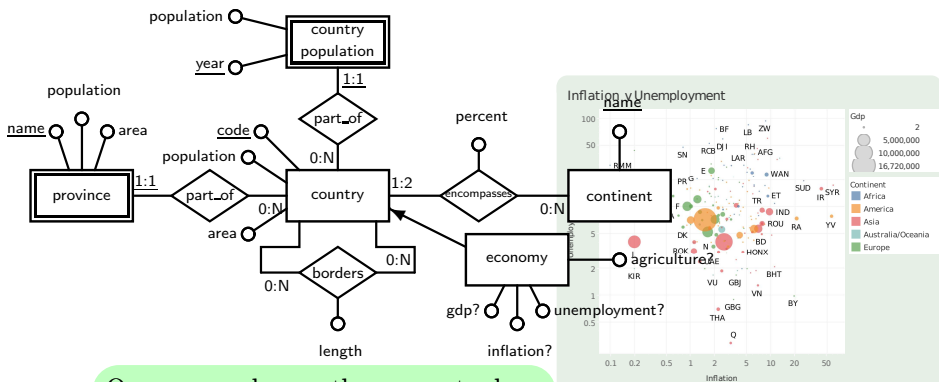
Considerable effort is needed to understand the data and decide on which visualisation.

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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1 Introduction

2 Visualisation Schema Patterns

- Basic Entity
- Weak Entity
- One-Many Relationship
- Many-Many Relationship

3 Transformations

- Pivot
- Denormalisation
- Attribute Specialisation

4 Conclusions

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'}
```

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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

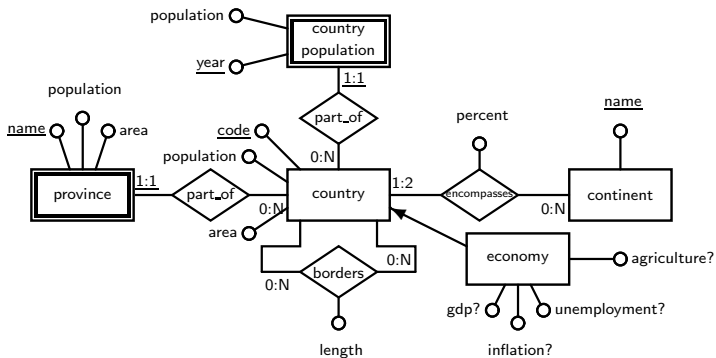
In our approach, each attribute of an entity and each participation of an entity in a relationship is associated with a dimension of the visualisation. Dimensions are of two types:

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

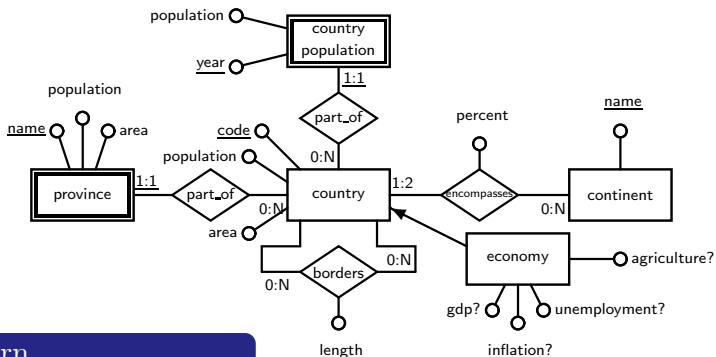
Scalar Dimension Example

```
borders.length={0.34,1.20,3.2,4.40,6.30,9.00,9.60,.. .,5150,6846,8893}
```

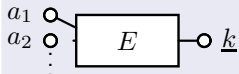
Visualisation Schema Pattern 1: Basic Entity



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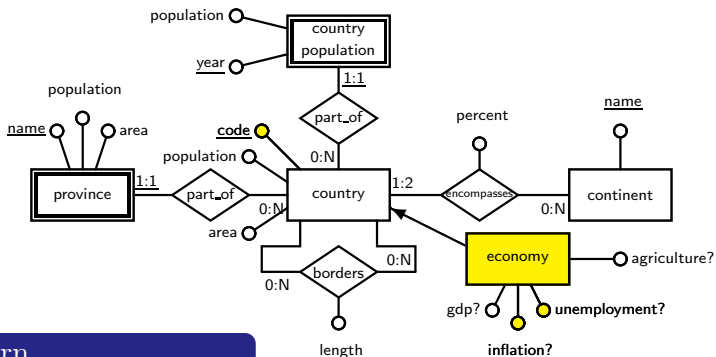


Pattern

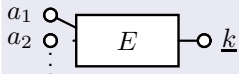


Match with the key of an entity, plus one or more attributes

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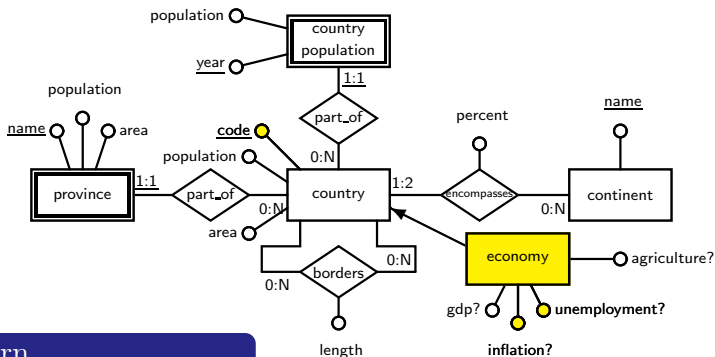


