

# Multi-Level Conceptual Modeling and OWL Full Example

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**Abstract.** In [1] we provided an example multi-level model using m-objects and m-relationships and introduced how to map m-objects and m-relationships to OWL. Herein we present the mapping-result of the full example.

## 1 Mapping Output - Full Example

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### Mapping Output 1 General Axioms

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$\top \sqsubseteq \leq 1 \text{ concretize}$   
 $\text{concretize} \sqsubseteq \text{concretize.t}$   
 $\text{concretize.t}^+ \sqsubseteq \text{concretize.t}$   
 $\top \sqsubseteq \leq 1 \text{ source} \sqcap \leq 1 \text{ target}$

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### Mapping Output 2 M-Object Product

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$\text{Catalog}(\text{Product})$   
 $\text{desc}(\text{Product}, \text{"Our Products"})$   
 $\text{IC}: \exists \text{concretize.t.}\{\text{Product}\} \sqcap \text{Category} \sqsubseteq \forall \text{taxRate.Integer} \sqcap =1 \text{ taxRate.T}$   
 $\text{IC}: \exists \text{concretize.t.}\{\text{Product}\} \sqcap \text{Model} \sqsubseteq \forall \text{listPrice.Float} \sqcap =1 \text{ listPrice.T}$   
 $\text{IC}: \exists \text{concretize.t.}\{\text{Product}\} \sqcap \text{PhysicalEntity} \sqsubseteq \forall \text{serialNr.String} \sqcap =1 \text{ serialNr.T}$   
 $\text{IC}: \exists \text{concretize.t.}\{\text{Product}\} \sqcap \text{Model} \sqsubseteq \exists \text{concretize.t.}(\exists \text{concretize.t.}\{\text{Product}\} \sqcap \text{Category})$   
 $\text{IC}: \exists \text{concretize.t.}\{\text{Product}\} \sqcap \text{PhysicalEntity} \sqsubseteq \exists \text{concretize.t.}(\exists \text{concretize.t.}\{\text{Product}\} \sqcap \text{Model})$   
 $\text{IC}: \exists \text{desc.T} \sqsubseteq (\exists \text{concretize.t.}\{\text{Product}\} \sqcup \{\text{Product}\}) \sqcap \text{Catalog}$   
 $\text{IC}: \exists \text{taxRate.T} \sqsubseteq (\exists \text{concretize.t.}\{\text{Product}\} \sqcup \{\text{Product}\}) \sqcap \text{Category}$   
 $\text{IC}: \exists \text{listPrice.T} \sqsubseteq (\exists \text{concretize.t.}\{\text{Product}\} \sqcup \{\text{Product}\}) \sqcap \text{Model}$   
 $\text{IC}: \exists \text{serialNr.T} \sqsubseteq (\exists \text{concretize.t.}\{\text{Product}\} \sqcup \{\text{Product}\}) \sqcap \text{PhysicalEntity}$   
 $\text{IC}: \text{Category} \sqsubseteq \exists \text{concretize.t.}\{\text{Product}\}$   
 $\text{IC}: \text{Model} \sqsubseteq \exists \text{concretize.t.}\{\text{Product}\}$   
 $\text{IC}: \text{PhysicalEntity} \sqsubseteq \exists \text{concretize.t.}\{\text{Product}\}$

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**Mapping Output 3** M-Object Car

