

# **Restricted Chase (Non)Termination for Existential Rules with Disjunctions**

Extended Abstract (IJCAI 2017)

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TU Dresden

$\forall x \forall y (\text{Features}(x, y) \rightarrow \text{Actor}(y))$

$\forall x \forall y (\text{ActsIn}(x, y) \rightarrow \text{Features}(y, x))$

$\forall x \forall y (\text{IsFilmDirectedBy}(x, y) \rightarrow \text{DirectsFilm}(y, x))$

$\forall x \forall y \forall z (\text{DirectsFilm}(x, y) \wedge \text{Features}(y, z) \rightarrow \text{DirectsActor}(x, z))$

$\text{ActsIn}(\text{travolta}, \text{pulpFiction})$

$\text{IsFilmDirectedBy}(\text{pulpFiction}, \text{tarantino})$

$\text{Director}(\text{tarantino})$

$\text{Film}(\text{pulpFiction})$

Features(x, y)  $\rightarrow$  Actor(y)

ActsIn(x, y)  $\rightarrow$  Features(y, x)

IsFilmDirectedBy(x, y)  $\rightarrow$  DirectsFilm(y, x)

DirectsFilm(x, y)  $\wedge$  Features(y, z)  $\rightarrow$  DirectsActor(x, z)

ActsIn(travolta, pulpFiction)

IsFilmDirectedBy(pulpFiction, tarantino)

Director(tarantino)

Film(pulpFiction)

Features(x, y)  $\rightarrow$  Actor(y)

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ActsIn(travolta, pulpFiction)

IsFilmDirectedBy(pulpFiction, tarantino)

Director(tarantino)

**Film(pulpFiction)**



pulpFiction : Film

Features(x, y)  $\rightarrow$  Actor(y)

ActsIn(x, y)  $\rightarrow$  Features(y, x)

IsFilmDirectedBy(x, y)  $\rightarrow$  DirectsFilm(y, x)

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ActsIn(travolta, pulpFiction)

IsFilmDirectedBy(pulpFiction, tarantino)

Director(tarantino)



pulpFiction : Film

Features(x, y)  $\rightarrow$  Actor(y)

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ActsIn(travolta, pulpFiction)

IsFilmDirectedBy(pulpFiction, tarantino)

**Director(tarantino)**

tarantino : Director



pulpFiction : Film

$\text{Features}(x, y) \rightarrow \text{Actor}(y)$

$\text{ActsIn}(x, y) \rightarrow \text{Features}(y, x)$

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$\text{ActsIn}(\text{travolta}, \text{pulpFiction})$

$\text{IsFilmDirectedBy}(\text{pulpFiction}, \text{tarantino})$

tarantino : Director



pulpFiction : Film

Features(x, y)  $\rightarrow$  Actor(y)

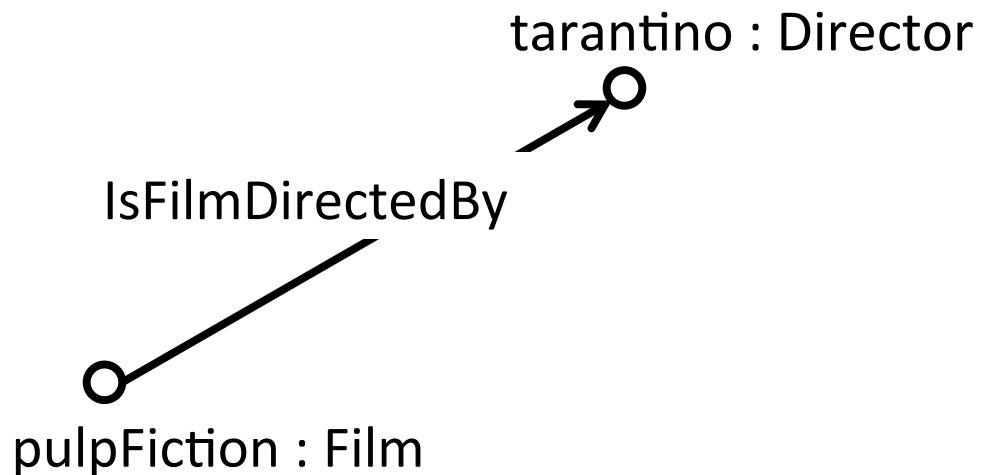
ActsIn(x, y)  $\rightarrow$  Features(y, x)

IsFilmDirectedBy(x, y)  $\rightarrow$  DirectsFilm(y, x)

DirectsFilm(x, y)  $\wedge$  Features(y, z)  $\rightarrow$  DirectsActor(x, z)

ActsIn(travolta, pulpFiction)

**IsFilmDirectedBy(pulpFiction, tarantino)**





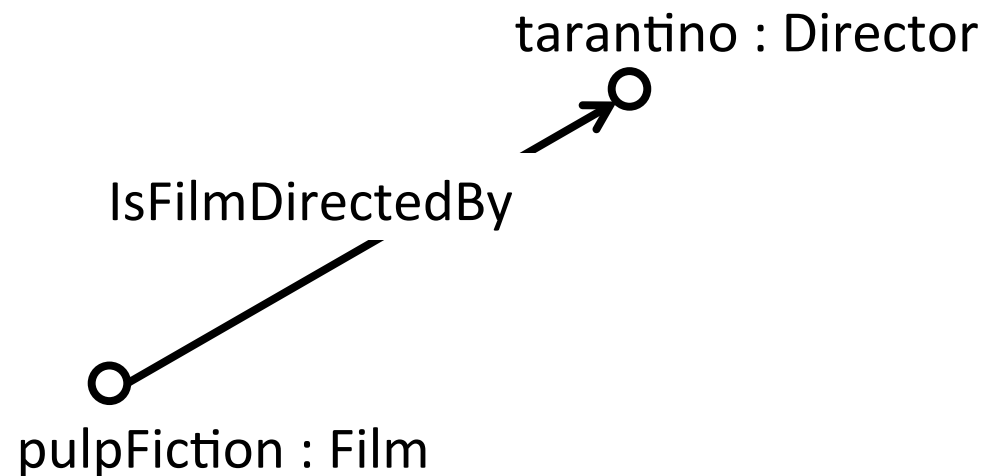
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$\text{DirectsFilm}(x, y) \wedge \text{Features}(y, z) \rightarrow \text{DirectsActor}(x, z)$

$\text{ActsIn}(\text{travolta}, \text{pulpFiction})$



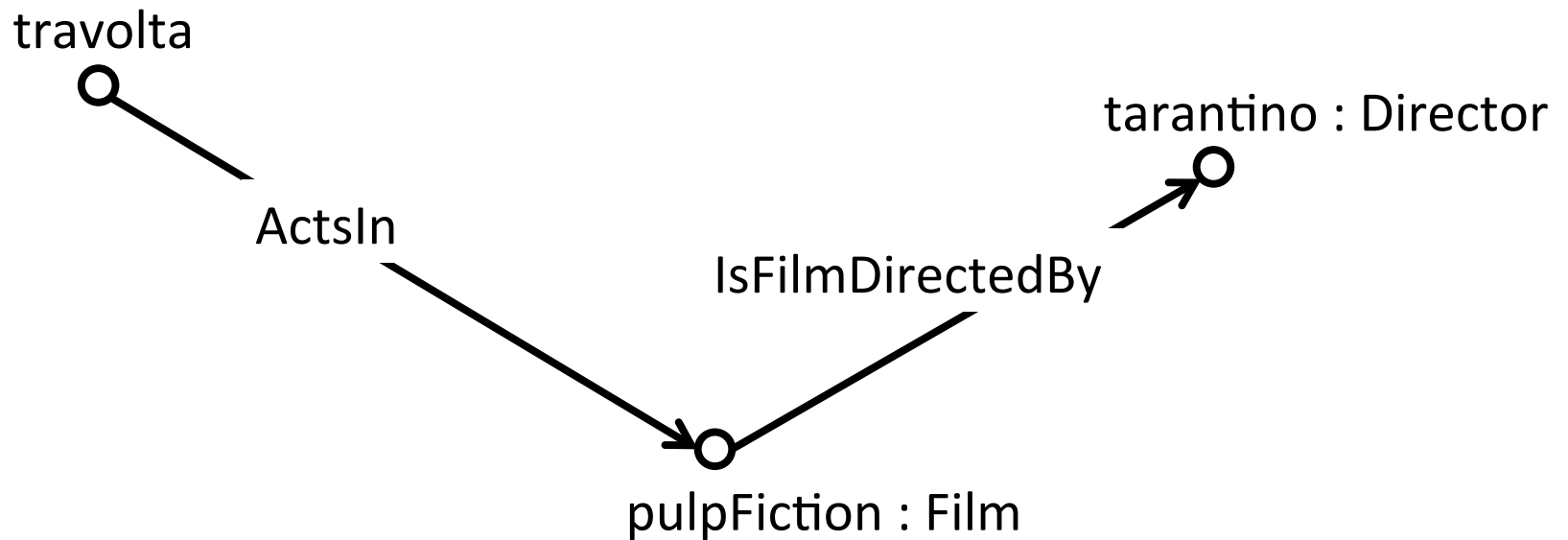
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$\text{DirectsFilm}(x, y) \wedge \text{Features}(y, z) \rightarrow \text{DirectsActor}(x, z)$

**$\text{ActsIn}(\text{travolta}, \text{pulpFiction})$**

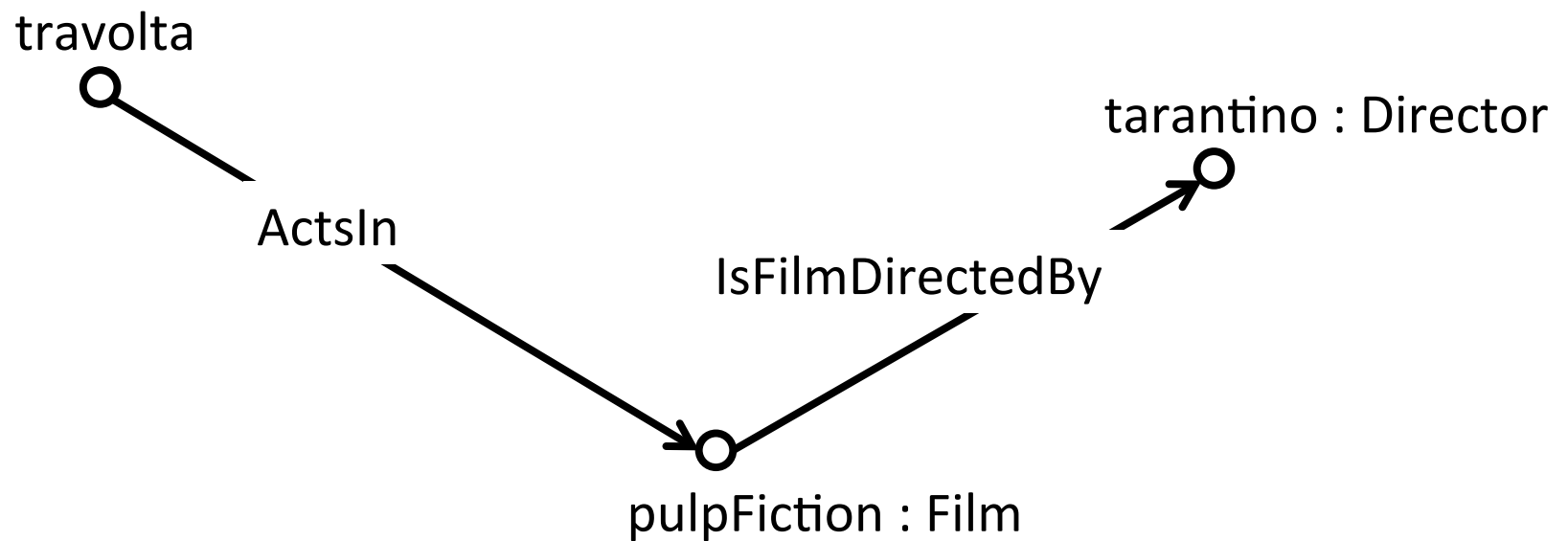


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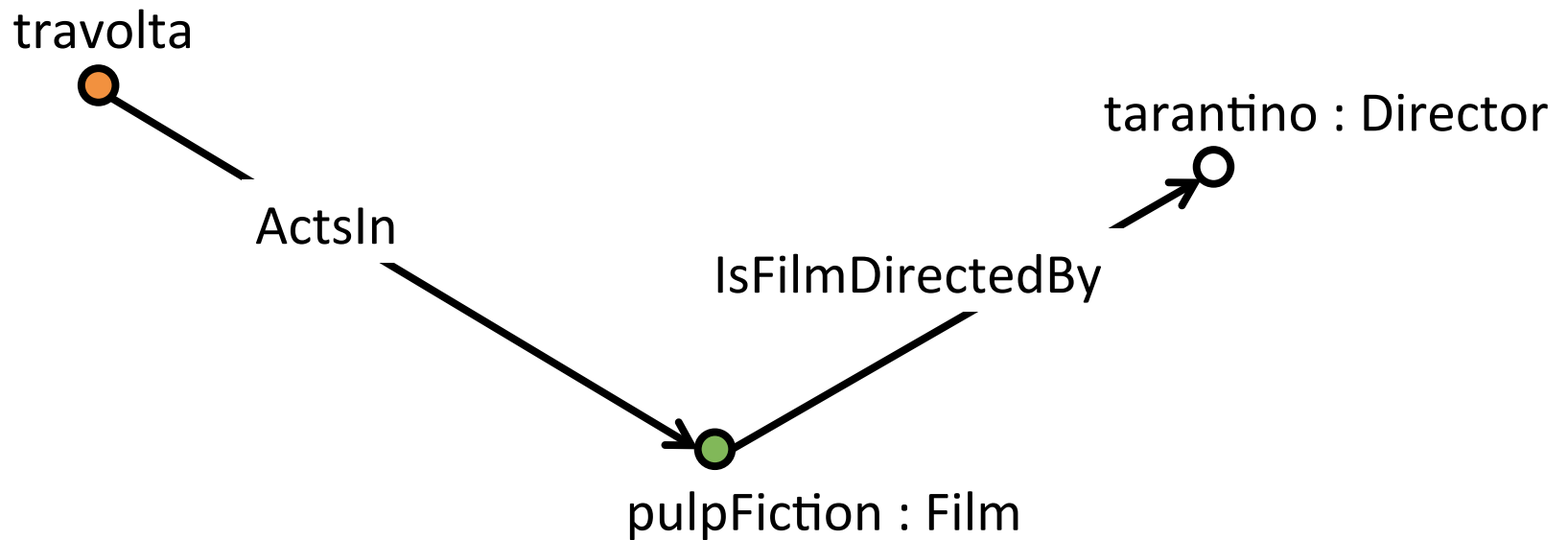


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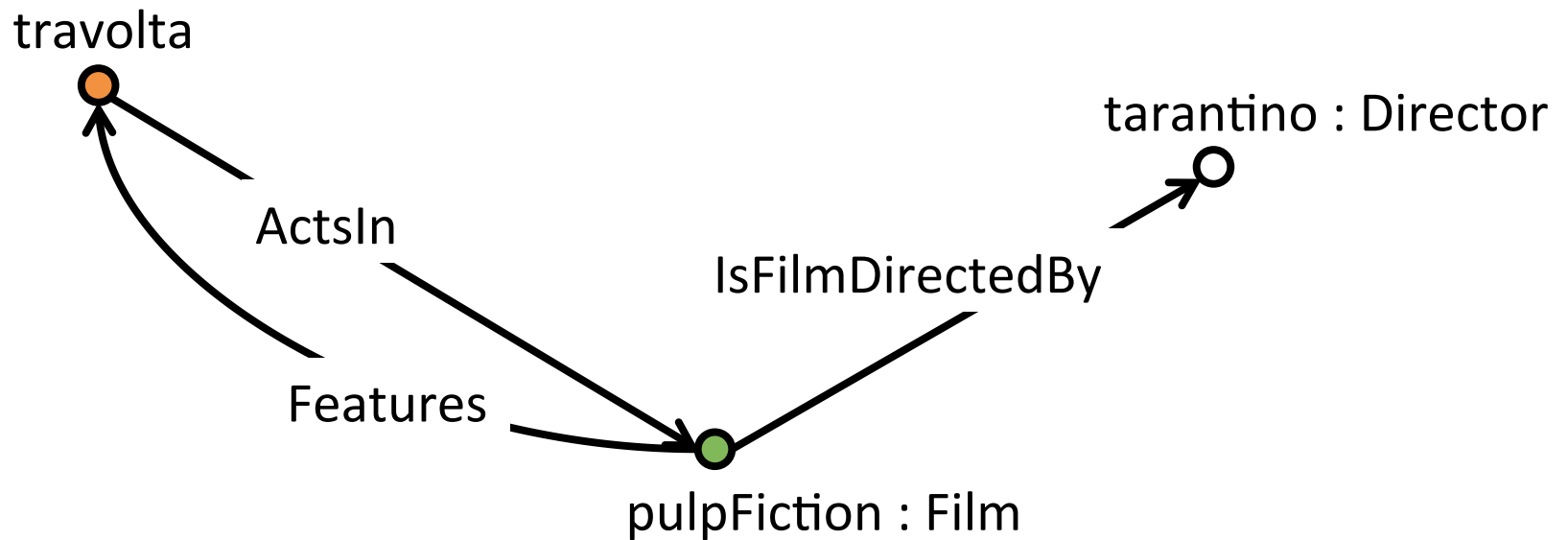


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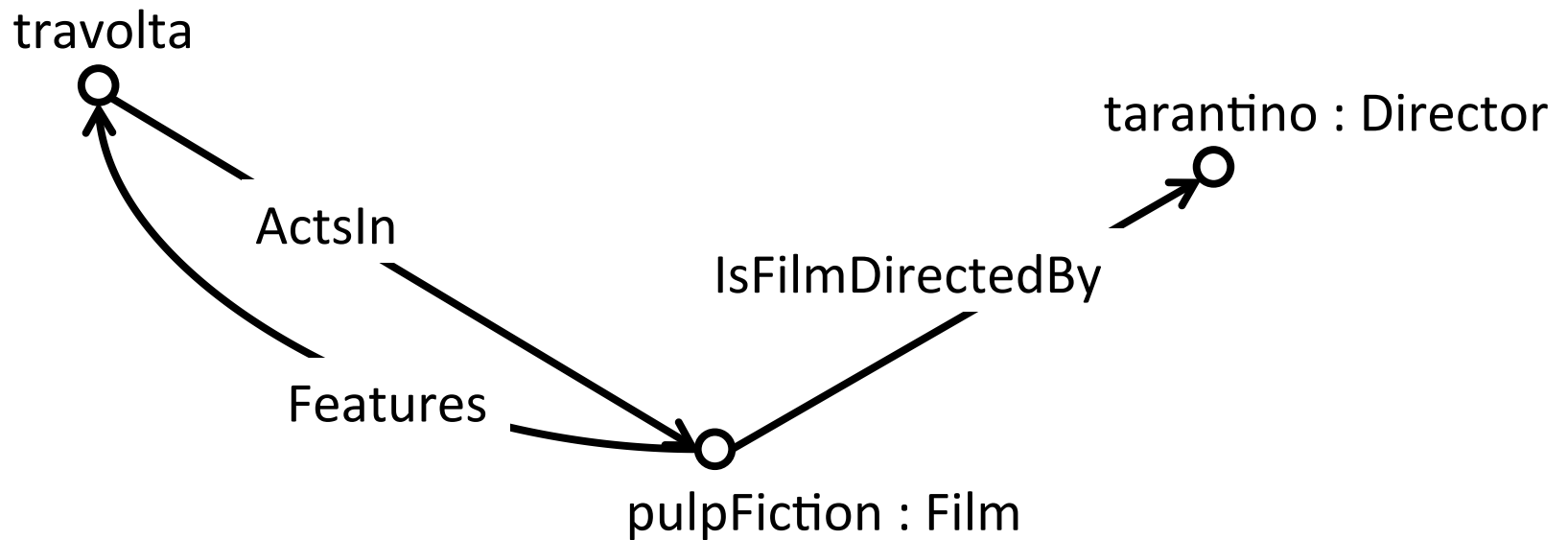


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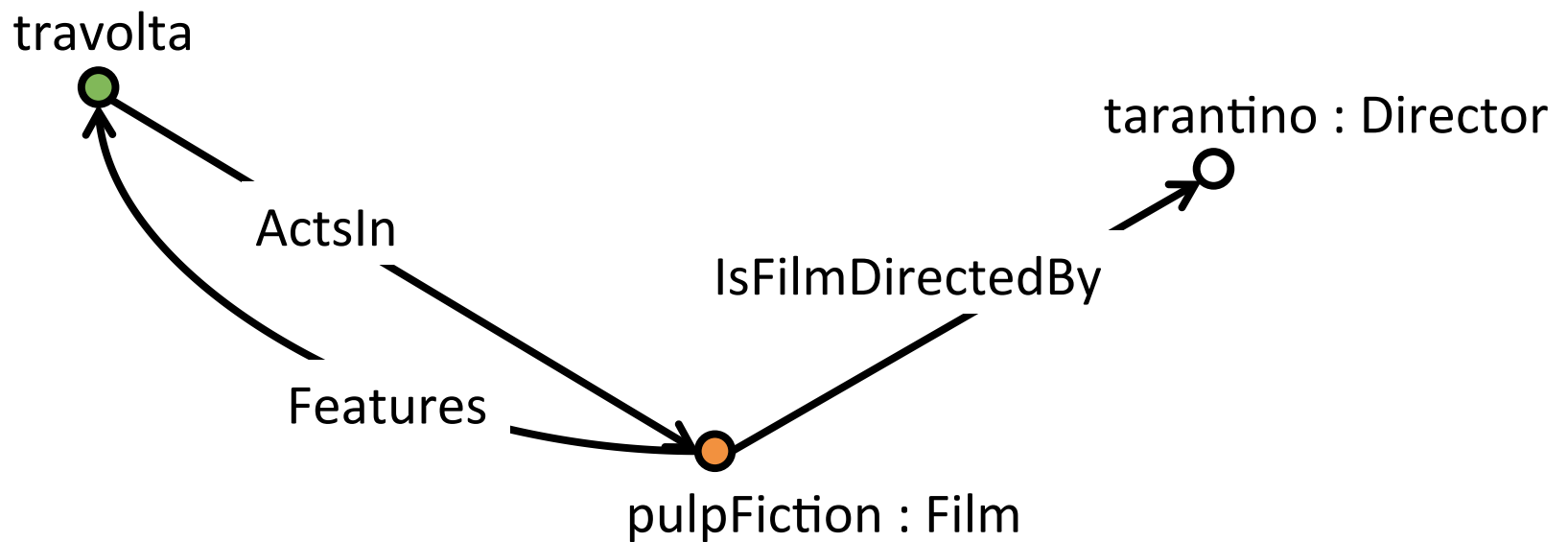


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ActsIn(x, y)  $\rightarrow$  Features(y, x)