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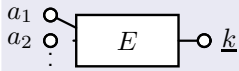


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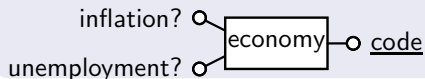


Pattern



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

Instantiation

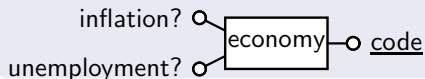


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Visualisation Types

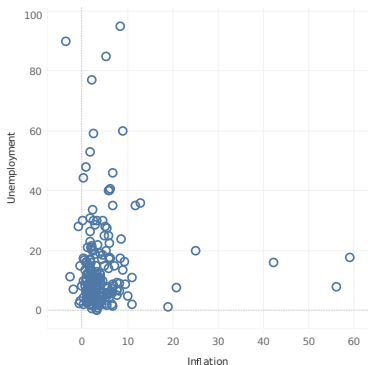
Basic Entity Visualisations			
Name	$ k $	mandatory	optional
Bar Chart	1..100	a_1 scalar	-
Calendar	1..*	a_1 temporal scalar	a_2 colour
Scatter Diagrams	1..*	a_1, a_2 scalar	a_3 colour
Bubble Charts	1..*	a_1, a_2, a_3 scalar	a_4 colour
Choropleth Maps	1..*	k geographical, a_1 colour	-
Word Clouds	1..*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

Instantiation



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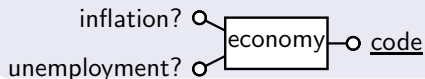
Inflation v Unemployment



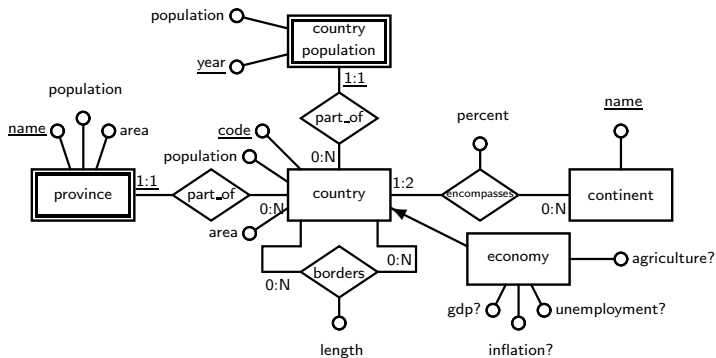
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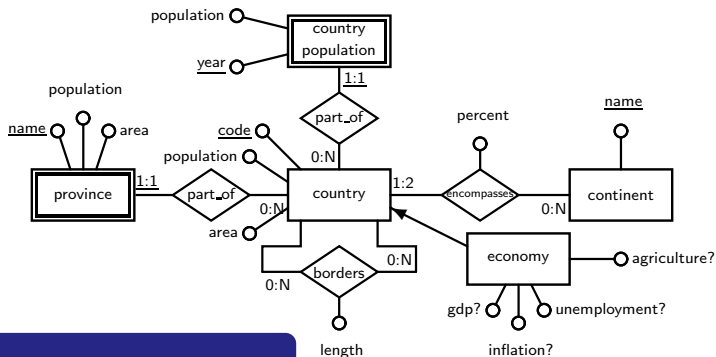
Instantiation



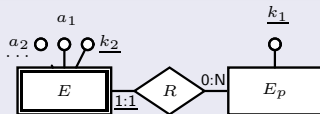
Visualisation Schema Pattern 2: Weak Entity



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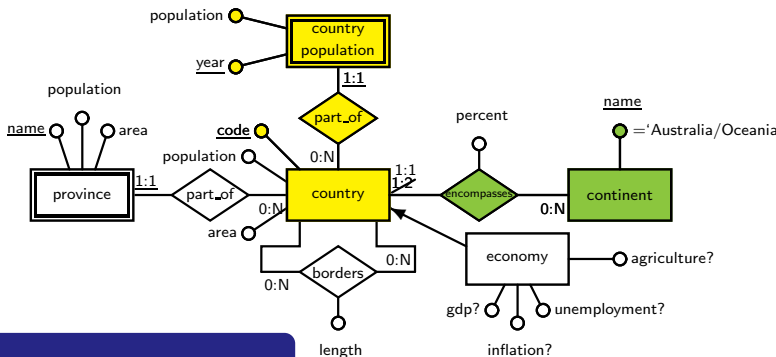


Pattern

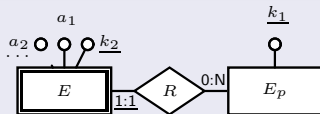


Match with the key of an entity, plus one or more attributes