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- 1: Category(Car)
  - 2: concretize(Car, Product)
  - 3: taxRate(Car, 20)
  - 4:  $IC: \exists \text{concretize.t.}\{Car\} \sqcap Brand \sqsubseteq \forall \text{marketLaunch.Date} \sqcap =1 \text{ marketLaunch.T}$
  - 5:  $IC: \exists \text{concretize.t.}\{Car\} \sqcap Model \sqsubseteq \forall \text{maxSpeed.Integer} \sqcap =1 \text{ maxSpeed.T}$
  - 6:  $IC: \exists \text{concretize.t.}\{Car\} \sqcap PhysicalEntity \sqsubseteq \forall \text{mileage.Integer} \sqcap =1 \text{ mileage.T}$
  - 7:  $IC: \exists \text{concretize.t.}\{Car\} \sqcap Model \sqsubseteq \exists \text{concretize.t.}(\exists \text{concretize.t.}\{Car\} \sqcap Brand)$
  - 8:  $IC: \exists \text{marketLaunch.T} \sqsubseteq (\exists \text{concretize.t.}\{Car\} \sqcup \{Car\}) \sqcap Brand$
  - 9:  $IC: \exists \text{maxSpeed.T} \sqsubseteq (\exists \text{concretize.t.}\{Car\} \sqcup \{Car\}) \sqcap Model$
  - 10:  $IC: \exists \text{mileage.T} \sqsubseteq (\exists \text{concretize.t.}\{Car\} \sqcup \{Car\}) \sqcap PhysicalEntity$
  - 11:  $IC: Brand \sqsubseteq \exists \text{concretize.t.}\{Car\}$
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**Mapping Output 4** M-Object Book

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- 1: Category(Book)
  - 2: concretize(Book, Product)
  - 3: taxRate(Book, 15)
  - 4:  $IC: \exists \text{concretize.t.}\{Book\} \sqcap Model \sqsubseteq \forall \text{author.String} \sqcap =1 \text{ author.T}$
  - 5:  $IC: \exists \text{author.T} \sqsubseteq (\exists \text{concretize.t.}\{Book\} \sqcup \{Book\}) \sqcap Model$
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**Mapping Output 5** M-Object Porsche911

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- 1: Brand(Porsche911)
  - 2: concretize(Porsche911, Car)
  - 3: marketLaunch(Porsche911, 1964)
  - 4:  $IC: \exists \text{concretize.t.}\{Porsche911\} \sqcap PhysicalEntity \sqsubseteq \forall \text{porsche911club.boolean} \sqcap =1 \text{ porsche911club.T}$
  - 5:  $IC: \exists \text{porsche911club.T} \sqsubseteq (\exists \text{concretize.t.}\{Porsche911\} \sqcup \{Porsche911\}) \sqcap PhysicalEntity$
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**Mapping Output 6** M-Object Porsche911CarreraS

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- 1: Model(Porsche911CarreraS)
  - 2: concretize(Porsche911CarreraS, Porsche911)
  - 3: listPrice(Porsche911CarreraS, 108083)
  - 4: maxSpeed(Porsche911CarreraS, 310)
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**Mapping Output 7** M-Object HarryPotter4

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- 1: Model(HarryPotter4)
  - 2: concretize(HarryPotter4, Book)
  - 3: listPrice(HarryPotter4, 11.50)
  - 4: author(Porsche911CarreraS, "J.K.Rowling")
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**Mapping Output 8** M-Object myPorsche911CarreraS

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- 1: PhysicalEntity(myPorsche911CarreraS)
  - 2: concretize(myPorsche911CarreraS, Porsche911CarreraS)
  - 3: serialNr(myPorsche911CarreraS, "C333333")
  - 4: mileage(myPorsche911CarreraS, 100000)
  - 5: porsche911club(myPorsche911CarreraS, true)
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**Mapping Output 9** M-Object myCopyOfHP4

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- 1: PhysicalEntity(myCopyOfHP4)
  - 2: concretize(myCopyOfHP4, HarryPotter4)
  - 3: serialNr(myCopyOfHP4, "A121212")
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**Mapping Output 10** M-Object Company

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- 1: Root(Company)
  - 2: IC: $\exists$ concretize.t.{Company}  $\sqcap$  Enterprise  $\sqsubseteq$   $\exists$ concretize.t.( $\exists$ concretize.t.{Company})  
 $\sqcap$  IndustrialSector)
  - 3: IC: $\exists$ concretize.t.{Company}  $\sqcap$  Factory  $\sqsubseteq$   $\exists$ concretize.t.( $\exists$ concretize.t.{Company})  $\sqcap$   
Enterprise)
  - 4: IC:IndustrialSector  $\sqsubseteq$   $\exists$ concretize.t.{Company}
  - 5: IC:Enterprise  $\sqsubseteq$   $\exists$ concretize.t.{Company}
  - 6: IC:Factory  $\sqsubseteq$   $\exists$ concretize.t.{Company}
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**Mapping Output 11** M-Object CarManufacturer