IsFilmDirectedBy(x, y)  $\rightarrow$  DirectsFilm(y, x)

DirectsFilm(x, y)  $\wedge$  Features(y, z)  $\rightarrow$  DirectsActor(x, z)

travolta : Actor



ActsIn

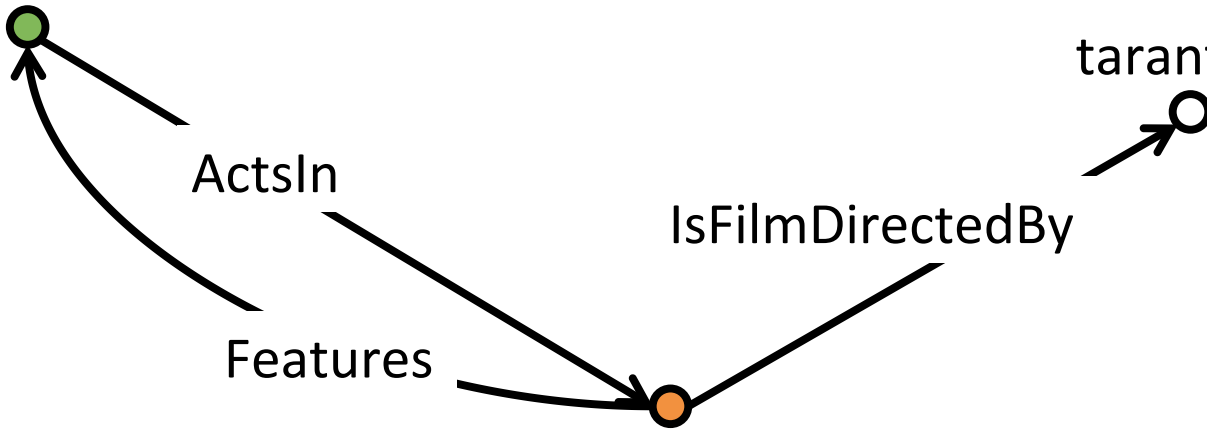
Features

IsFilmDirectedBy

tarantino : Director



pulpFiction : Film





$\text{Features}(x, y) \rightarrow \text{Actor}(y)$

$\text{ActsIn}(x, y) \rightarrow \text{Features}(y, x)$

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travolta : Actor



ActsIn

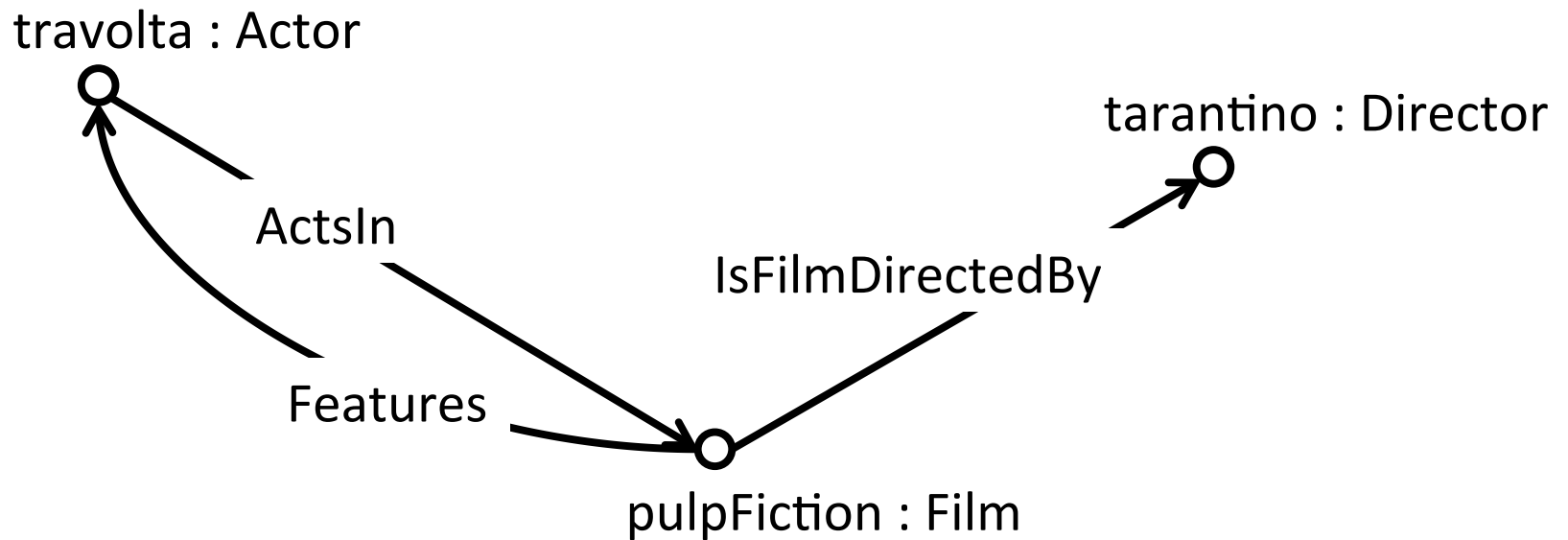
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pulpFiction : Film



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$\text{DirectsFilm}(x, y) \wedge \text{Features}(y, z) \rightarrow \text{DirectsActor}(x, z)$

travolta : Actor



ActsIn

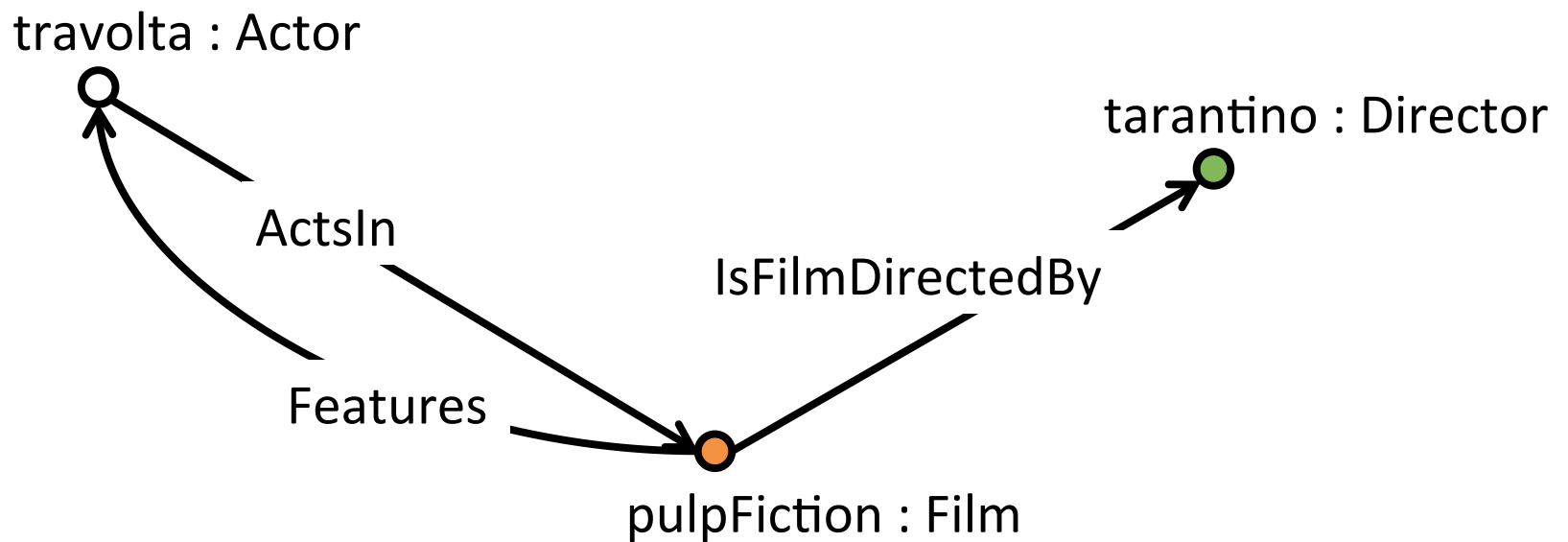
Features

IsFilmDirectedBy

tarantino : Director



pulpFiction : Film



$\text{Features}(x, y) \rightarrow \text{Actor}(y)$

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$\text{DirectsFilm}(x, y) \wedge \text{Features}(y, z) \rightarrow \text{DirectsActor}(x, z)$

travolta : Actor



ActsIn

Features

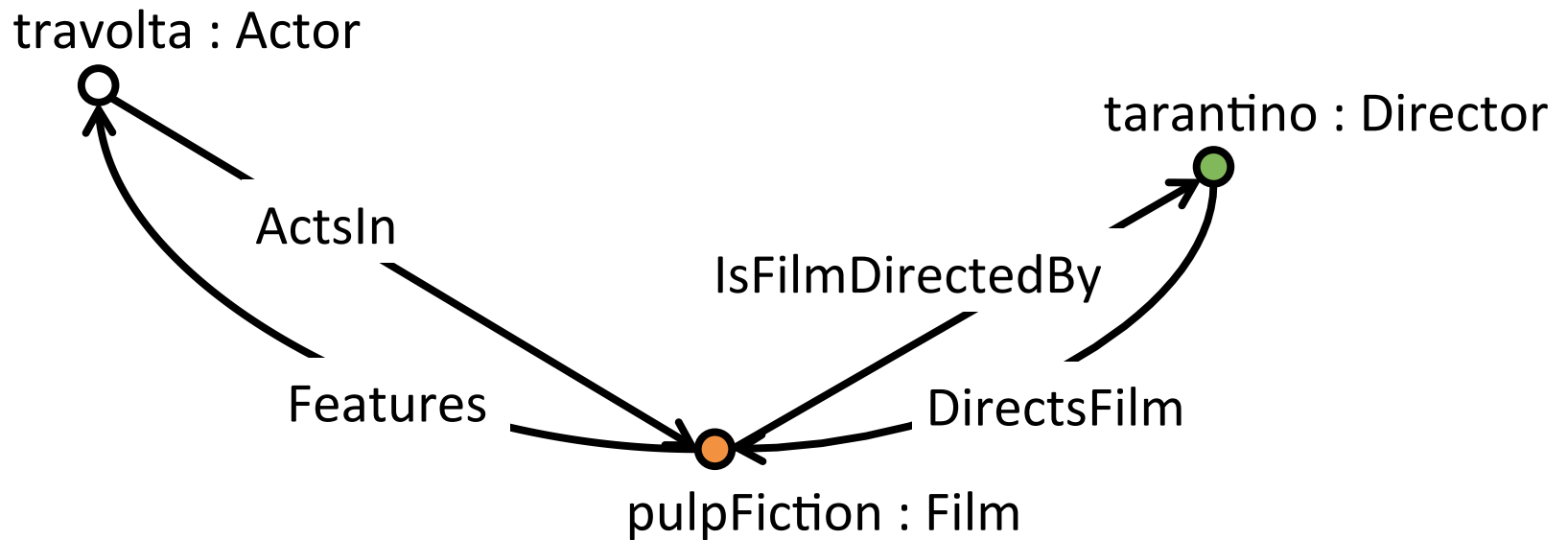
IsFilmDirectedBy

tarantino : Director



DirectsFilm

pulpFiction : Film



$\text{Features}(x, y) \rightarrow \text{Actor}(y)$

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$\text{DirectsFilm}(x, y) \wedge \text{Features}(y, z) \rightarrow \text{DirectsActor}(x, z)$

travolta : Actor



ActsIn

Features

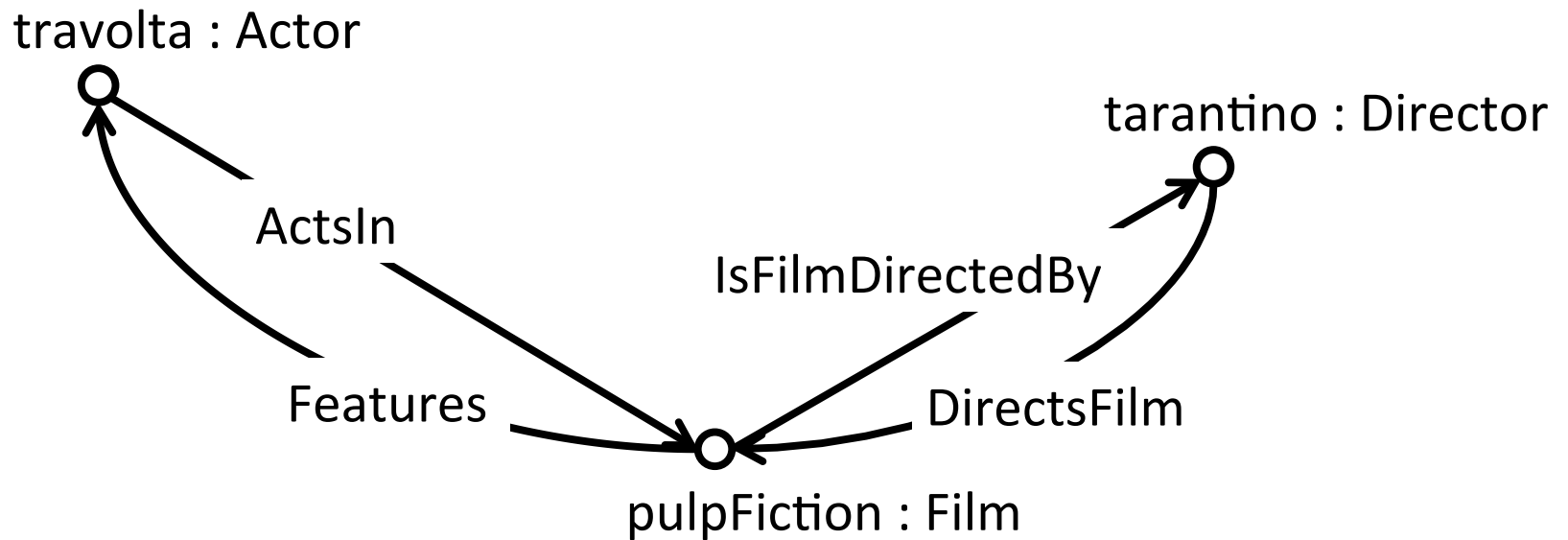
IsFilmDirectedBy

tarantino : Director



DirectsFilm

pulpFiction : Film



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travolta : Actor



ActsIn

Features

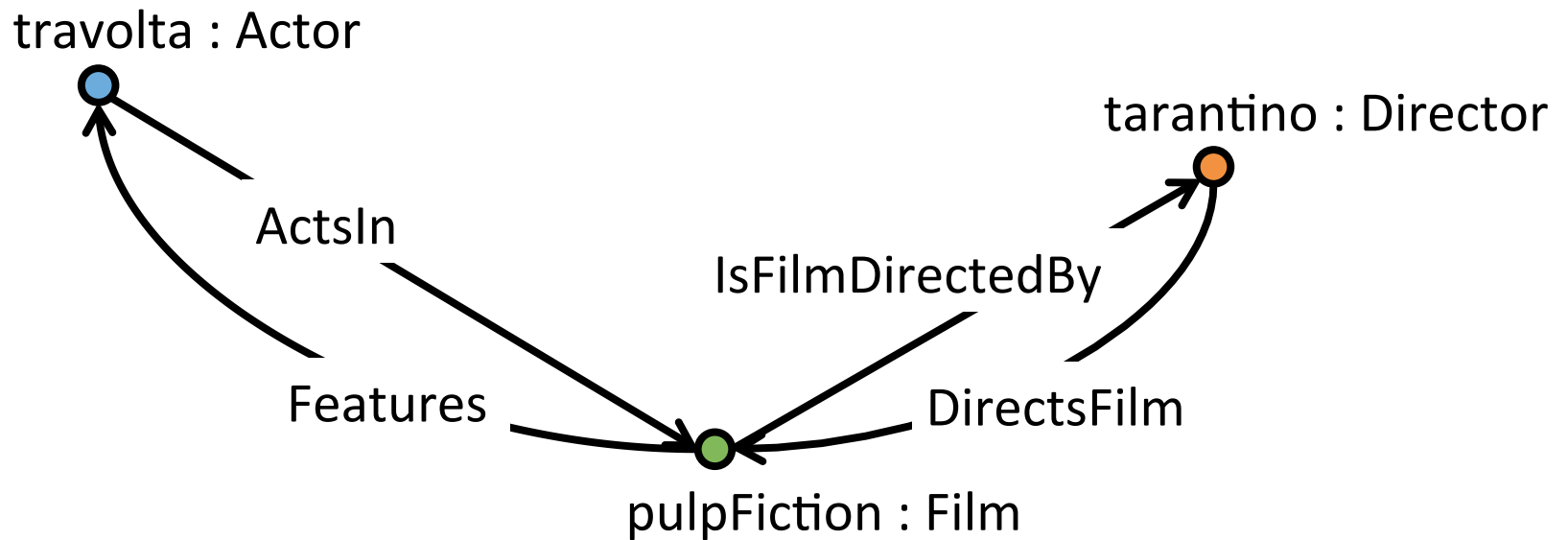
IsFilmDirectedBy

tarantino : Director



DirectsFilm

pulpFiction : Film

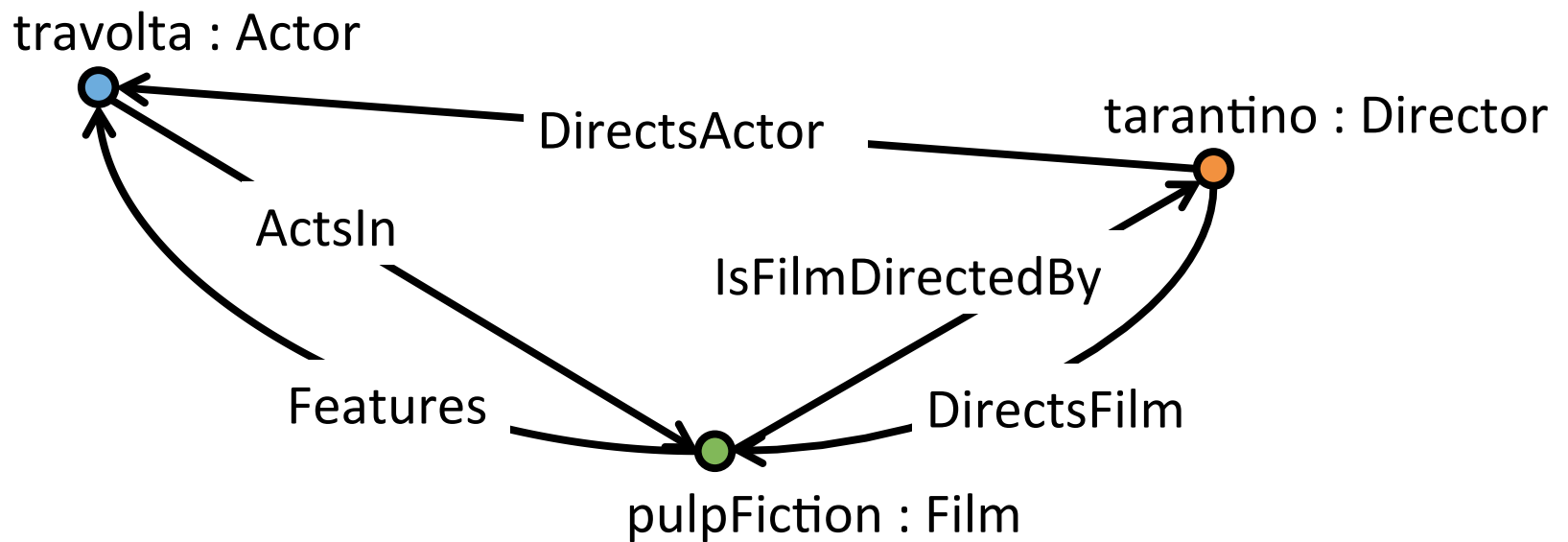


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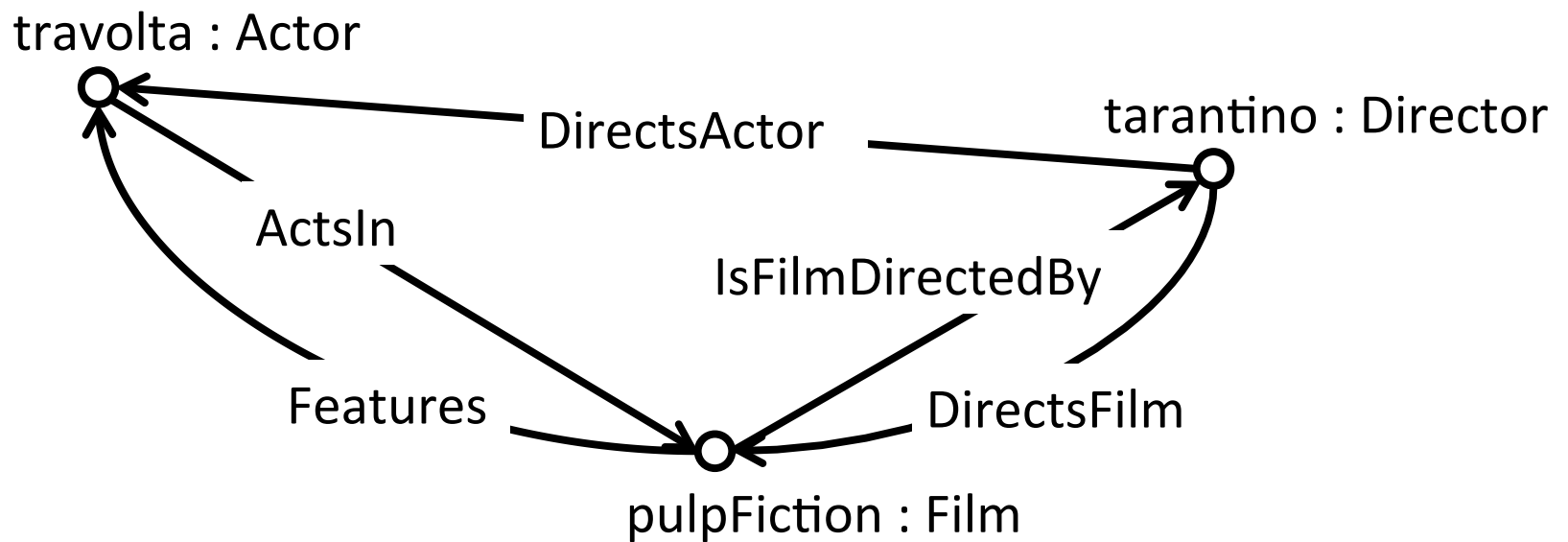


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Actor(travolta)

Director(tarantino)

Film(pulpFiction)

ActsIn(travolta, pulpFiction)

DirectsActor(tarantino, travolta)

DirectsFilm(tarantino, pulpFiction)

Features(pulpFiction, travolta)

IsFilmDirectedBy(pulpFiction, tarantino)



$\text{Film}(x) \rightarrow \exists y . \text{IsFilmDirectedBy}(x, y) \wedge \text{Director}(y)$

$\text{Director}(x) \rightarrow \exists z . \text{DirectsFilm}(x, z) \wedge \text{Film}(z)$