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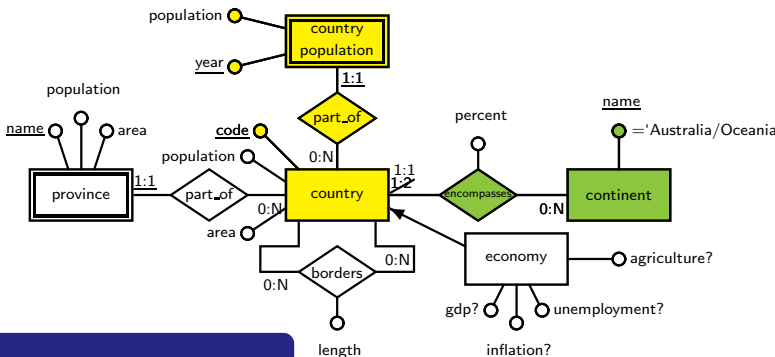


Pattern

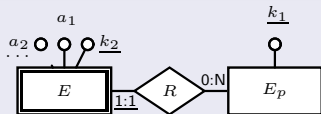


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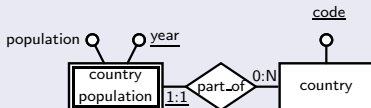


Pattern



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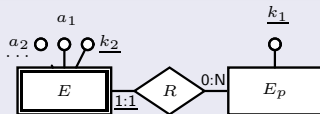


Visualisation Schema Pattern 2: Weak Entity

Visualisation Types

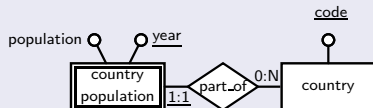
Weak Entity Visualisations					
Name	$ k_1 $	$ k_2 $	complete	mandatory	optional
Line Chart	1..20	1..*	no	k_2, a_1 scalar	a_2 scalar
Stacked Bar Chart	1..20	1..20	yes	a_1 scalar	-
Grouped Bar Chart	1..20	1..20	no	a_1 scalar	-
Spider Chart	3..10	1..20	yes	a_1 scalar	-

Pattern



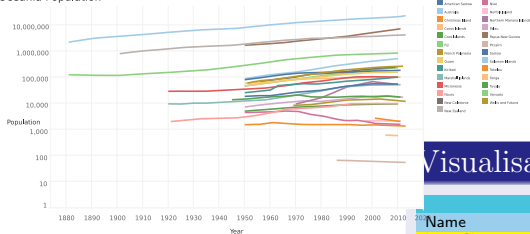
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Visualisation Schema Pattern 2: Weak Entity

Oceania Population

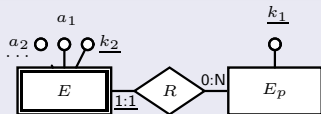


Visualisation Types

Weak Entity Visualisations

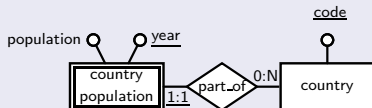
Name	$ k_1 $	$ k_2 $	complete	mandatory	optional
Line Chart	1..20	1..*	no	k_2, a_1 scalar	a_2 scalar
Stacked Bar Chart	1..20	1..20	yes	a_1 scalar	-
Grouped Bar Chart	1..20	1..20	no	a_1 scalar	-
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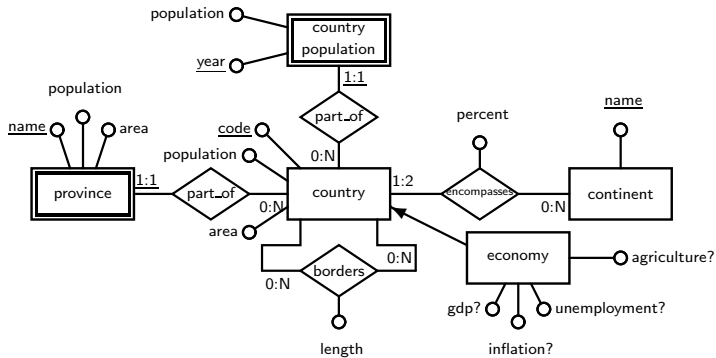


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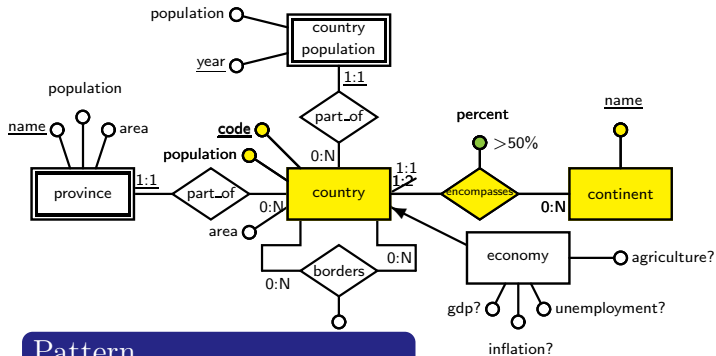