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- 1: IndustrialSector(CarManufacturer)
  - 2: concretize(CarManufacturer, Company)
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**Mapping Output 12** M-Object PorscheLtd

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- 1: Enterprise(PorscheLtd)
  - 2: concretize(PorscheLtd, CarManufacturer)
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**Mapping Output 13** M-Object PorscheZuffenhausen

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- 1: Factory(PorscheZuffenhausen)
  - 2: concretize(PorscheZuffenhausen, PorscheLtd)
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**Mapping Output 14** Levels are disjoint, only shown for level Category

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- 1: Category  $\sqcap$  Catalog  $\sqsubseteq$   $\perp$
  - 2: Category  $\sqcap$  Model  $\sqsubseteq$   $\perp$
  - 3: Category  $\sqcap$  PhysicalEntity  $\sqsubseteq$   $\perp$
  - 4: Category  $\sqcap$  Brand  $\sqsubseteq$   $\perp$
  - 5: Category  $\sqcap$  Root  $\sqsubseteq$   $\perp$
  - 6: Category  $\sqcap$  IndustrialSector  $\sqsubseteq$   $\perp$
  - 7: Category  $\sqcap$  Enterprise  $\sqsubseteq$   $\perp$
  - 8: Category  $\sqcap$  Factory  $\sqsubseteq$   $\perp$
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**Mapping Output 15** Unique Name Assumption (only shown for Car)
 

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- 1: Car  $\not\approx$  Product
  - 2: Car  $\not\approx$  Book
  - 3: Car  $\not\approx$  Porsche911
  - 4: Car  $\not\approx$  Porsche911CarreraS
  - 5: Car  $\not\approx$  MyPorsche911CarreraS
  - 6: Car  $\not\approx$  HarryPotter4
  - 7: Car  $\not\approx$  MyCopyOfHP4
  - 8: Car  $\not\approx$  Company
  - 9: Car  $\not\approx$  CarManufacturer
  - 10: Car  $\not\approx$  PorscheLtd
  - 11: Car  $\not\approx$  PorscheZuffenhausen
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**Mapping Output 16** M-Relationship Product-producedBy-Company
 

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- 1: source(Product-producedBy-Company, Product)
  - 2: target(Product-producedBy-Company, Company)
  - 3:  $IC: \exists \text{concretize}_t.\{\text{Product-producedBy-Company}\} \sqsubseteq (\forall \text{source}.\{\exists \text{concretize}_t.\{\text{Product}\} \sqcup \{\text{Product}\}\} \sqcap \forall \text{target}.\{\exists \text{concretize}_t.\{\text{Company}\}\} \sqcup (\forall \text{source}.\{\exists \text{concretize}_t.\{\text{Product}\} \sqcap \forall \text{target}.\{\exists \text{concretize}_t.\{\text{Company}\} \sqcup \{\text{Company}\}\}))$
  - 4:  $IC: \exists \text{concretize}_t.\{\text{Product-producedBy-Company}\} \sqcap (\exists \text{source}.\{\exists \text{concretize}_t.\text{Category} \sqcup \exists \text{target}.\{\exists \text{concretize}_t.\text{IndustrialSector}\}\} \sqsubseteq \exists \text{concretize}_t.\{\exists \text{concretize}_t.\{\text{Product-producedBy-Company}\} \sqcap \exists \text{source}.\text{Category} \sqcap \exists \text{target}.\text{IndustrialSector}\}$
  - 5:  $IC: \exists \text{concretize}_t.\{\text{Product-producedBy-Company}\} \sqcap (\exists \text{source}.\{\exists \text{concretize}_t.\text{Model} \sqcup \exists \text{target}.\{\exists \text{concretize}_t.\text{Enterprise}\}\} \sqsubseteq \exists \text{concretize}_t.\{\exists \text{concretize}_t.\{\text{Product-producedBy-Company}\} \sqcap \exists \text{source}.\text{Model} \sqcap \exists \text{target}.\text{Enterprise}\}$
  - 6:  $IC: \exists \text{concretize}_t.\{\text{Product-producedBy-Company}\} \sqcap (\exists \text{source}.\{\exists \text{concretize}_t.\text{PhysicalEntity} \sqcup \exists \text{target}.\{\exists \text{concretize}_t.\text{Factory}\}\} \sqsubseteq \exists \text{concretize}_t.\{\exists \text{concretize}_t.\{\text{Product-producedBy-Company}\} \sqcap \exists \text{source}.\text{PhysicalEntity} \sqcap \exists \text{target}.\text{Factory}\}$
  - 7: Product-producedBy-Company  $\not\approx$  Car-producedBy-CarManufacturer
  - 8: Product-producedBy-Company  $\not\approx$  Porsche911CarreraS-producedBy-PorscheLtd
  - 9: Product-producedBy-Company  $\not\approx$  MyPorsche911CarreraS-producedBy-PorscheZuffenhausen
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**Mapping Output 17** M-Relationship Car-producedBy-CarManufacturer