$\text{Film}(\text{pulpFiction})$

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pulpFiction : Film

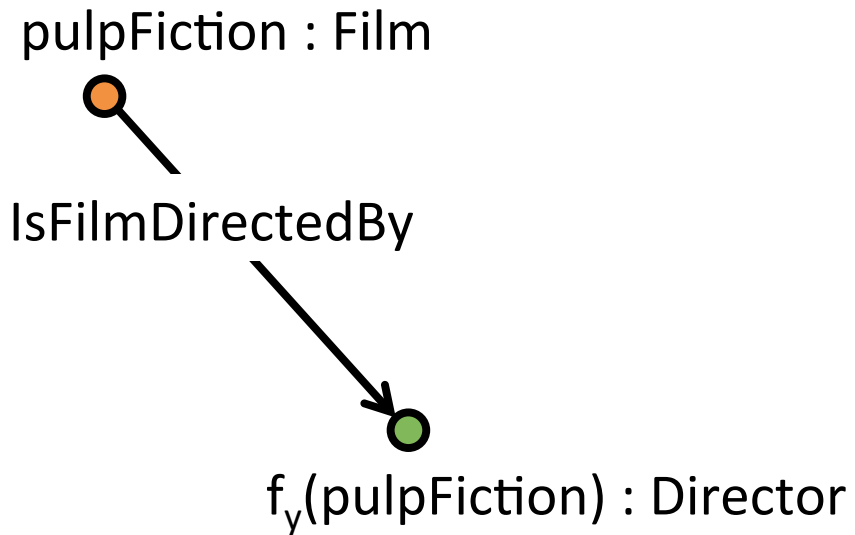


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pulpFiction : Film

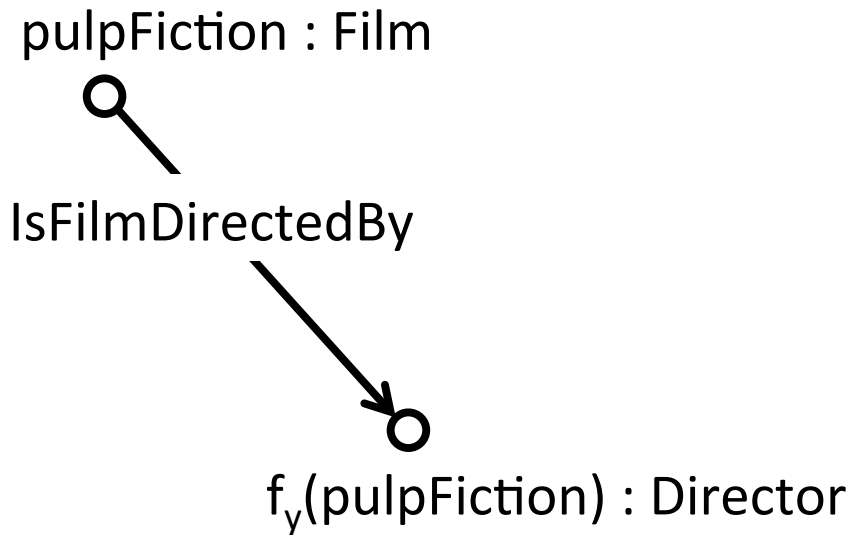


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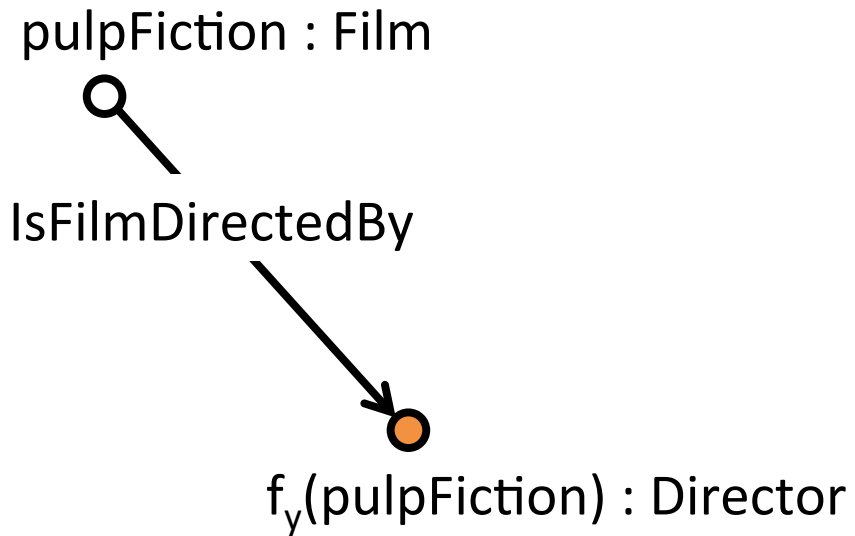


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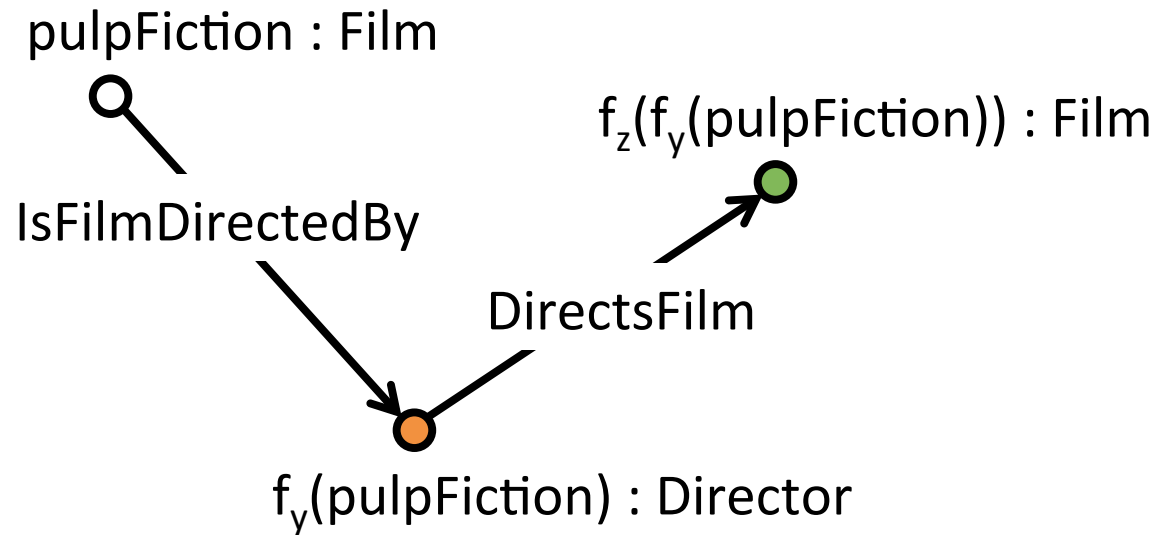


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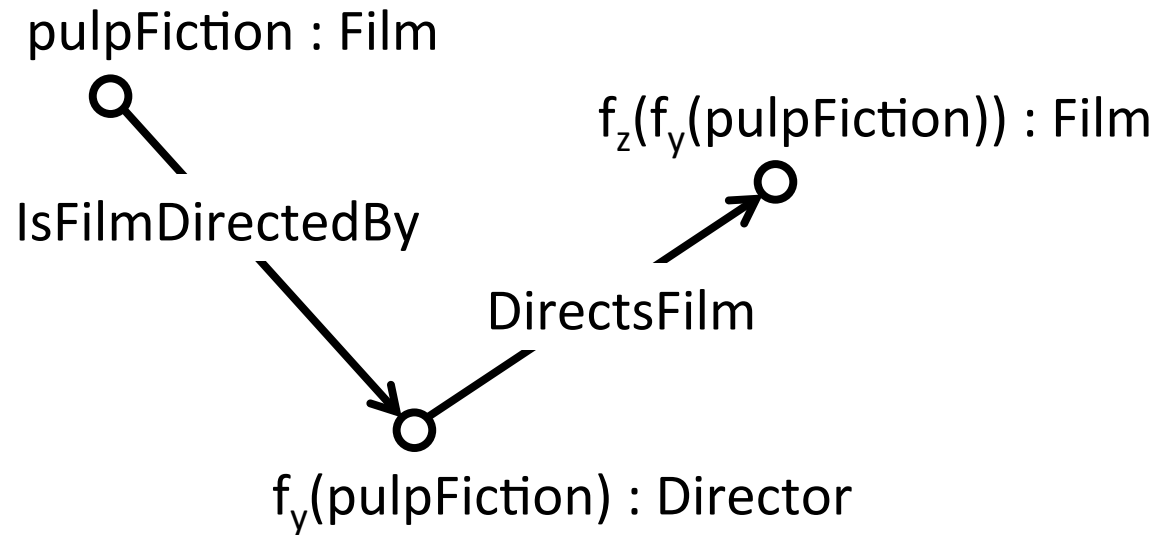


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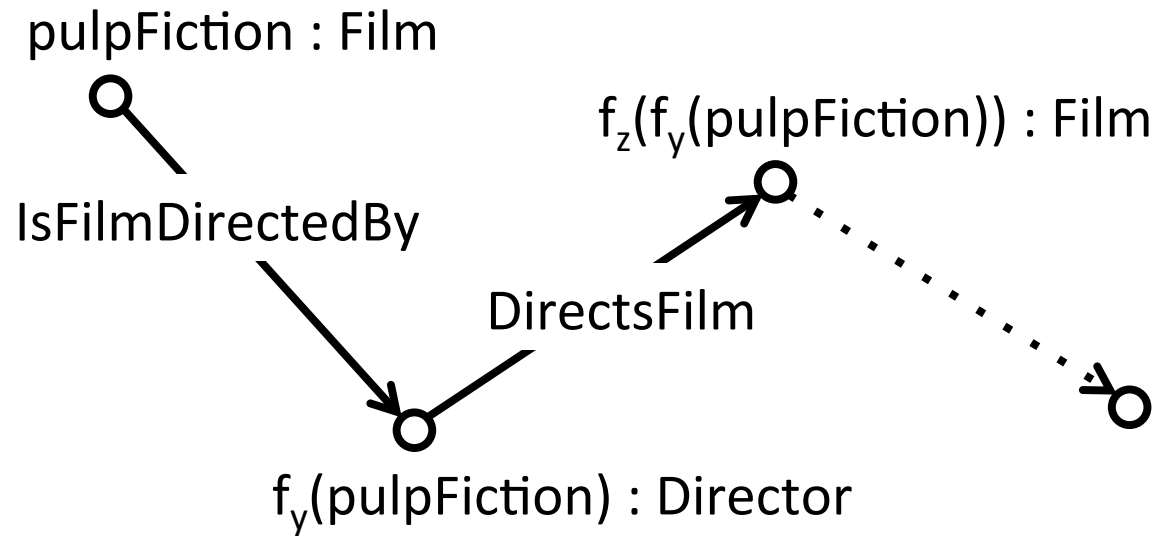


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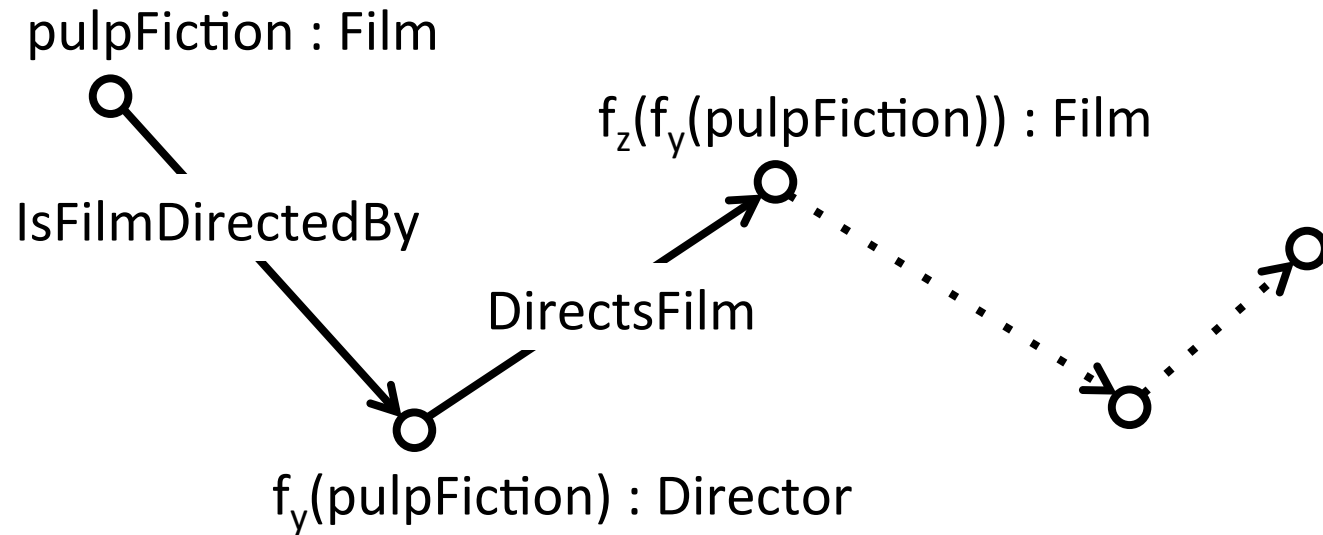


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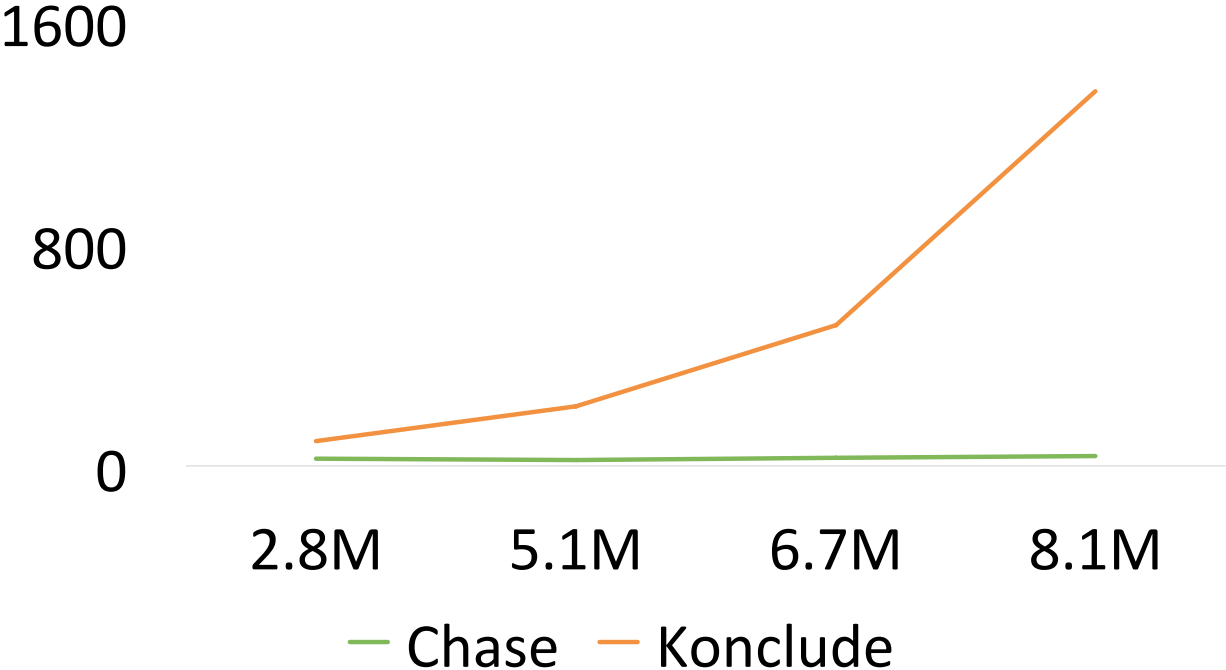


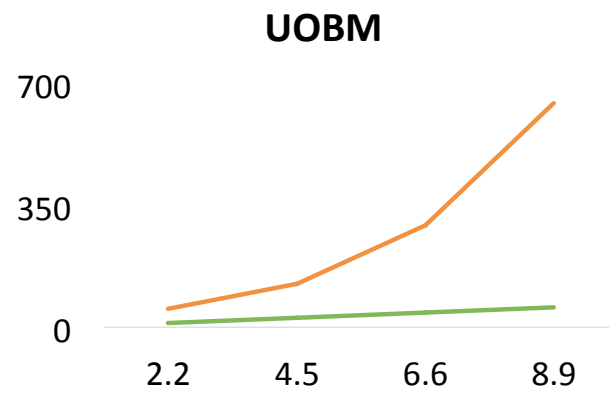
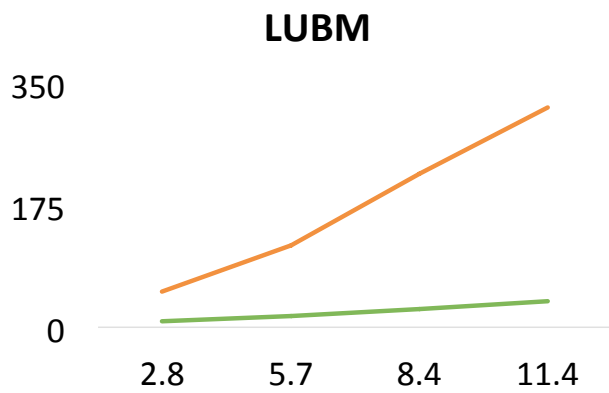
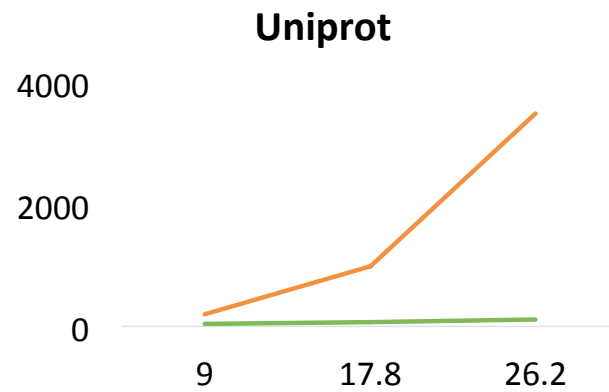
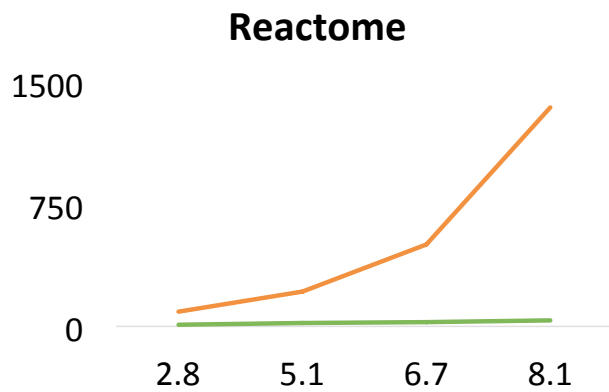
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# Reactome





2005: Weak Acyclicity (WA)

2011: Joint Acyclicity (JA)

2013: Model Summarizing Acyclicity (MSA)  
and Model Faithful Acyclicity (MFA)

- Restricted JA (RJA)
- Restricted MFA (RMFA)
- Restricted MSA (RMSA)

$\text{Film}(x) \rightarrow \exists w . \text{IsFilmDirectedBy}(x, w)$

$\text{IsFilmDirectedBy}(x, y) \rightarrow \text{DirectsFilm}(y, x)$

$\text{Director}(x) \rightarrow \exists z . \text{DirectsFilm}(x, z) \wedge \text{Film}(z)$

$\text{DirectsFilm}(x, y) \rightarrow \text{IsFilmDirectedBy}(y, x)$

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$\text{DirectsFilm}(x, y) \rightarrow \text{IsFilmDirectedBy}(y, x)$