Instantiation



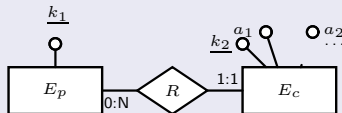
Visualisation Schema Pattern 3: One-Many Relationship



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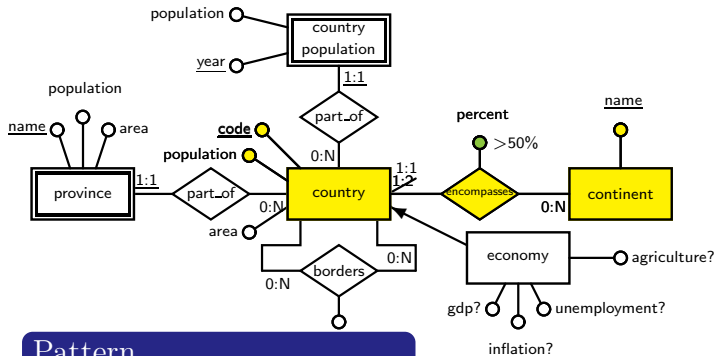


Pattern

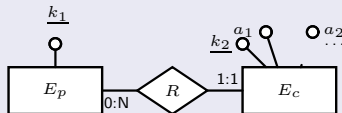


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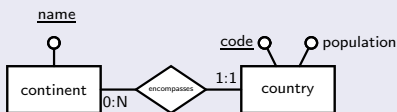


Pattern



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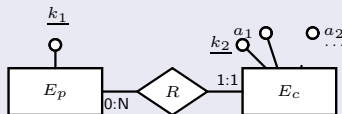


Visualisation Schema Pattern 3: One-Many Relationship

Visualisation Types

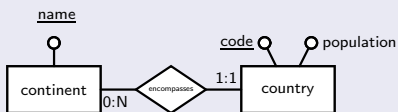
One-many relationships					
Name	$ k_1 $	$ k_2 $	per k_1	mandatory	optional
Tree Map	1..100	1..100	a_1	scalar	a_2 colour
Hierarchy Tree	1..100	1..100	-		a_1 colour
Circle Packing	1..100	1..100	a_1	scalar	a_2 colour

Pattern



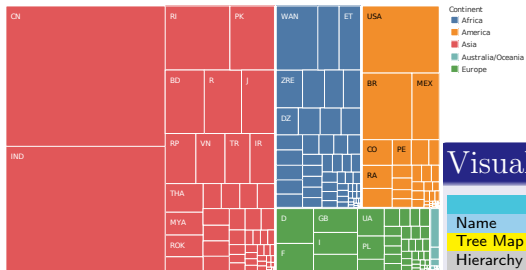
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Visualisation Schema Pattern 3: One-Many Relationship

Population of Continents

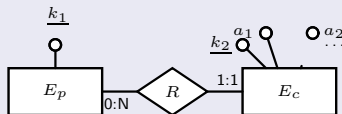


Visualisation Types

One-many relationships

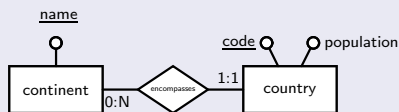
Name	$ k_1 $	$ k_2 $	per k_1	mandatory	optional
Tree Map	1..100	1..100	a_1	scalar	a_2 colour
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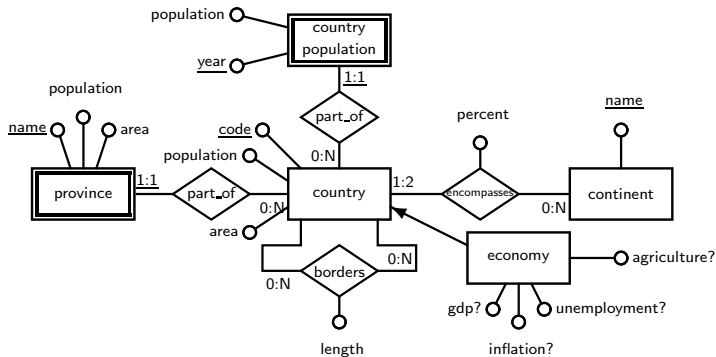


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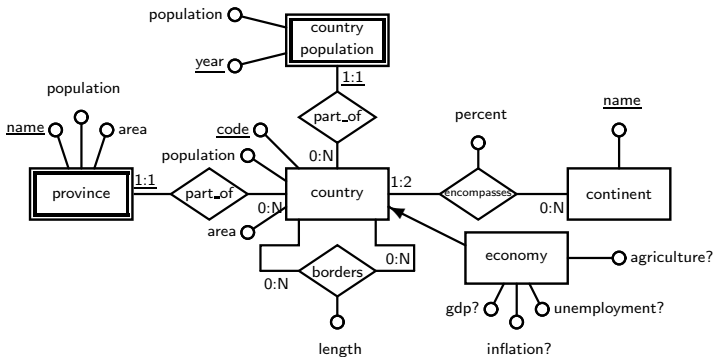