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- 1: concretize(Car-producedBy-CarManufacturer, Product-producedBy-Company)
  - 2: source(Car-producedBy-CarManufacturer, Car)
  - 3: target(Car-producedBy-CarManufacturer, CarManufacturer)
  - 4:  $IC: \exists \text{concretize.t.} \{ \text{Car-producedBy-CarManufacturer} \} \sqsubseteq (\forall \text{source.} (\exists \text{concretize.t.} \{ \text{Car} \} \sqcup \{ \text{Car} \} ) \sqcap \forall \text{target.} \exists \text{concretize.t.} \{ \text{CarManufacturer} \} ) \sqcup (\forall \text{source.} \exists \text{concretize.t.} \{ \text{Car} \} \sqcap \forall \text{target.} (\exists \text{concretize.t.} \{ \text{CarManufacturer} \} \sqcup \{ \text{CarManufacturer} \} ))$
  - 5:  $IC: \exists \text{concretize.t.} \{ \text{Car-producedBy-CarManufacturer} \} \sqcap (\exists \text{source.} \exists \text{concretize.t.} \text{Model} \sqcup \exists \text{target.} \exists \text{concretize.t.} \text{Enterprise}) \sqsubseteq \exists \text{concretize.t.} (\exists \text{concretize.t.} \{ \text{Car-producedBy-CarManufacturer} \} \sqcap \exists \text{source.} \text{Model} \sqcap \exists \text{target.} \text{Enterprise})$
  - 6:  $IC: \exists \text{concretize.t.} \{ \text{Car-producedBy-CarManufacturer} \} \sqcap (\exists \text{source.} \exists \text{concretize.t.} \text{PhysicalEntity} \sqcup \exists \text{target.} \exists \text{concretize.t.} \text{Factory}) \sqsubseteq \exists \text{concretize.t.} (\exists \text{concretize.t.} \{ \text{Car-producedBy-CarManufacturer} \} \sqcap \exists \text{source.} \text{PhysicalEntity} \sqcap \exists \text{target.} \text{Factory})$
  - 7: Car-producedBy-CarManufacturer  $\not\approx$  Product-producedBy-Company
  - 8: Car-producedBy-CarManufacturer  $\not\approx$  Porsche911CarreraS-producedBy-PorscheLtd
  - 9: Car-producedBy-CarManufacturer  $\not\approx$  MyPorsche911CarreraS-producedBy-PorscheZuffenhausen
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**Mapping Output 18** M-Relationship Porsche911CarreraS-producedBy-PorscheLtd