$\text{Film}(\star)$

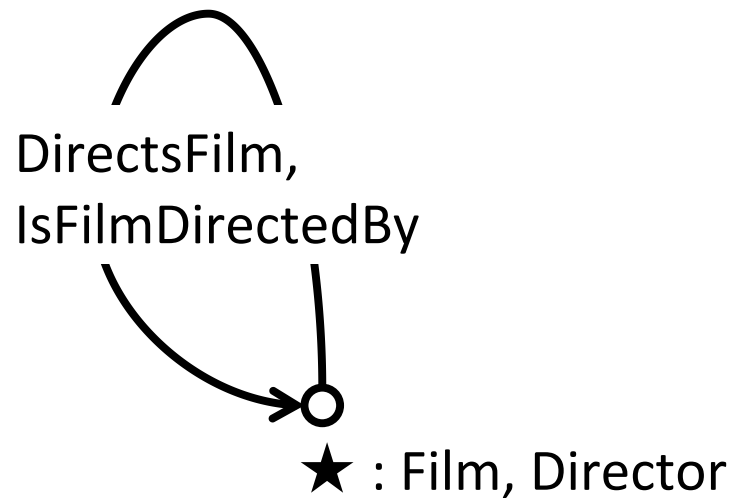
$\text{IsFilmDirectedBy}(\star, \star)$

$\text{Director}(\star)$

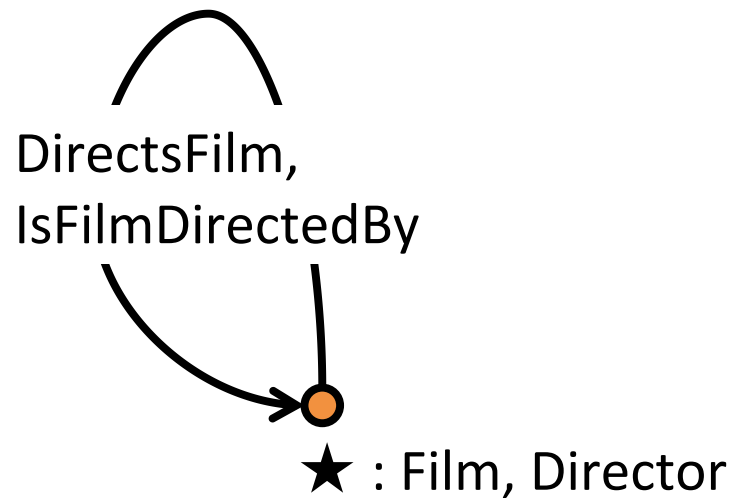
$\text{DirectsFilm}(\star, \star)$



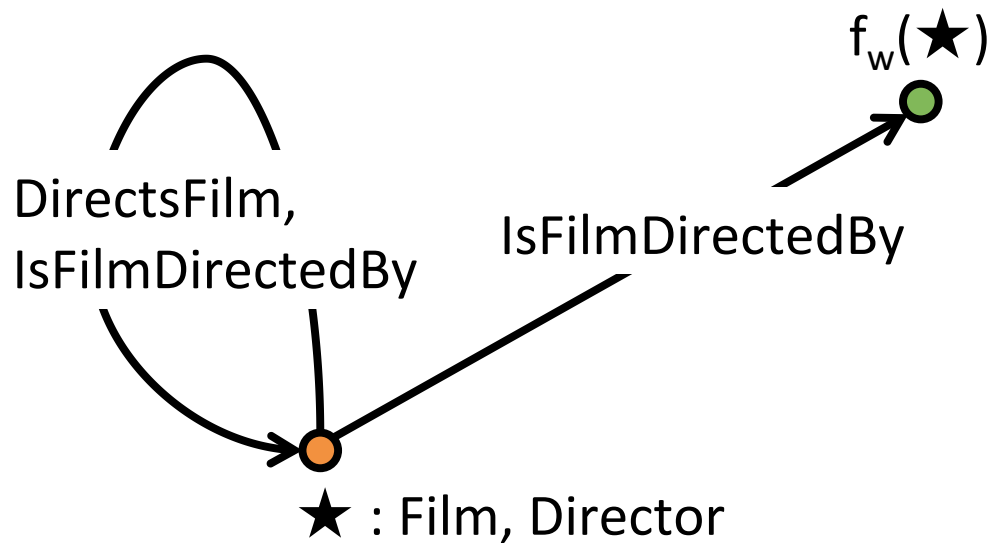
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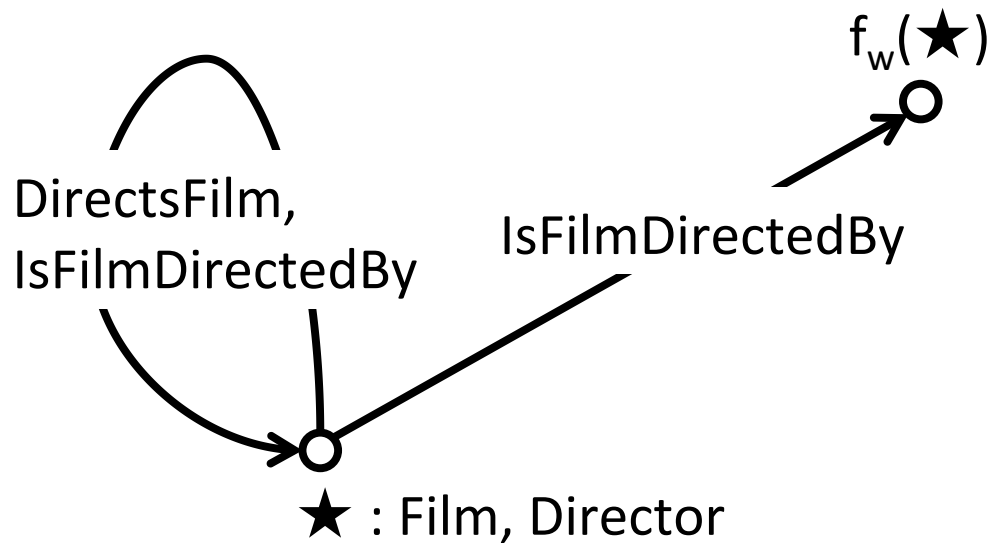
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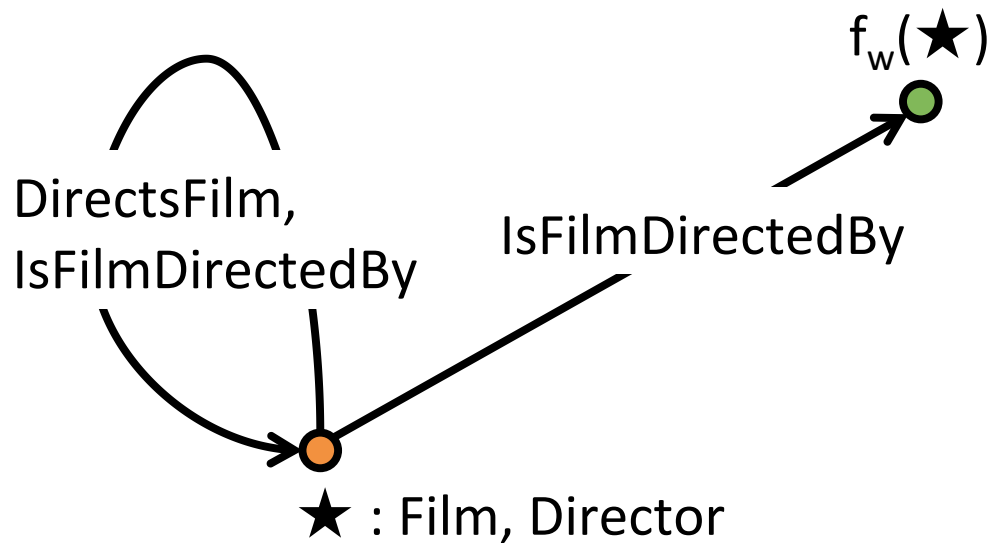
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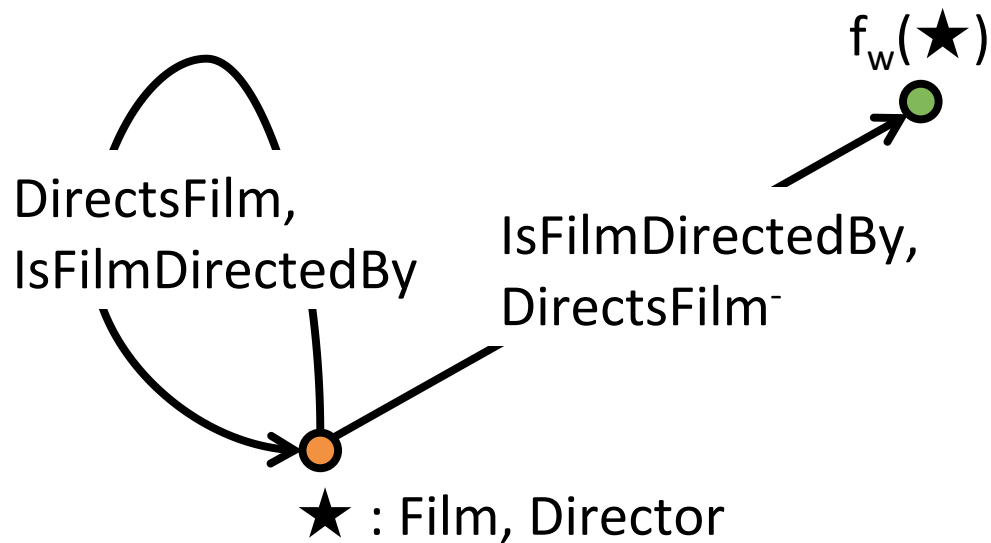
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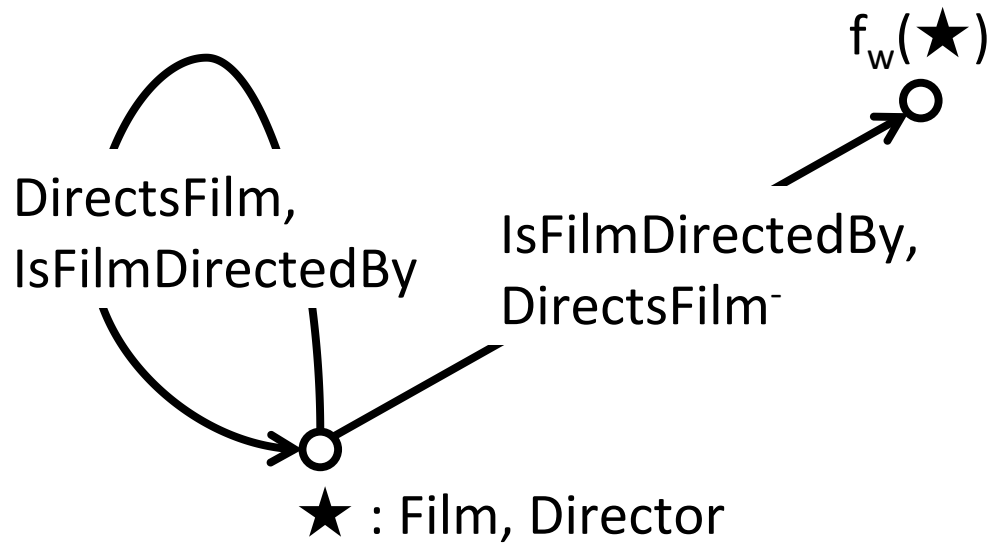
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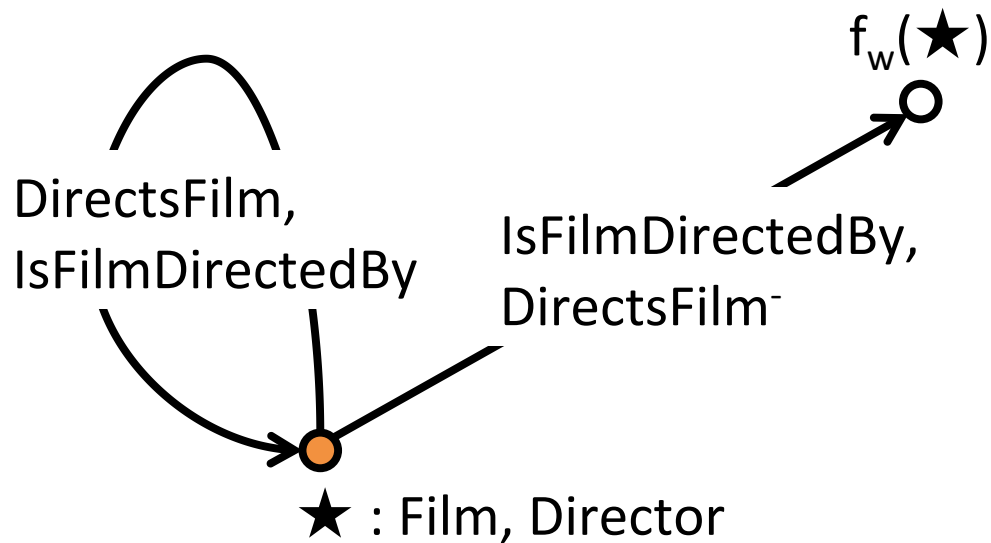
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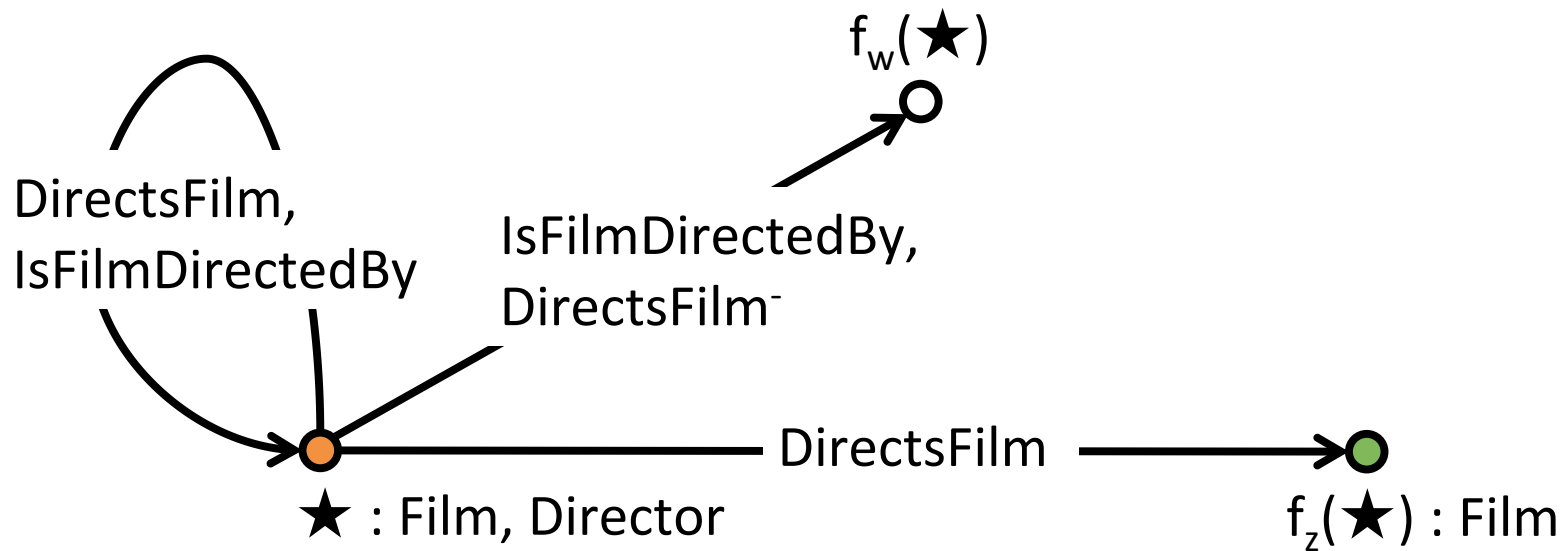


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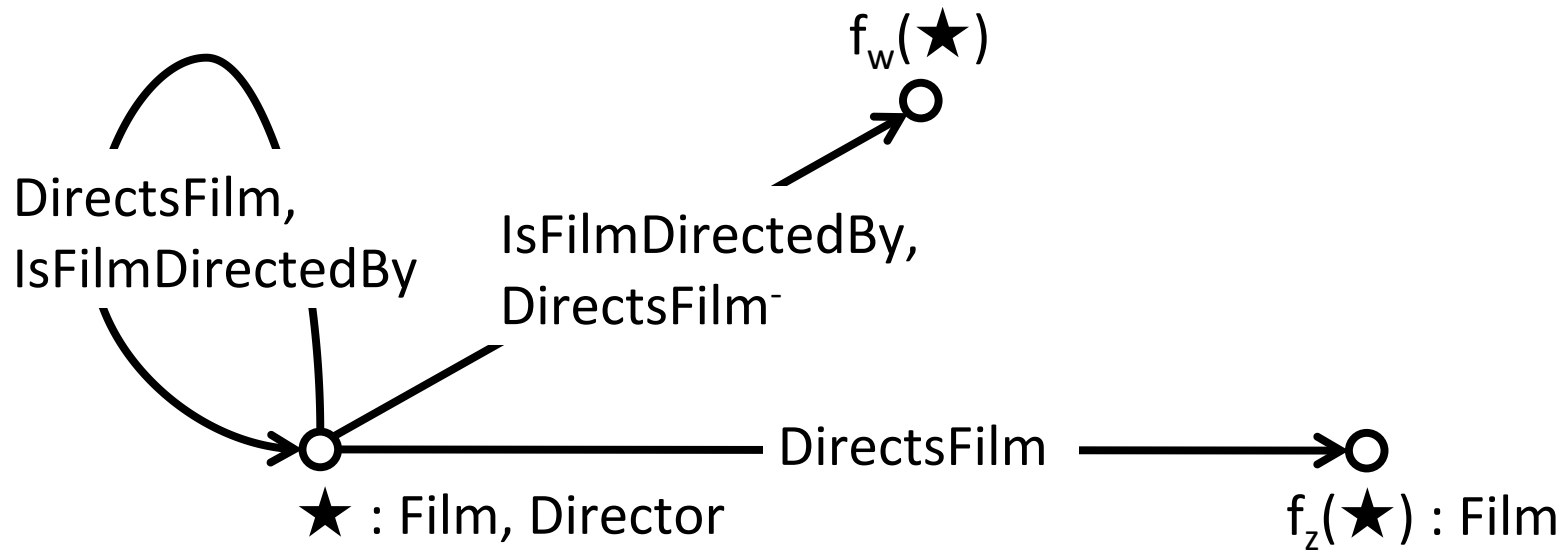




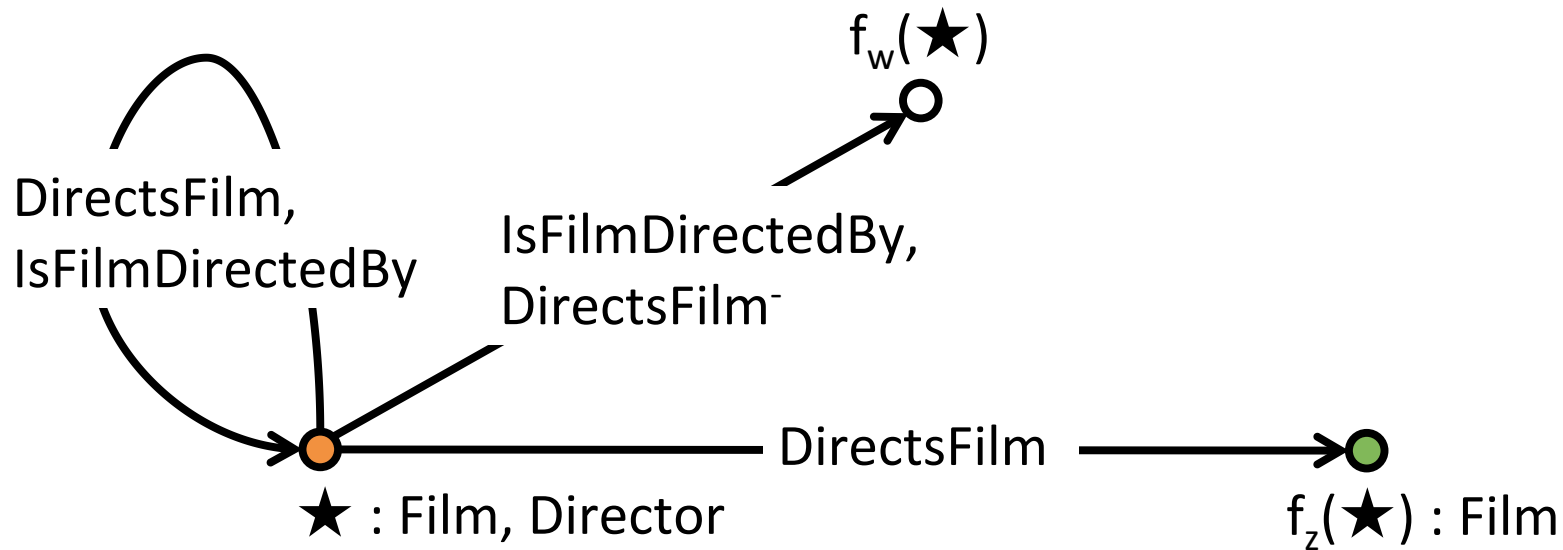
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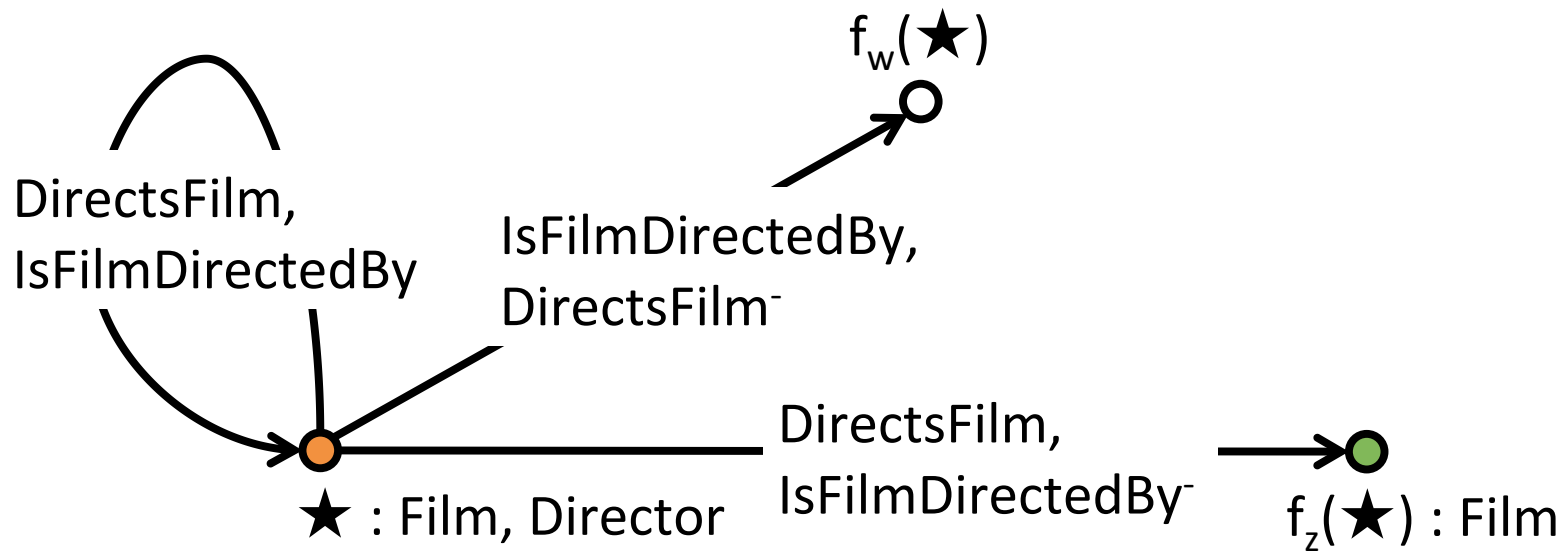
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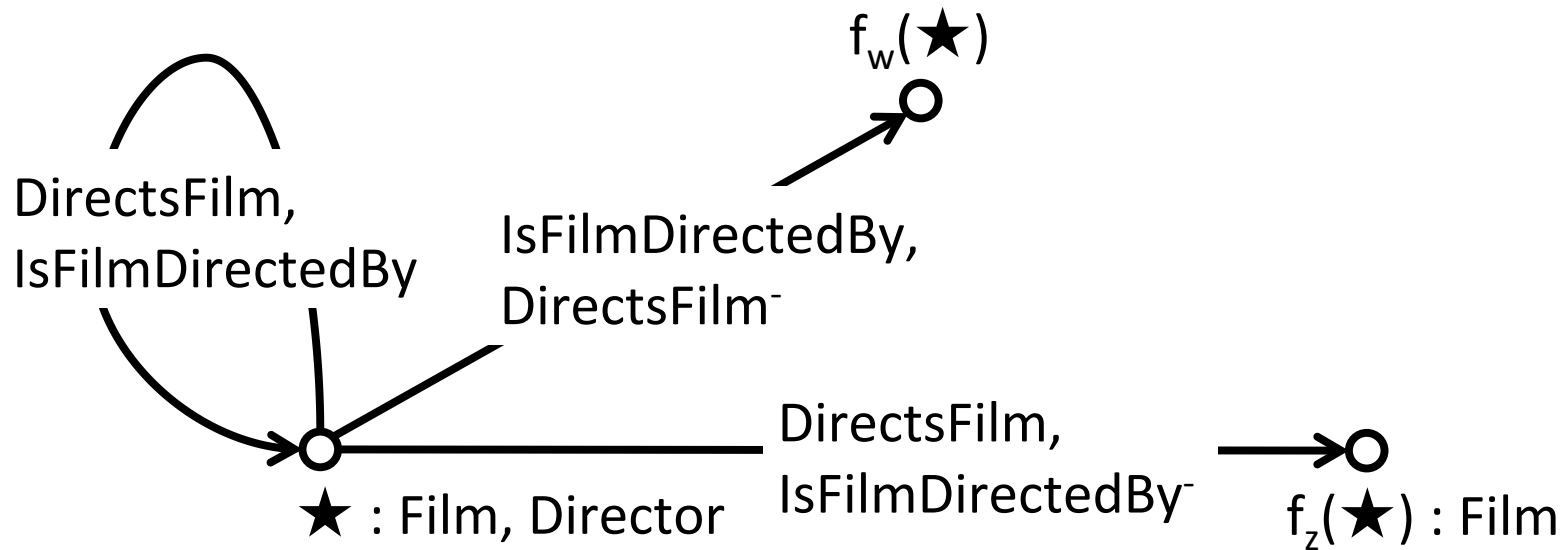
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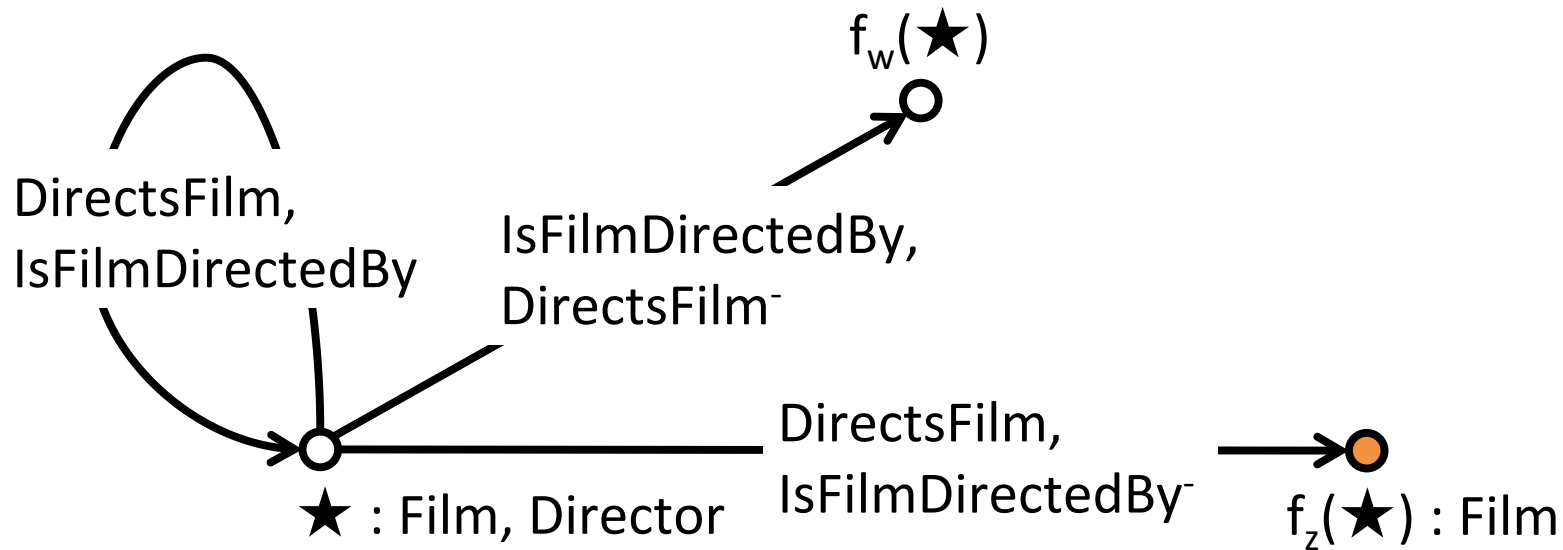
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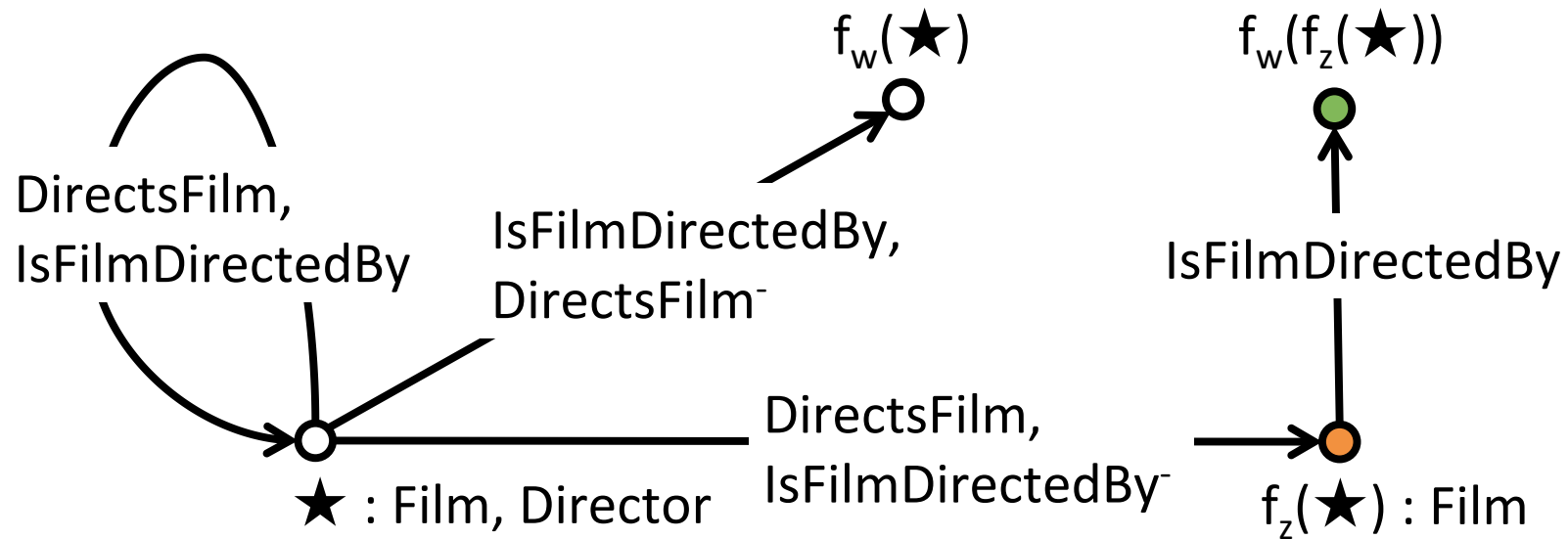