Instantiation



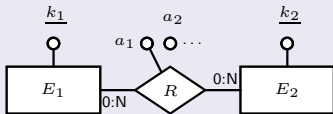
Visualisation Schema Pattern 4: Many-Many Relationship



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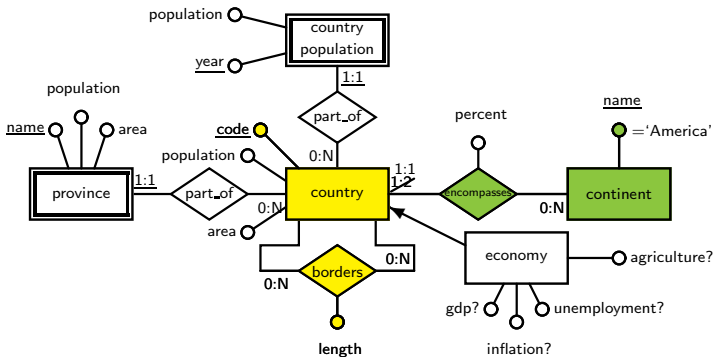


Pattern

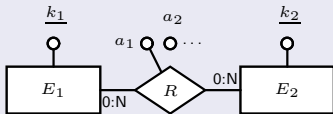


Match a (possibly reflexive) many-many relationship

Visualisation Schema Pattern 4: Many-Many Relationship

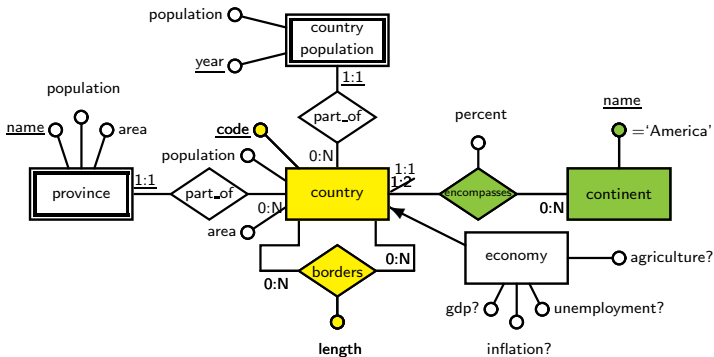


Pattern

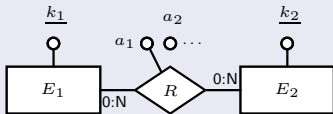


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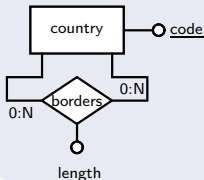


Pattern



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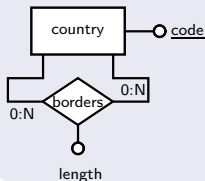


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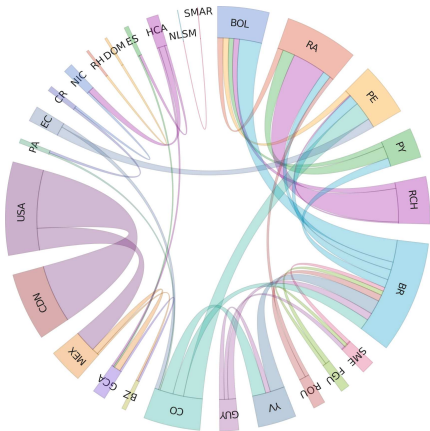
Visualisation Types

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



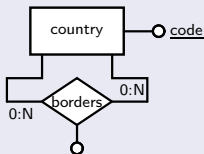
Visualisation Schema Pattern 4: Many-Many Relationship



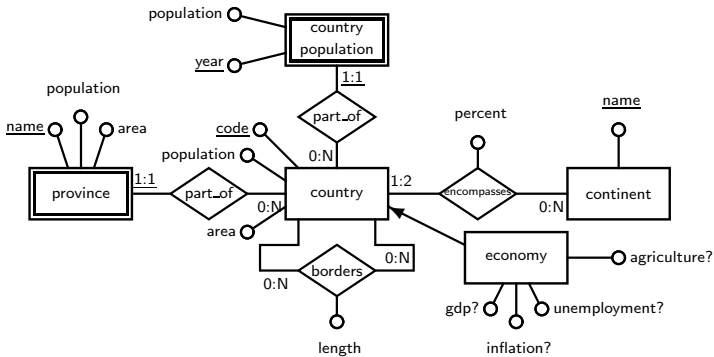
Visualisation Types

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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

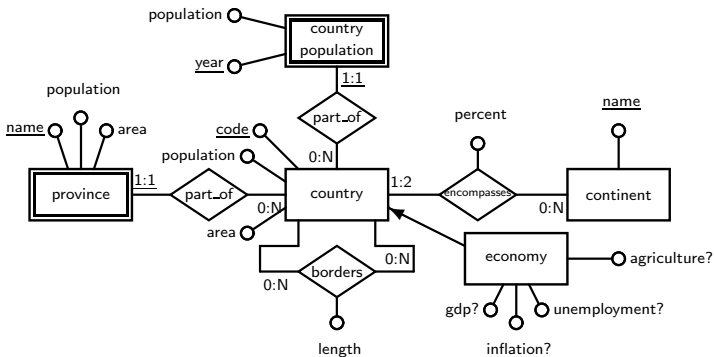
Instantiation



Transformations: Pivot



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Transformation

Pivot $E(a, b) \{v_1, \dots, v_n\} \rightarrow$

$E_p(a_{v_1}, \dots, a_{v_n}) :-$