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- 1: concretize(Porsche911CarreraS-producedBy-PorscheLtd, Car-producedBy-CarManufacturer)
  - 2: source(Porsche911CarreraS-producedBy-PorscheLtd, Porsche911CarreraS)
  - 3: target(Porsche911CarreraS-producedBy-PorscheLtd, PorscheLtd)
  - 4:  $IC: \exists \text{concretize.t.} \{ \text{Porsche911CarreraS-producedBy-PorscheLtd} \} \sqsubseteq (\forall \text{source.} (\exists \text{concretize.t.} \{ \text{Porsche911CarreraS} \} \sqcup \{ \text{Porsche911CarreraS} \} ) \sqcap \forall \text{target.} \exists \text{concretize.t.} \{ \text{PorscheLtd} \} ) \sqcup (\forall \text{source.} \exists \text{concretize.t.} \{ \text{Porsche911CarreraS} \} \sqcap \forall \text{target.} (\exists \text{concretize.t.} \{ \text{PorscheLtd} \} \sqcup \{ \text{PorscheLtd} \} ))$
  - 5:  $IC: \exists \text{concretize.t.} \{ \text{Porsche911CarreraS-producedBy-PorscheLtd} \} \sqcap (\exists \text{source.} \exists \text{concretize.t.} \text{PhysicalEntity} \sqcup \exists \text{target.} \exists \text{concretize.t.} \text{Factory}) \sqsubseteq \exists \text{concretize.t.} (\exists \text{concretize.t.} \{ \text{Porsche911CarreraS-producedBy-PorscheLtd} \} \sqcap \exists \text{source.} \text{PhysicalEntity} \sqcap \exists \text{target.} \text{Factory})$
  - 6: Porsche911CarreraS-producedBy-PorscheLtd  $\not\approx$  Product-producedBy-Company
  - 7: Porsche911CarreraS-producedBy-PorscheLtd  $\not\approx$  Car-producedBy-CarManufacturer
  - 8: Porsche911CarreraS-producedBy-PorscheLtd  $\not\approx$  MyPorsche911CarreraS-producedBy-PorscheZuffenhausen
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## References

1. Neumayr, B., Schrefl, M.: Multi-level conceptual modeling and OWL. To appear in : Proceedings of the Joint International Workshop on Metamodels, Ontologies, Semantic Technologies and Information Systems for the Semantic Web (MOST-ONISW 2009) held in conjunction with the 28th International Conference on Conceptual Modeling (ER 2009), November 9-12, 2009, Gramado, Brazil, 2009.

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### Mapping Output 19 M-Relationship MyPorsche911CarreraS-producedBy-PorscheZuffenhausen

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- 1: concretize(MyPorsche911CarreraS-producedBy-PorscheZuffenhausen, Porsche911CarreraS-producedBy-PorscheLtd)
  - 2: source(MyPorsche911CarreraS-producedBy-PorscheZuffenhausen, MyPorsche911CarreraS)
  - 3: target(MyPorsche911CarreraS-producedBy-PorscheZuffenhausen, PorscheZuffenhausen)
  - 4: IC:  $\exists \text{concretize.t.}\{\text{MyPorsche911CarreraS-producedBy-PorscheZuffenhausen}\} \sqsubseteq (\forall \text{source.}(\exists \text{concretize.t.}\{\text{MyPorsche911CarreraS}\} \sqcup \{\text{MyPorsche911CarreraS}\}) \sqcap \forall \text{target.}(\exists \text{concretize.t.}\{\text{PorscheZuffenhausen}\}) \sqcup (\forall \text{source.}(\exists \text{concretize.t.}\{\text{MyPorsche911CarreraS}\} \sqcap \forall \text{target.}(\exists \text{concretize.t.}\{\text{PorscheZuffenhausen}\} \sqcup \{\text{PorscheZuffenhausen}\})))$
  - 5: MyPorsche911CarreraS-producedBy-PorscheZuffenhausen  $\not\approx$  Product-producedBy-Company
  - 6: MyPorsche911CarreraS-producedBy-PorscheZuffenhausen  $\not\approx$  Car-producedBy-CarManufacturer
  - 7: MyPorsche911CarreraS-producedBy-PorscheZuffenhausen  $\not\approx$  Porsche911CarreraS-producedBy-PorscheLtd
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