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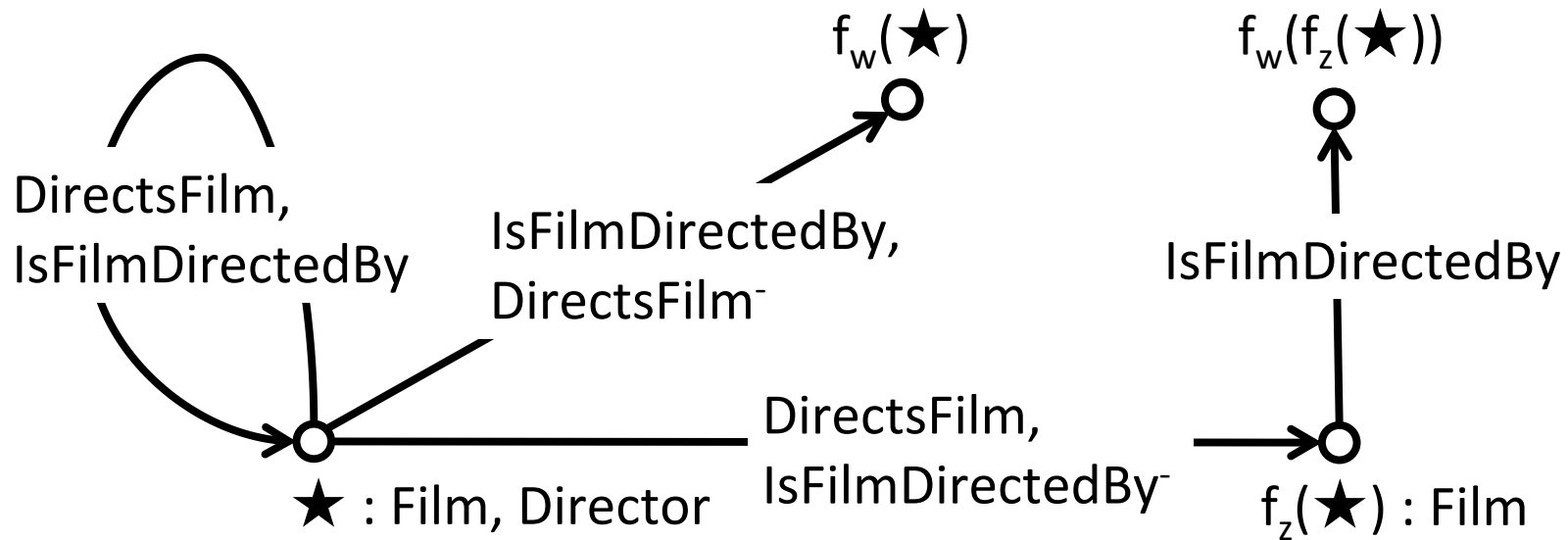


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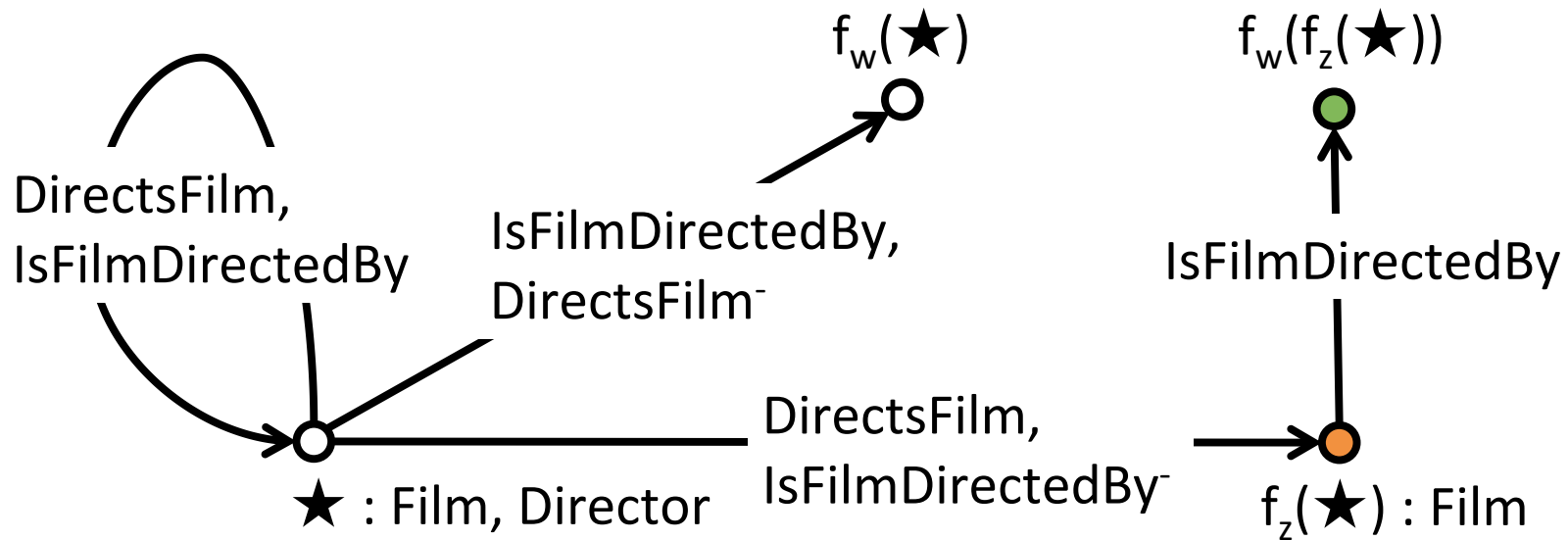


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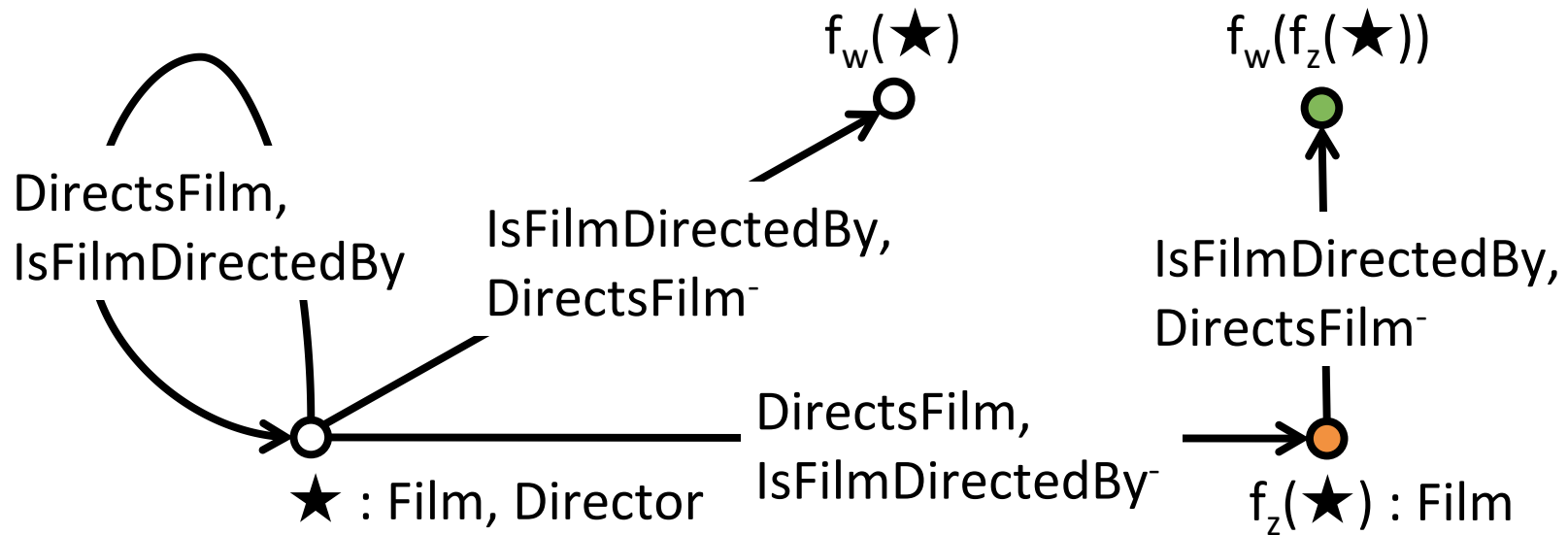


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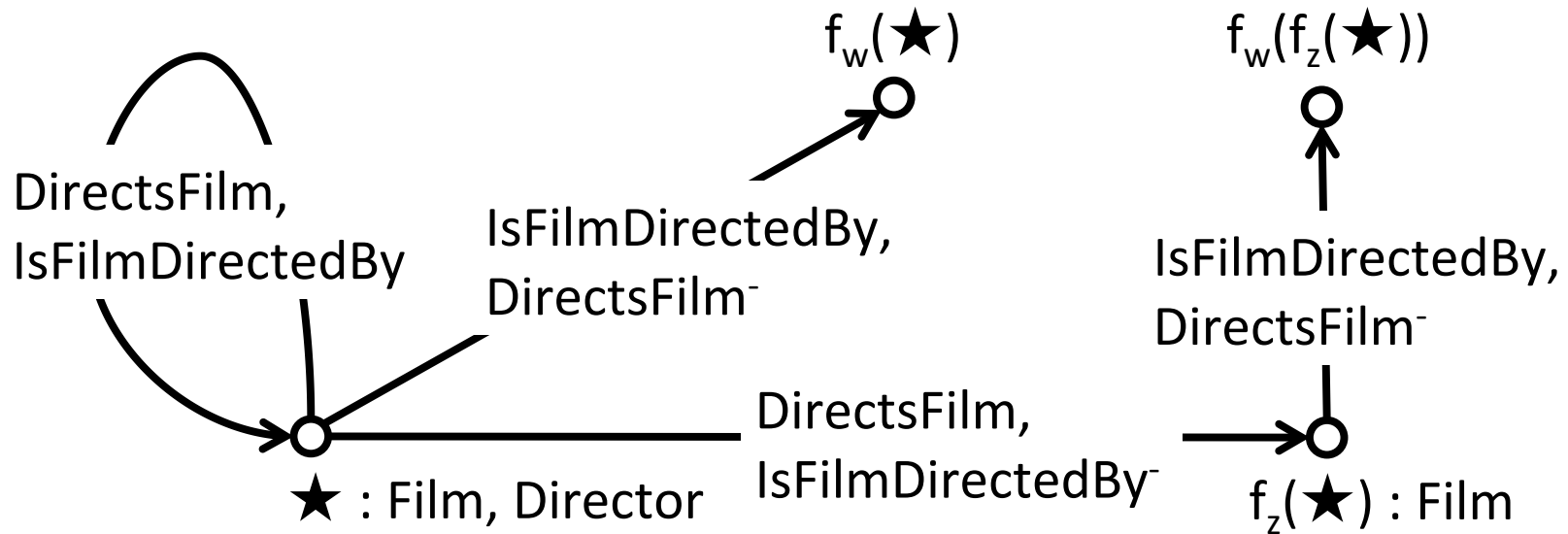
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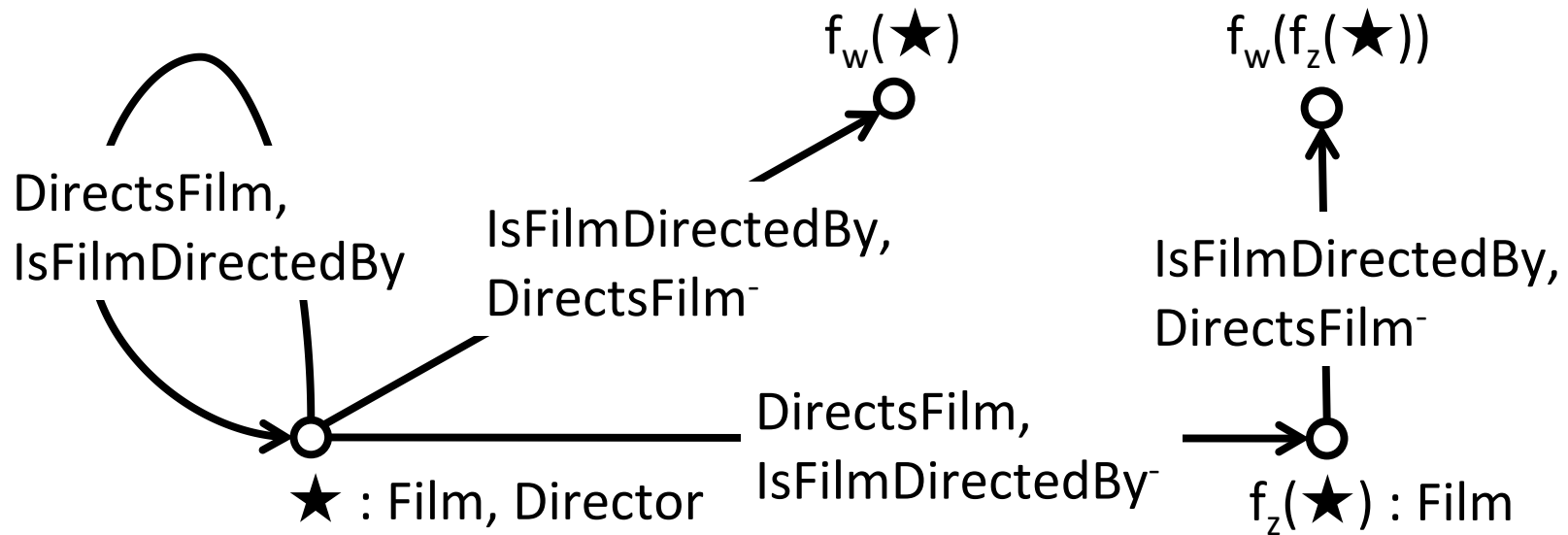


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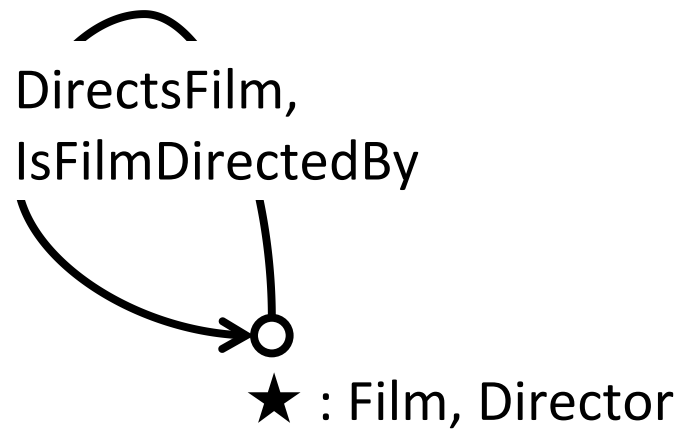
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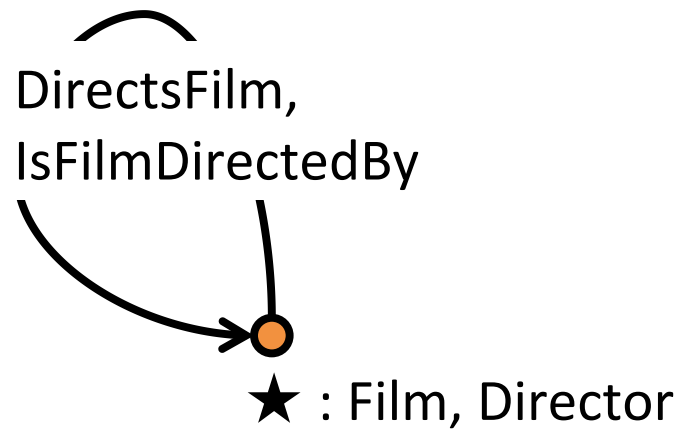


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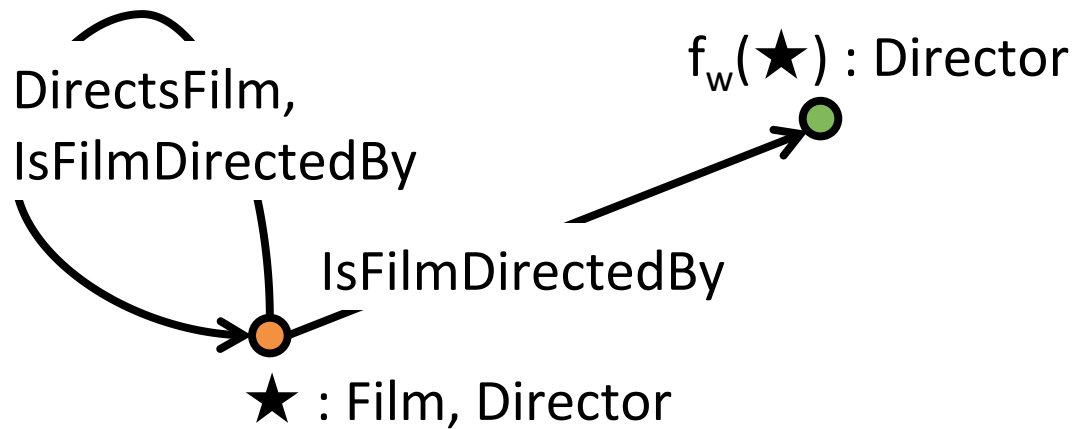