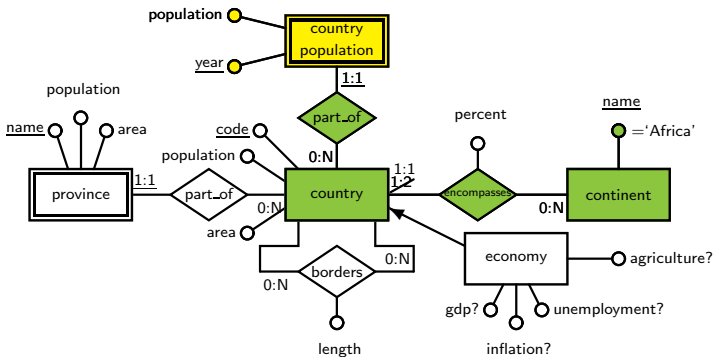
$E(v_1, a_{v_1}),$

$\dots;$

$E(v_n, a_{v_n}).$

Not information preserving

Transformations: Pivot



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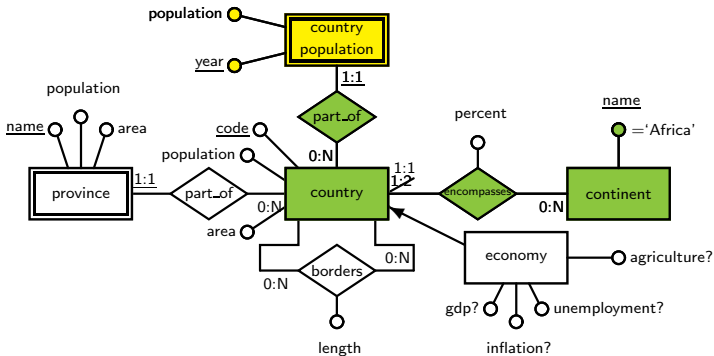
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Transformations: Pivot



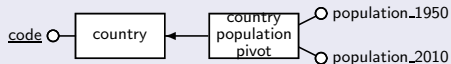
Transformation

Pivot $E(a, b) \{v_1, \dots, v_n\} \rightarrow$
 $E_p(a_{-v_1}, \dots, a_{-v_n}) :-$
 $E(v_1, a_{-v_1}),$
 $\dots,$
 $E(v_n, a_{-v_n}).$

Not information preserving

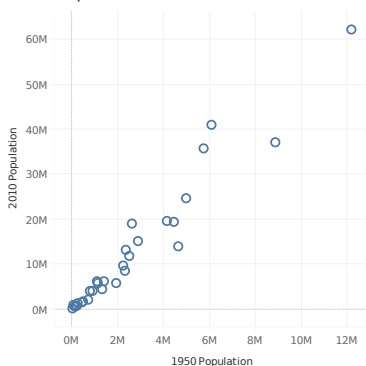
Application to Schema

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



Transformations: Pivot

Africa Population Growth



Transformation

Pivot $E(a, b) \{v_1, \dots, v_n\} \rightarrow$

$E_p(a_{\rightarrow v_1}, \dots, a_{\rightarrow v_n}) :-$

$E(v_1, a_{\rightarrow v_1}),$

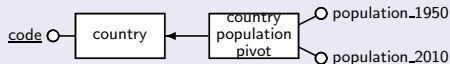
$\dots,$

$E(v_n, a_{\rightarrow v_n}).$

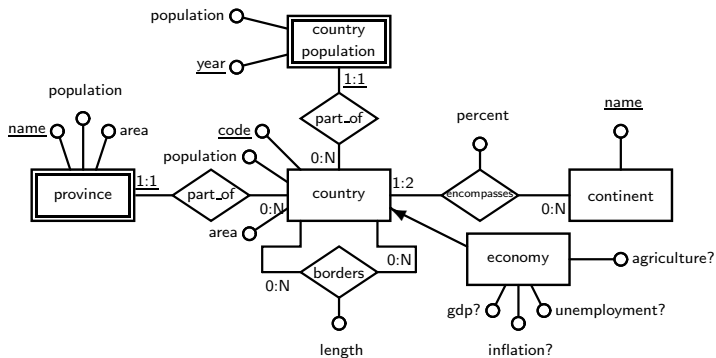
Not information preserving

Application to Schema

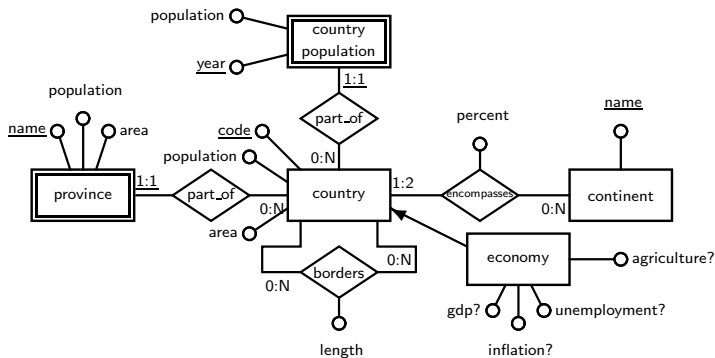
Pivot `country_population(year, population) {1950, 2010}`



Transformations: Denormalisation



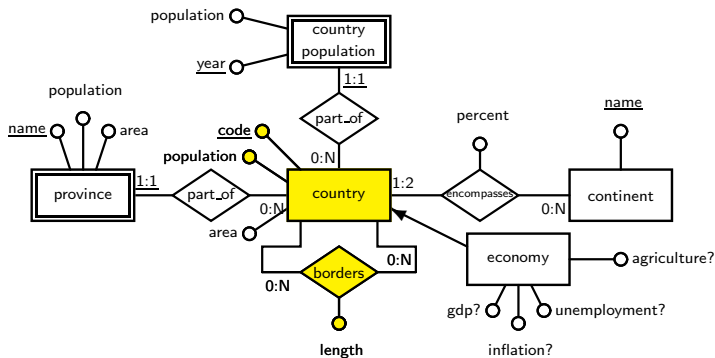
Transformations: Denormalisation



Transformation

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

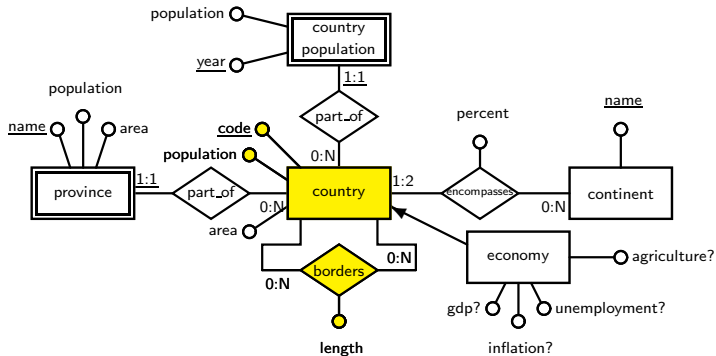
Transformations: Denormalisation