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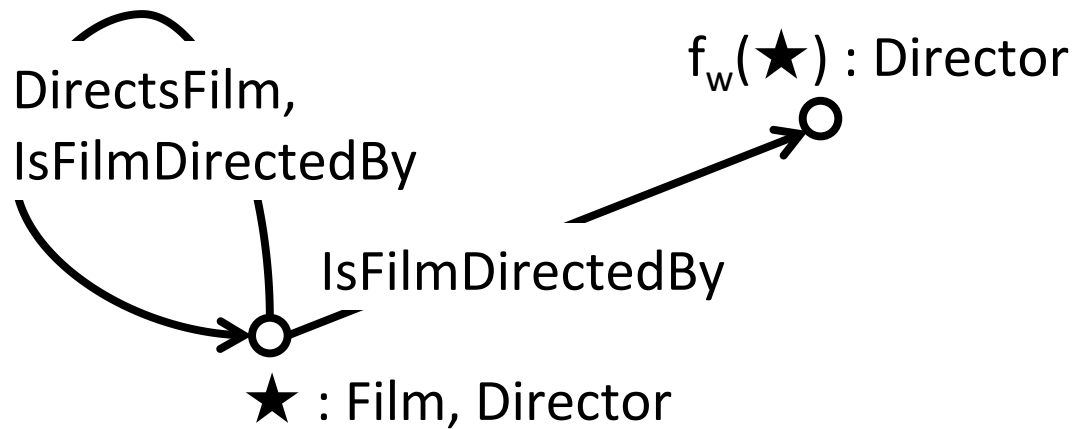


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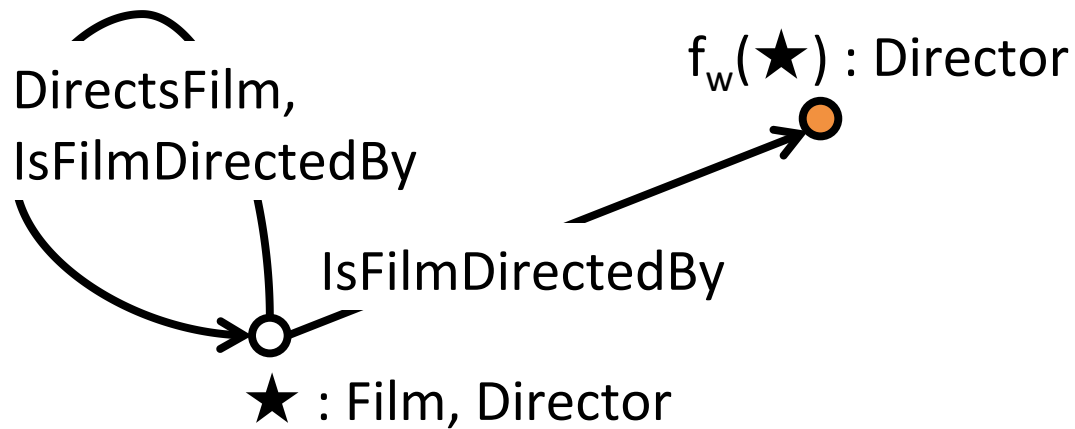


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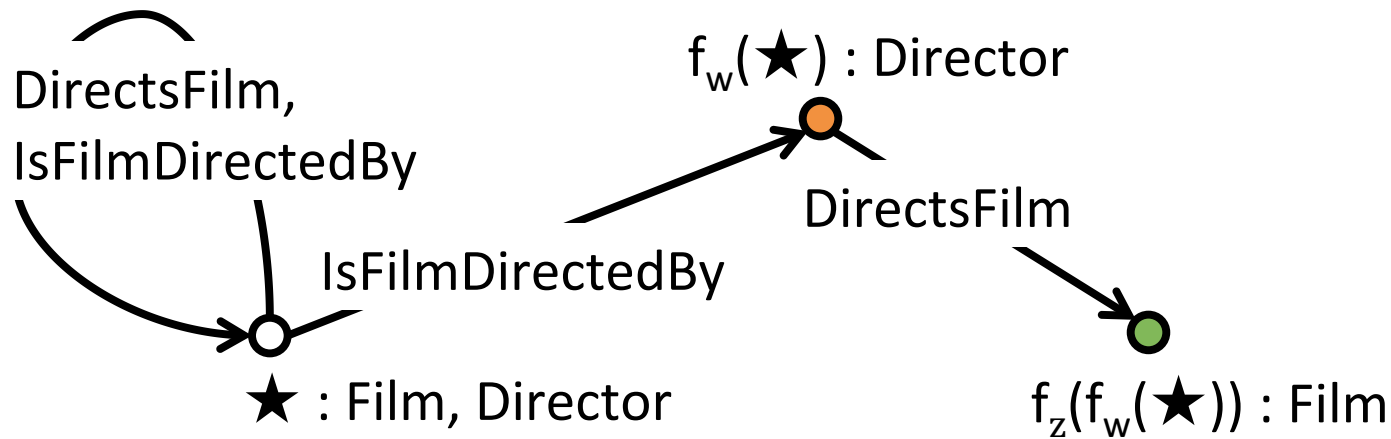
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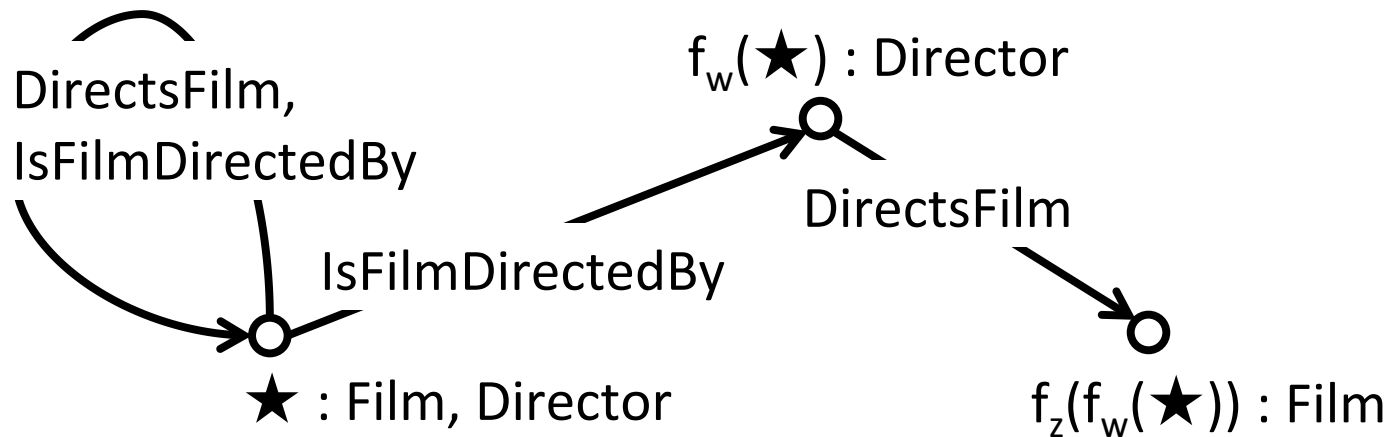
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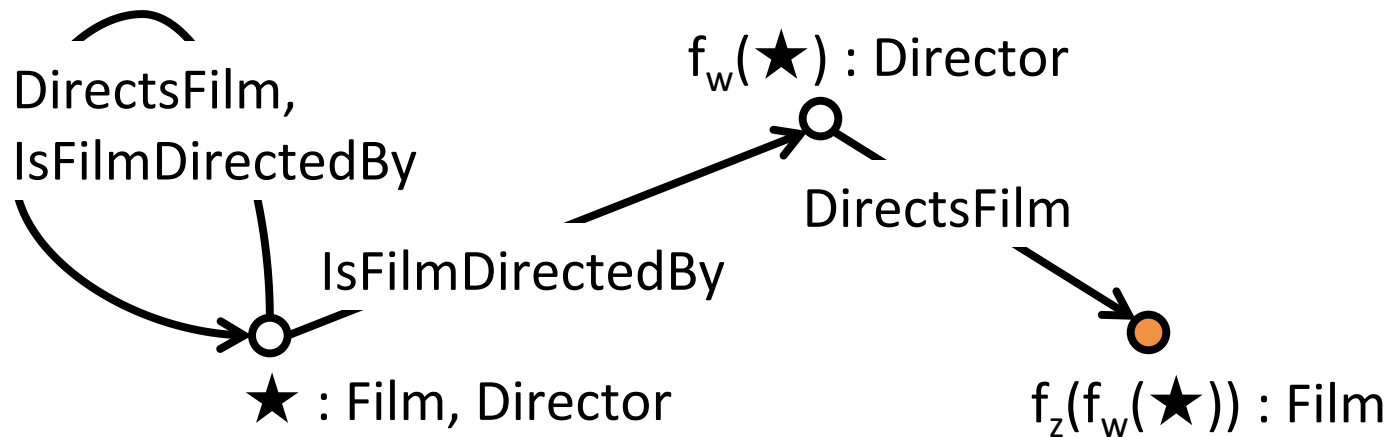
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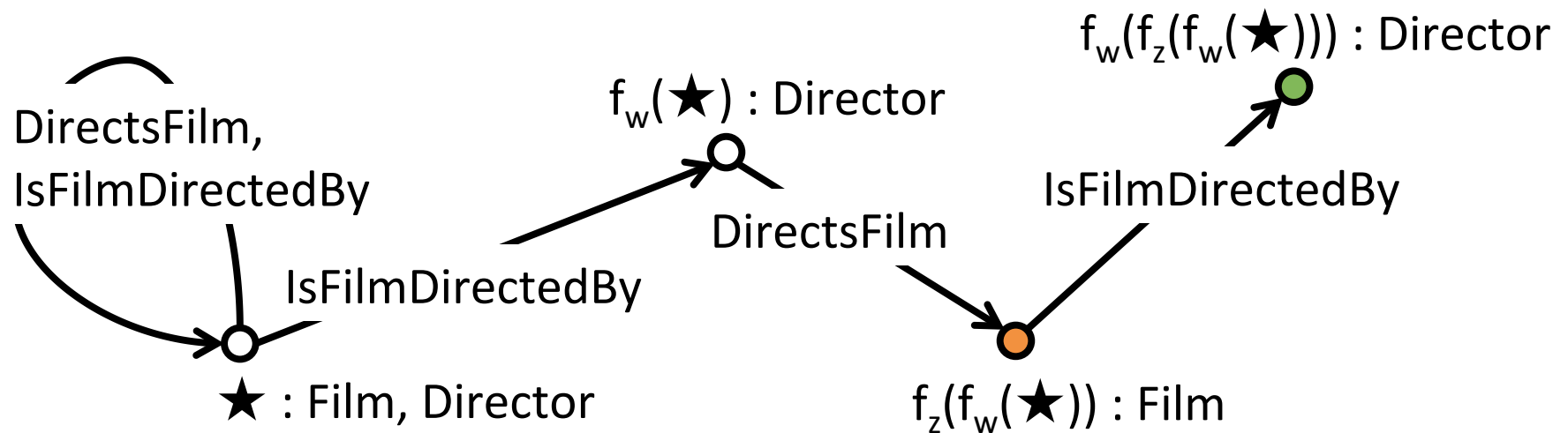


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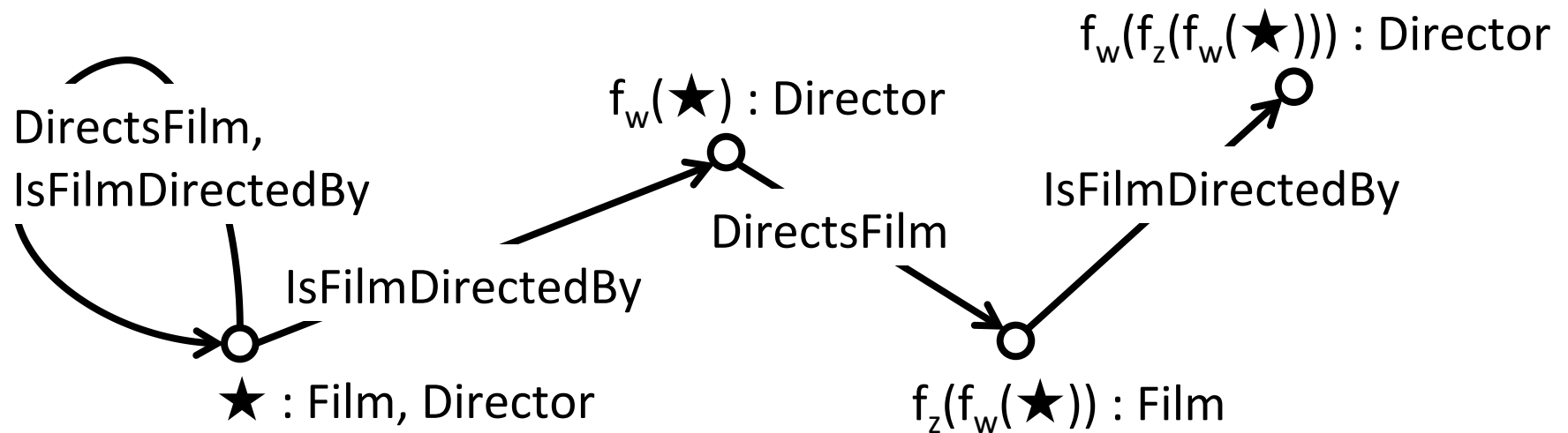


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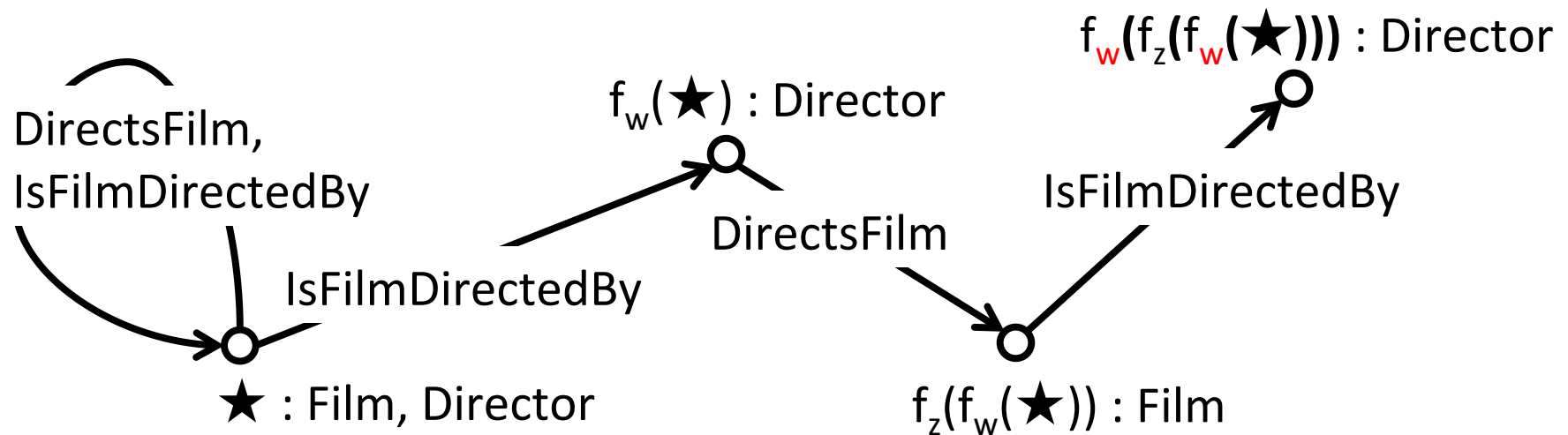


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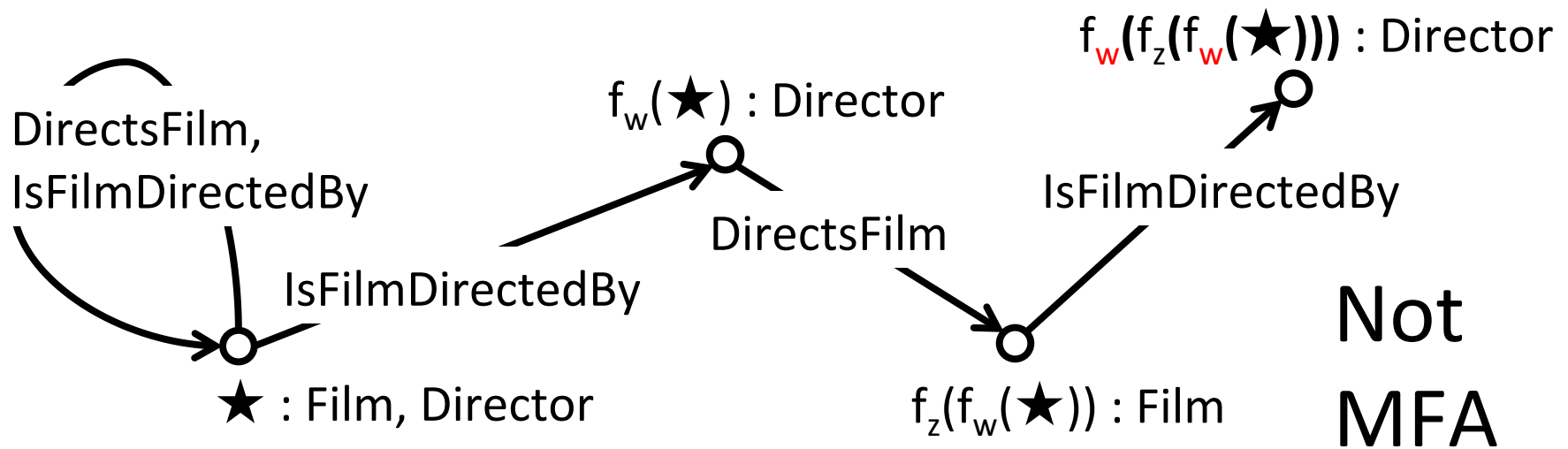


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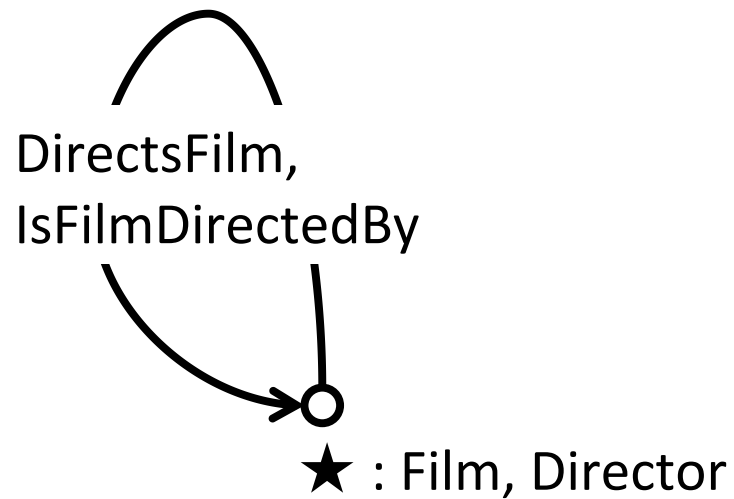
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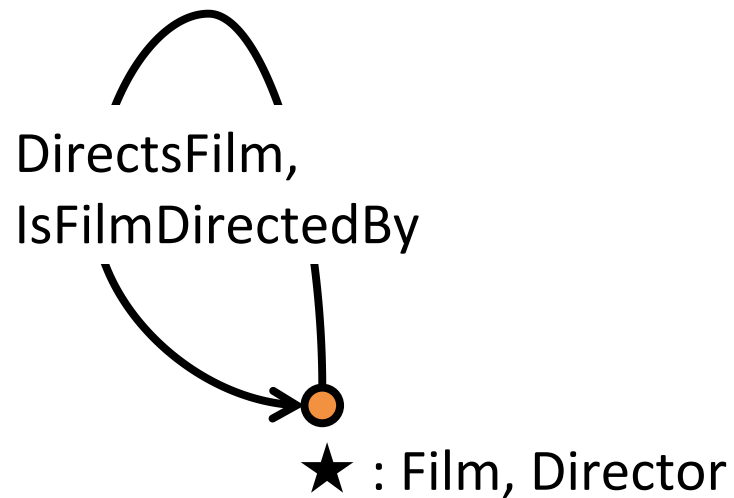


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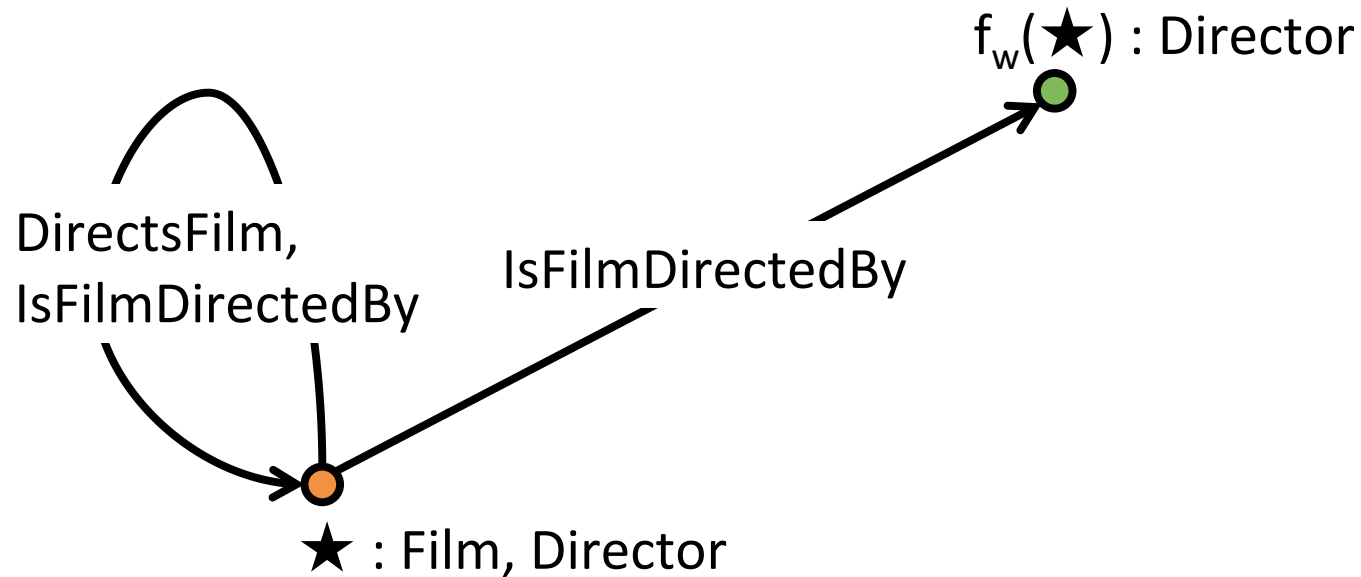


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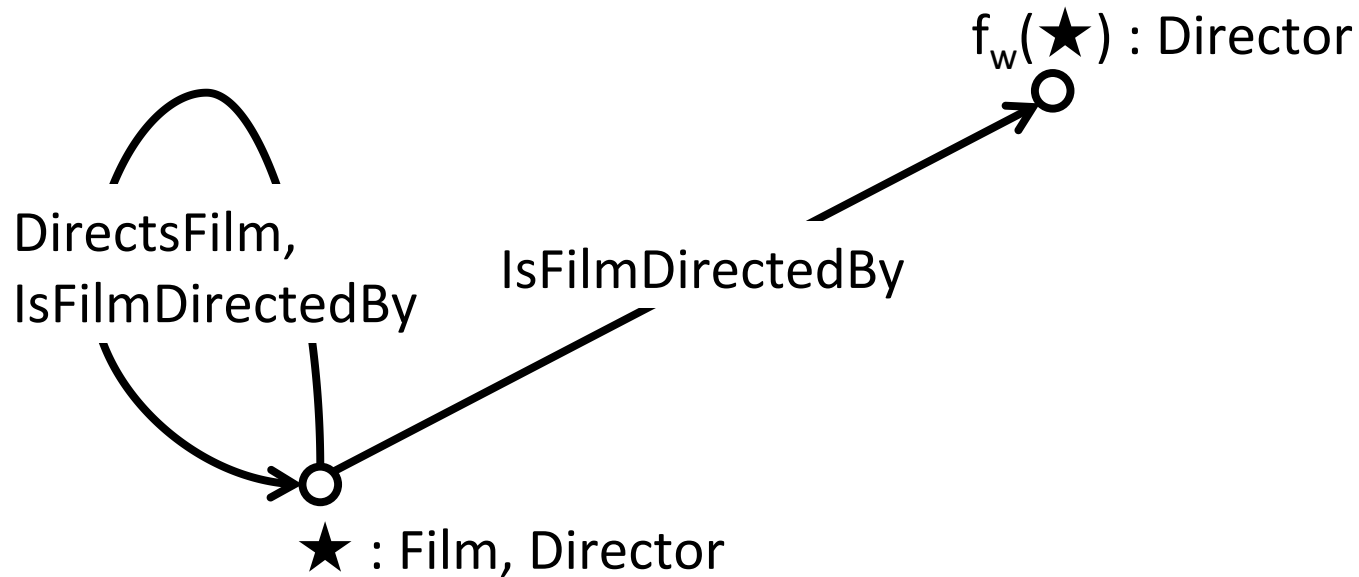
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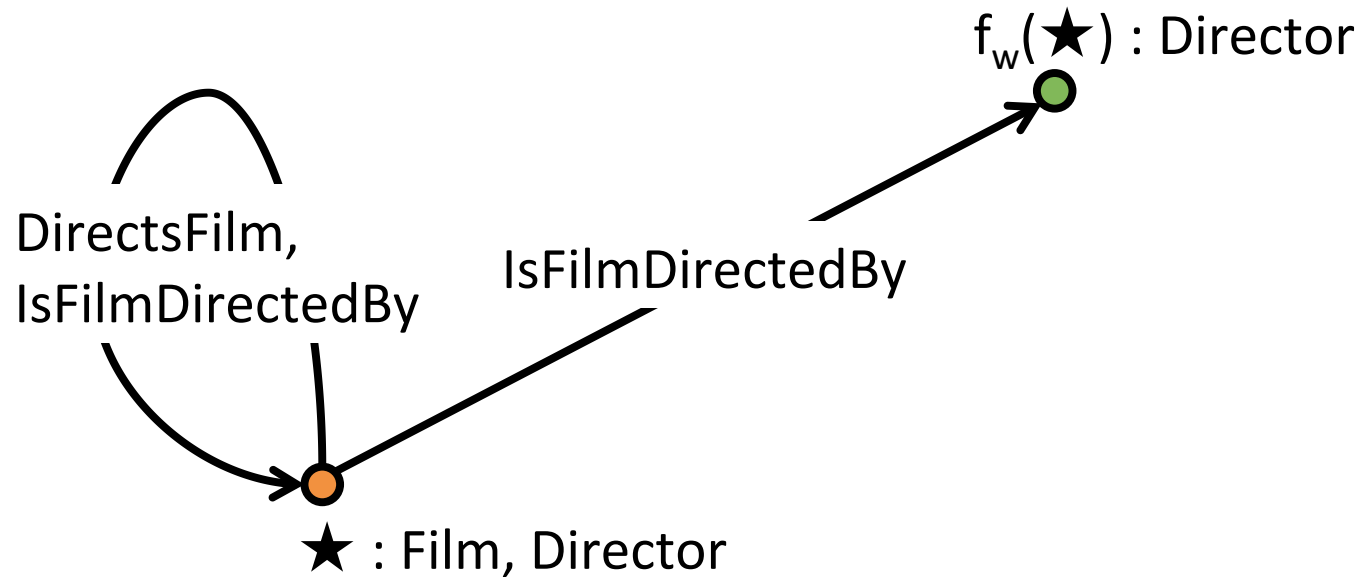


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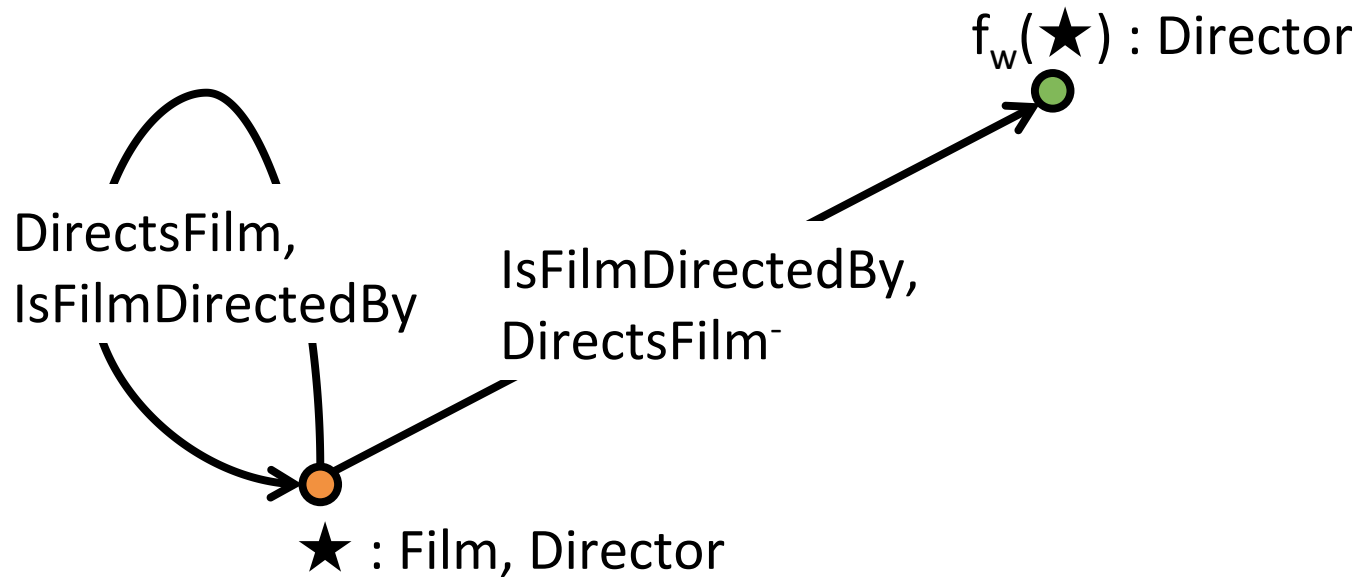


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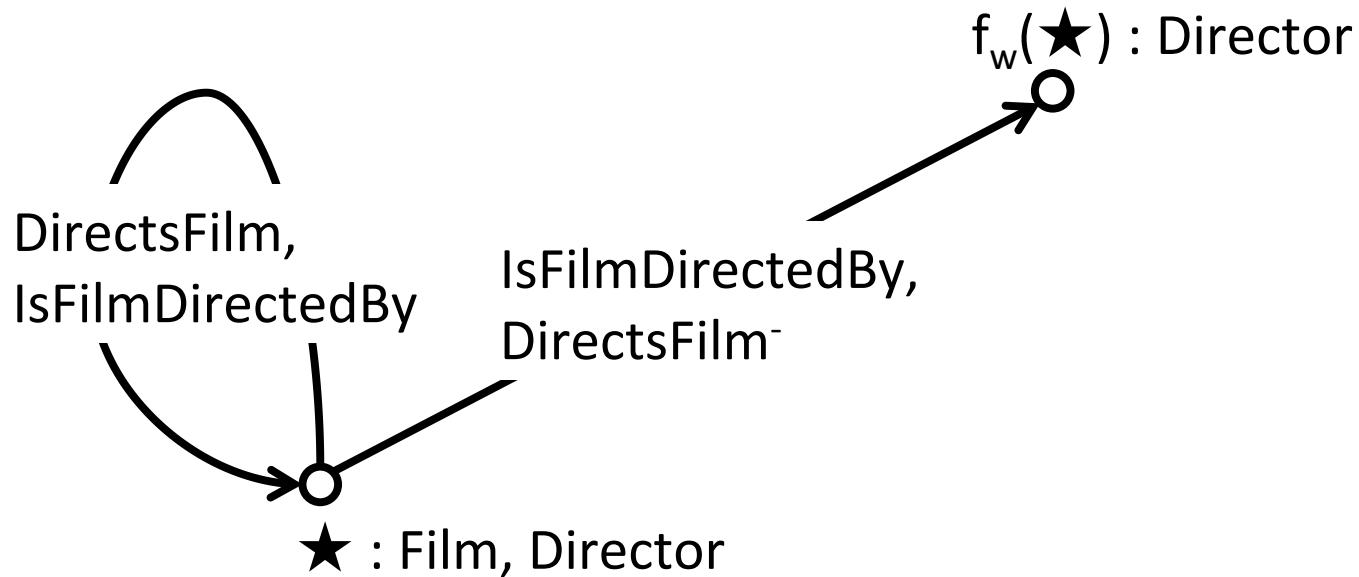
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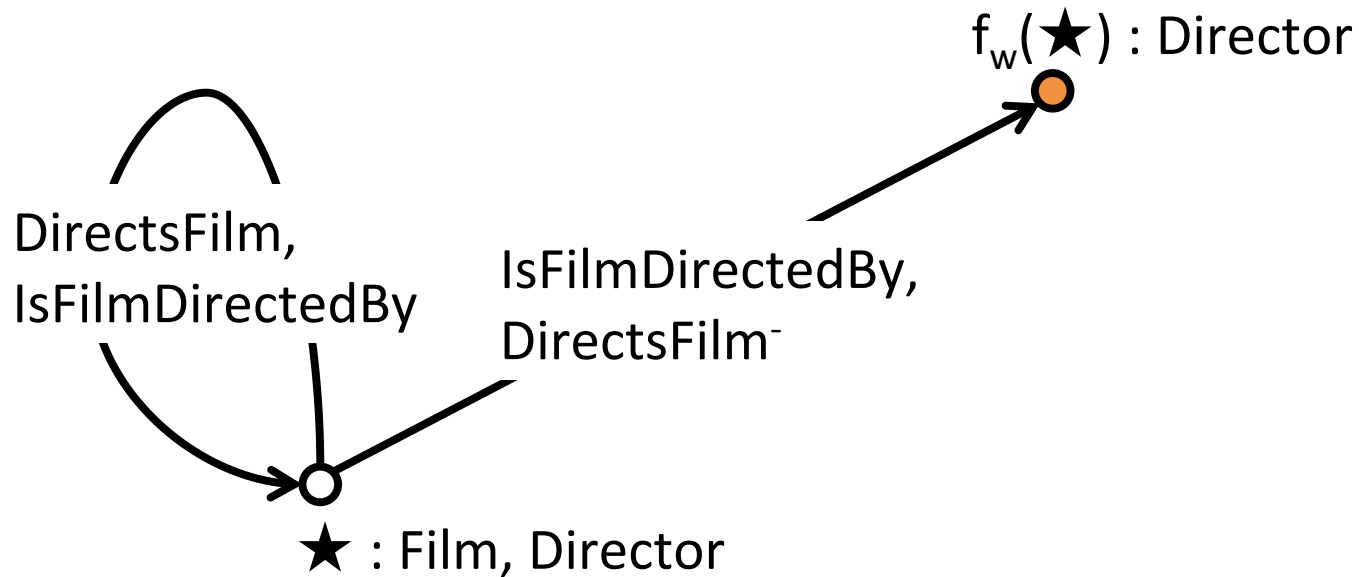
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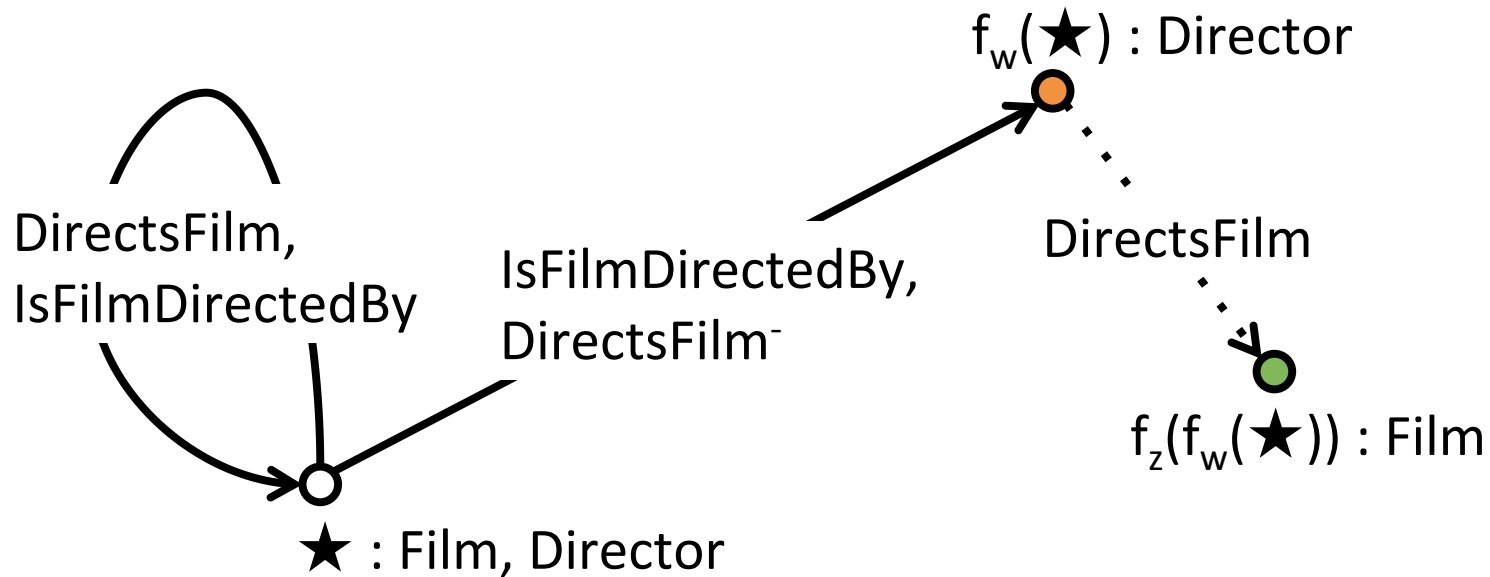
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$f_z(f_w(t))$

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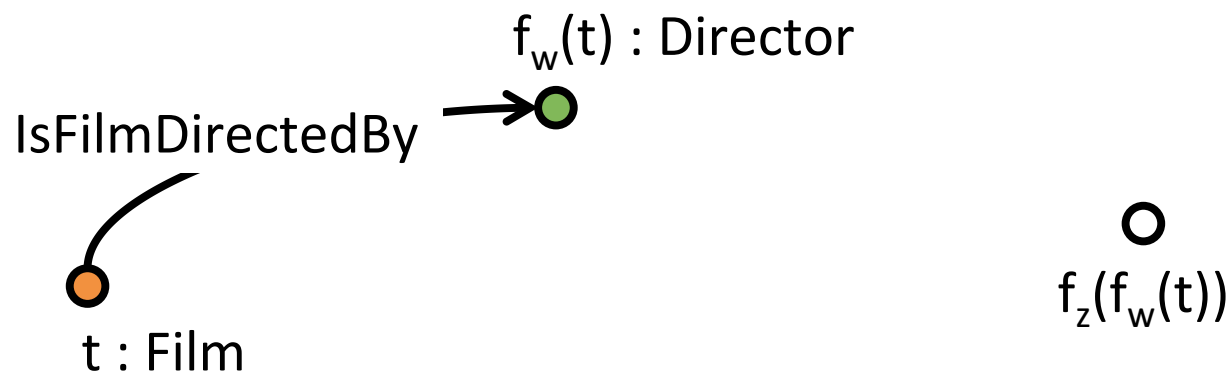
○  
 $f_z(f_w(t))$

$\text{Film}(x) \rightarrow \exists w . \text{IsFilmDirectedBy}(x, w) \wedge \text{Director}(w)$

$\text{IsFilmDirectedBy}(x, y) \rightarrow \text{DirectsFilm}(y, x)$

$\text{Director}(x) \rightarrow \exists z . \text{DirectsFilm}(x, z) \wedge \text{Film}(z)$

$\text{DirectsFilm}(x, y) \rightarrow \text{IsFilmDirectedBy}(y, x)$



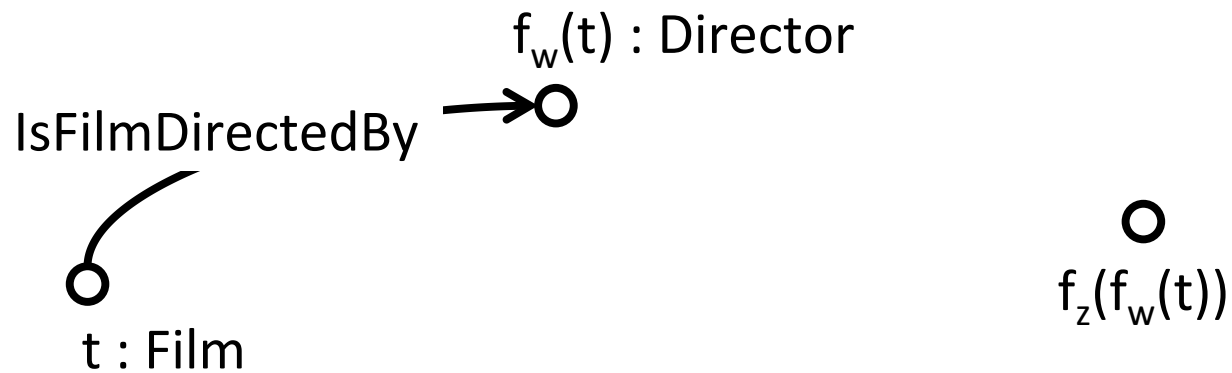


$\text{Film}(x) \rightarrow \exists w . \text{IsFilmDirectedBy}(x, w) \wedge \text{Director}(w)$

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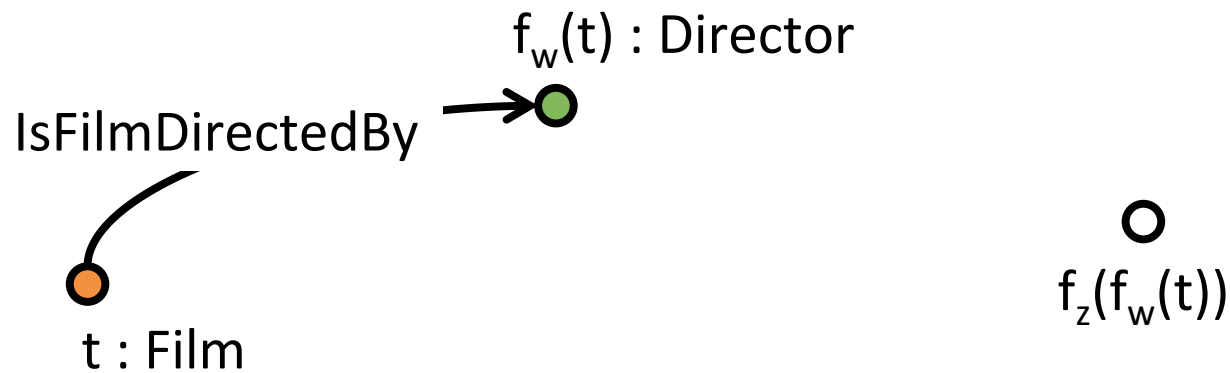


$\text{Film}(x) \rightarrow \exists w . \text{IsFilmDirectedBy}(x, w) \wedge \text{Director}(w)$

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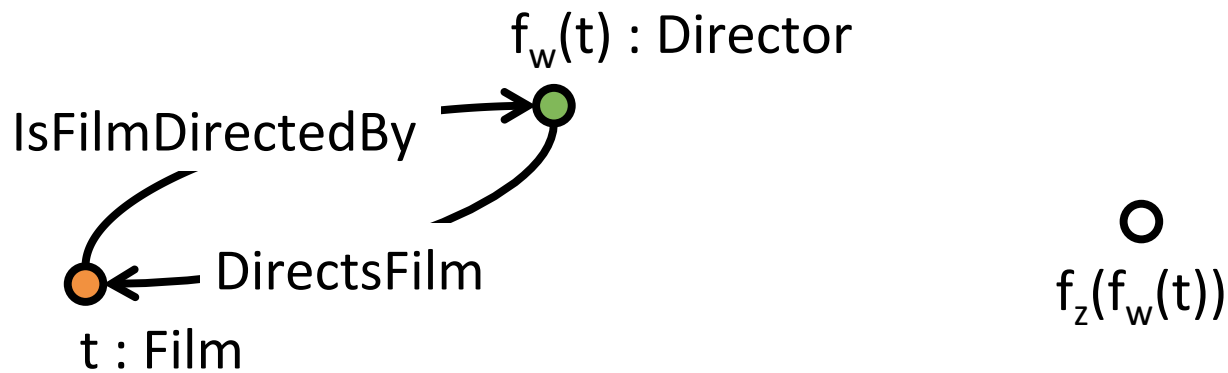


$\text{Film}(x) \rightarrow \exists w . \text{IsFilmDirectedBy}(x, w) \wedge \text{Director}(w)$

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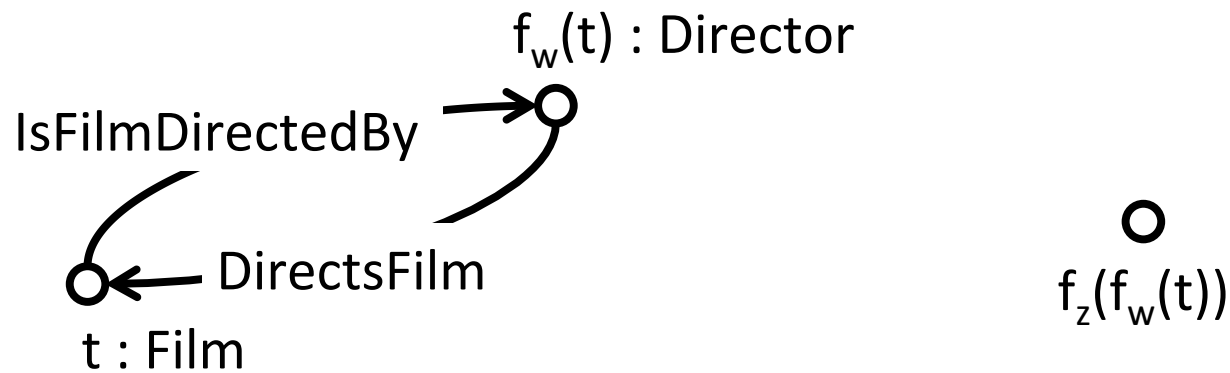