Transformation

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

Transformations: Denormalisation

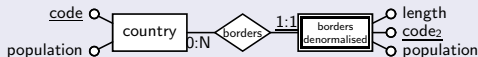


Transformation

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

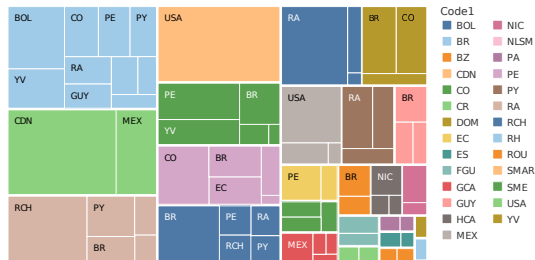
Application to Schema

Denormalise country(code, population) borders(code₁, code₂, length)



Transformations: Denormalisation

Border Lengths in the Americas

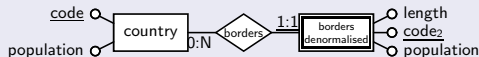


Transformation

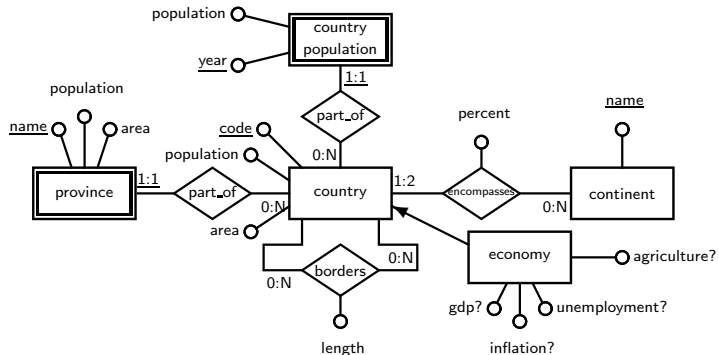
Denormalise $E_2(k_2, x, \dots)$
 $R(k_1, k_2, a, \dots) \rightarrow$
 $ED_2(k_1, k_2, x, \dots, a, \dots) :-$
 $E_2(k_2, x, \dots),$
 $R(k_1, k_2, a, \dots).$
 Information preserving

Application to Schema

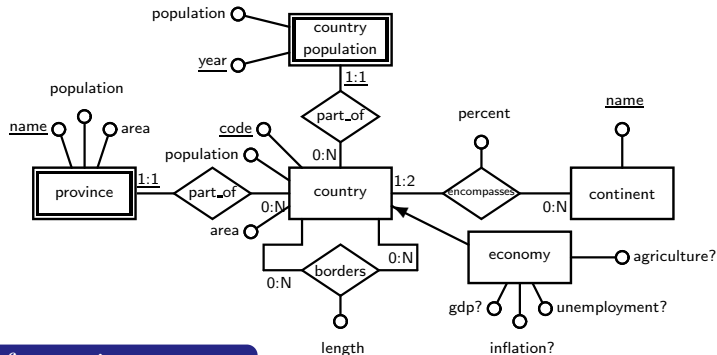
Denormalise `country(code, population) borders(code1, code2, length)`



Transformations: Attribute Specialisation



Transformations: Attribute Specialisation



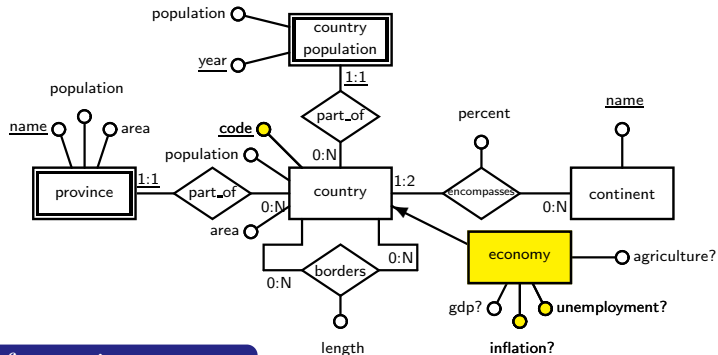
Transformation

Mandatory $E(k, a_1, \dots, a_n) \rightarrow$

$EM(k, a_1, \dots, a_n) :-$
 $E(k, a_1, \dots, a_n),$
 $IsNotNull(a_1),$
 $\dots,$
 $IsNotNull(a_n).$

Not information preserving

Transformations: Attribute Specialisation



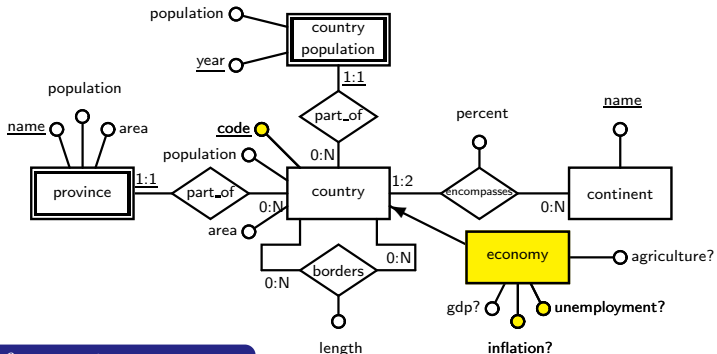
Transformation

Mandatory $E(k, a_1, \dots, a_n) \rightarrow$

$EM(k, a_1, \dots, a_n) :-$
 $E(k, a_1, \dots, a_n),$
 $IsNotNull(a_1),$
 $\dots,$
 $IsNotNull(a_n).$

Not information preserving

Transformations: Attribute Specialisation



Transformation

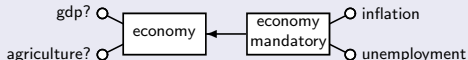
Mandatory $E(k, a_1, \dots, a_n) \rightarrow$

$EM(k, a_1, \dots, a_n) :-$
 $E(k, a_1, \dots, a_n),$
 $IsNotNull(a_1),$
 $\dots,$
 $IsNotNull(a_n).$

Not information preserving

Application to Schema (1)

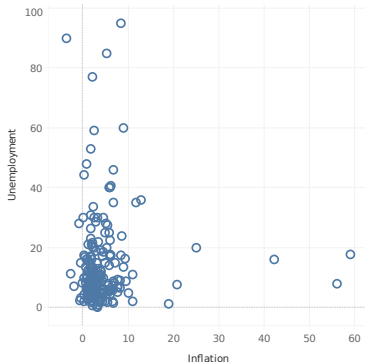
Mandatory $economy(\text{code}, \text{inflation}, \text{unemployment})$



Transformations: Attribute Specialisation

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

Inflation v Unemployment

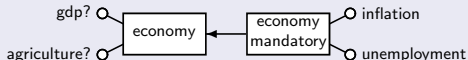


Transformation

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

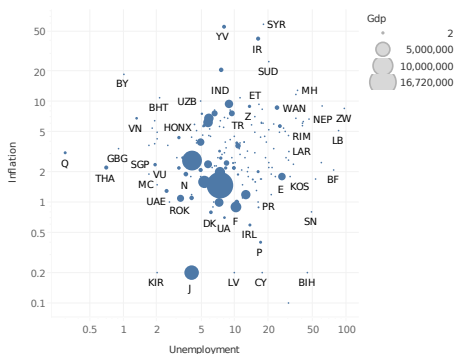
Application to Schema (1)

Mandatory economy(code, inflation, unemployment)



Transformations: Attribute Specialisation

GDP Size of Countries



Transformation

Mandatory $E(k, a_1, \dots, a_n) \rightarrow$

$EM(k, a_1, \dots, a_n) :-$
 $E(k, a_1, \dots, a_n),$
 $IsNotNull(a_1),$
 $\dots,$
 $IsNotNull(a_n).$

Not information preserving

Application to Schema (2)

Mandatory economy(code, inflation, unemployment, gdp)



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By applying well-known schema transformations, additional visualisation matchings can be generated

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