$\text{Film}(x) \rightarrow \exists w . \text{IsFilmDirectedBy}(x, w) \wedge \text{Director}(w)$

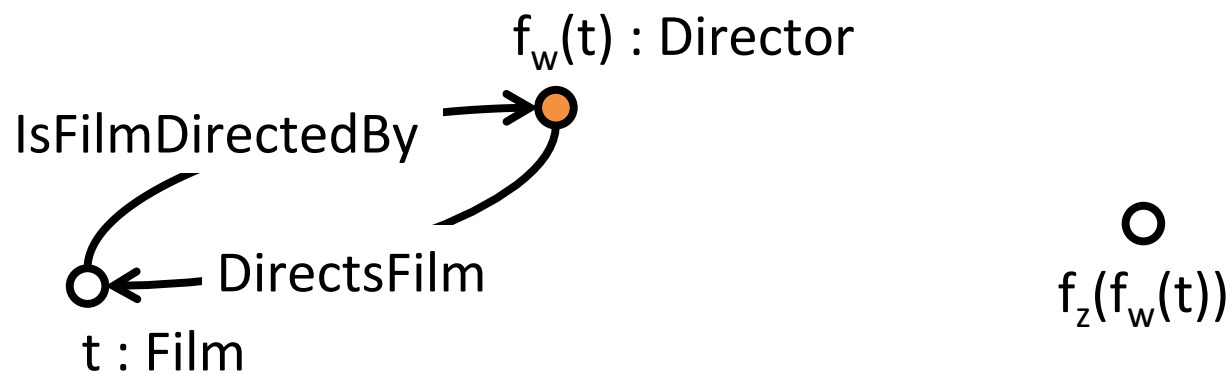
$\text{IsFilmDirectedBy}(x, y) \rightarrow \text{DirectsFilm}(y, x)$

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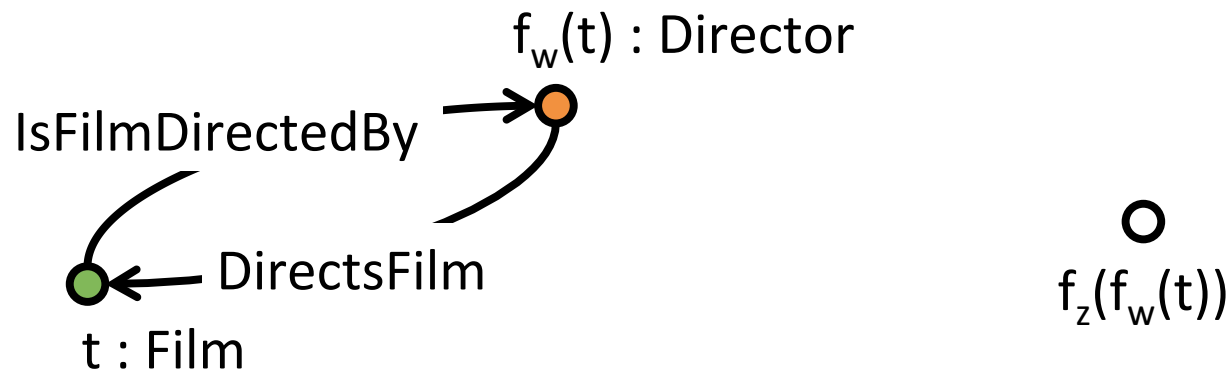


$\text{Film}(x) \rightarrow \exists w . \text{IsFilmDirectedBy}(x, w) \wedge \text{Director}(w)$

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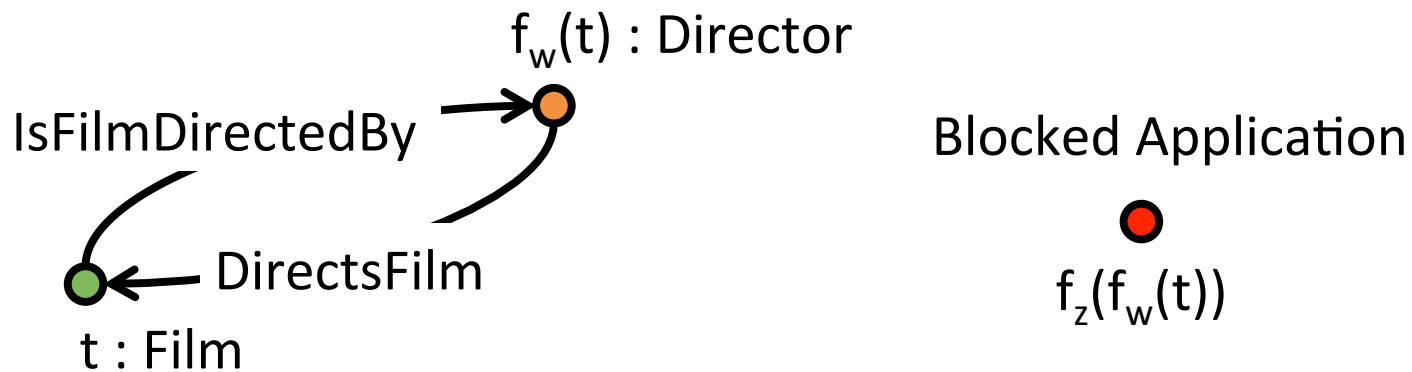


$\text{Film}(x) \rightarrow \exists w . \text{IsFilmDirectedBy}(x, w) \wedge \text{Director}(w)$

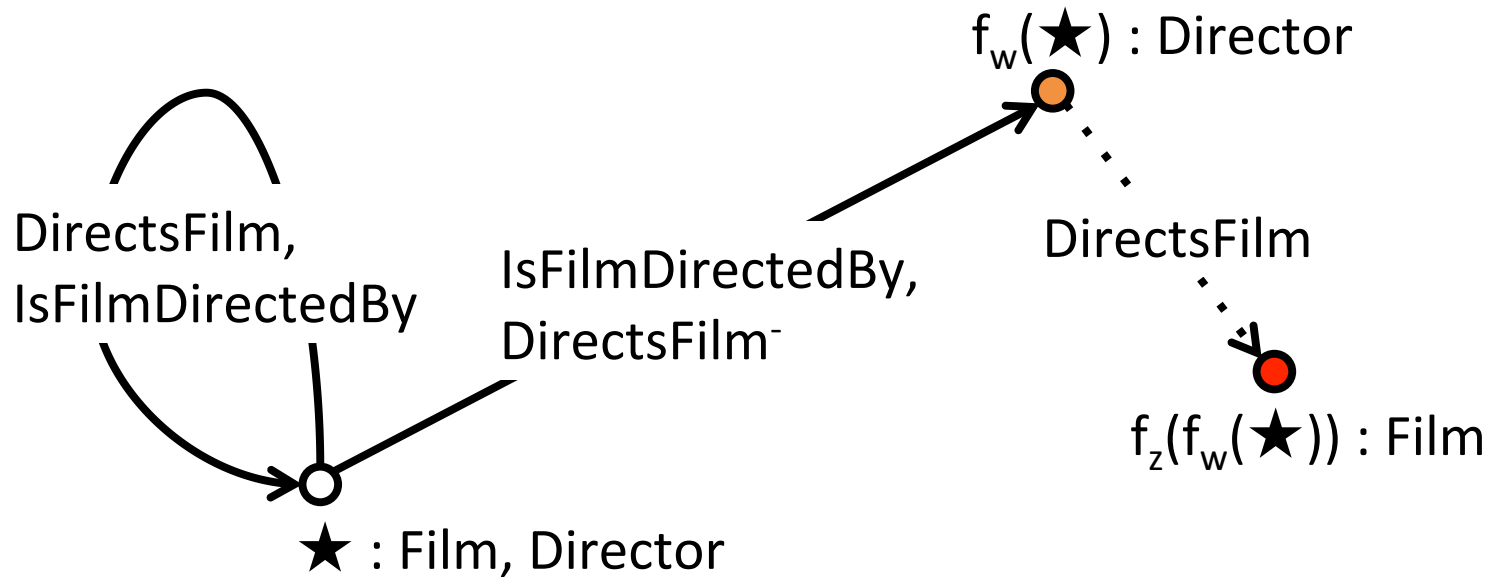
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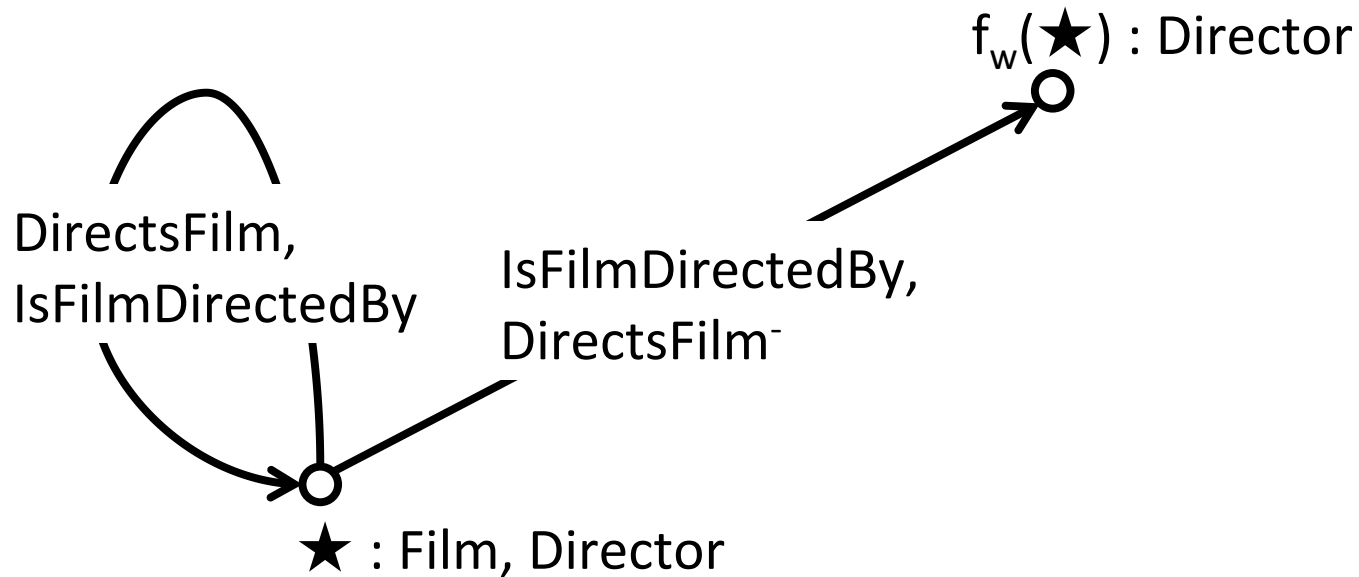


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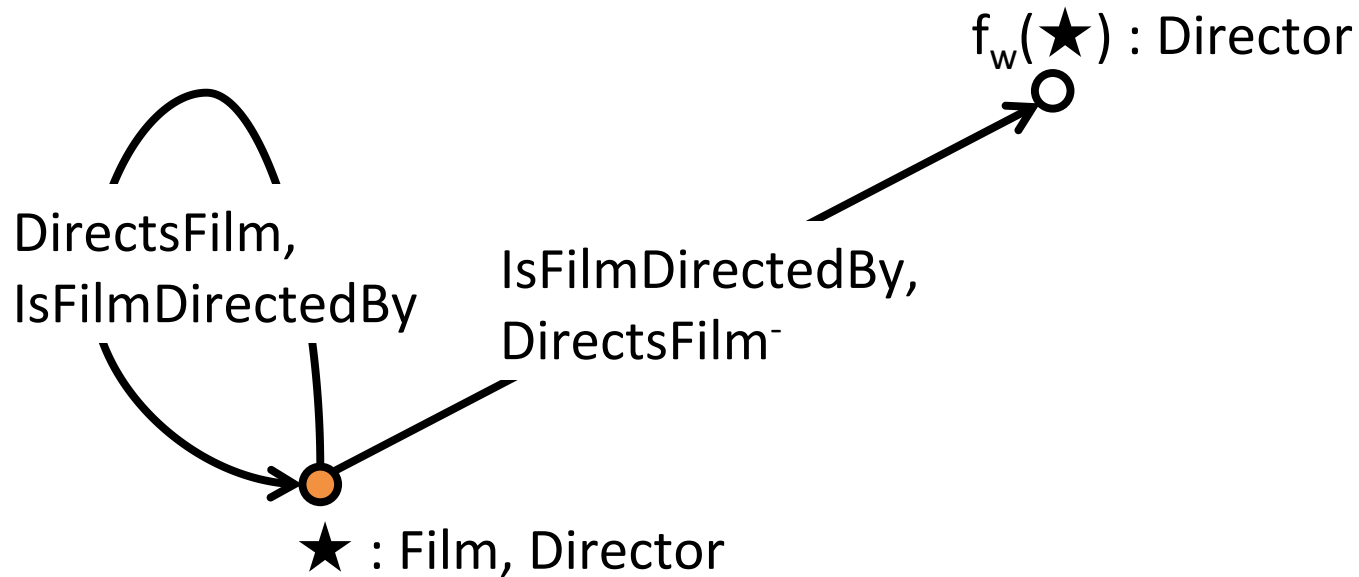




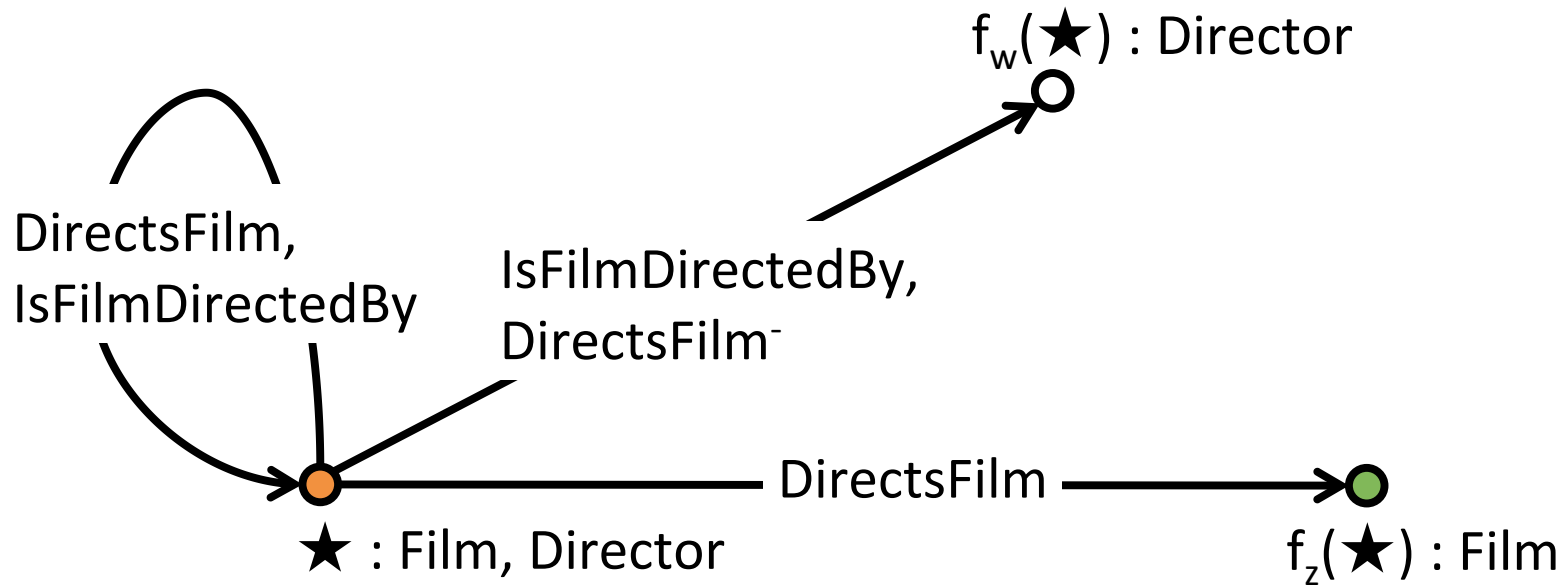
$\text{Film}(x) \rightarrow \exists w . \text{IsFilmDirectedBy}(x, w) \wedge \text{Director}(w)$   
 $\text{IsFilmDirectedBy}(x, y) \rightarrow \text{DirectsFilm}(y, x)$   
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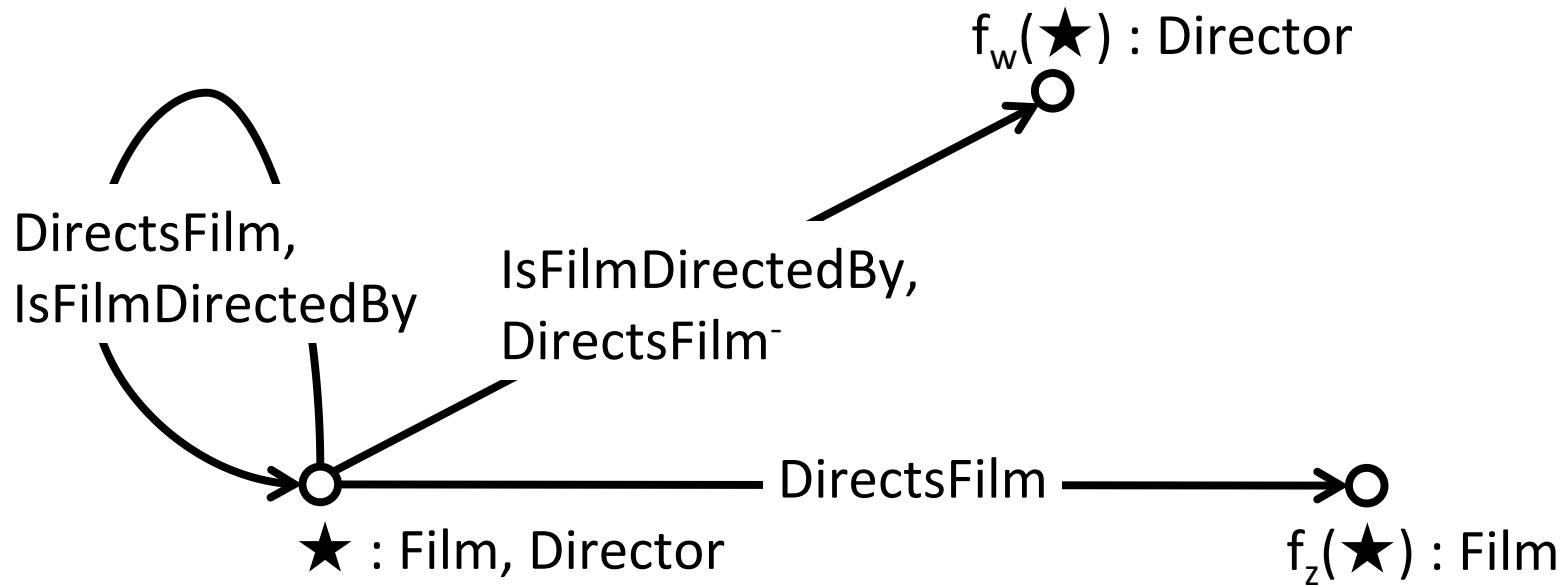


$\text{Film}(x) \rightarrow \exists w . \text{IsFilmDirectedBy}(x, w) \wedge \text{Director}(w)$

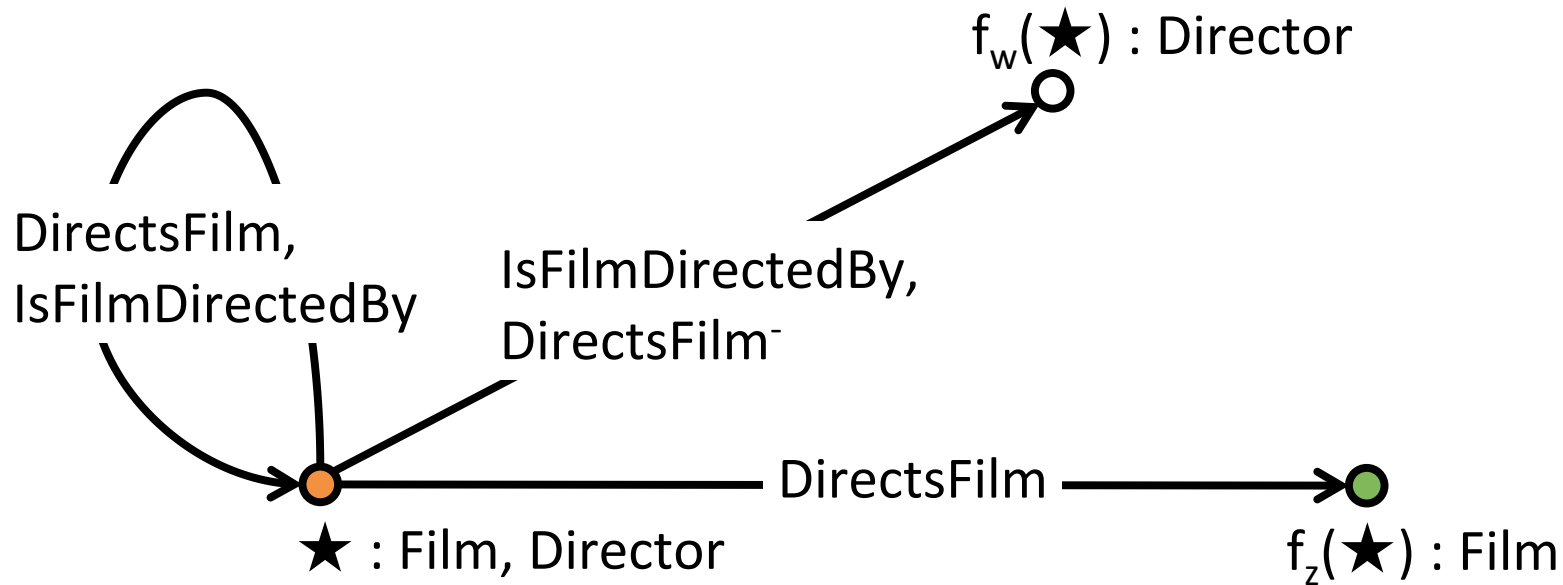
$\text{IsFilmDirectedBy}(x, y) \rightarrow \text{DirectsFilm}(y, x)$

$\text{Director}(x) \rightarrow \exists z . \text{DirectsFilm}(x, z) \wedge \text{Film}(z)$

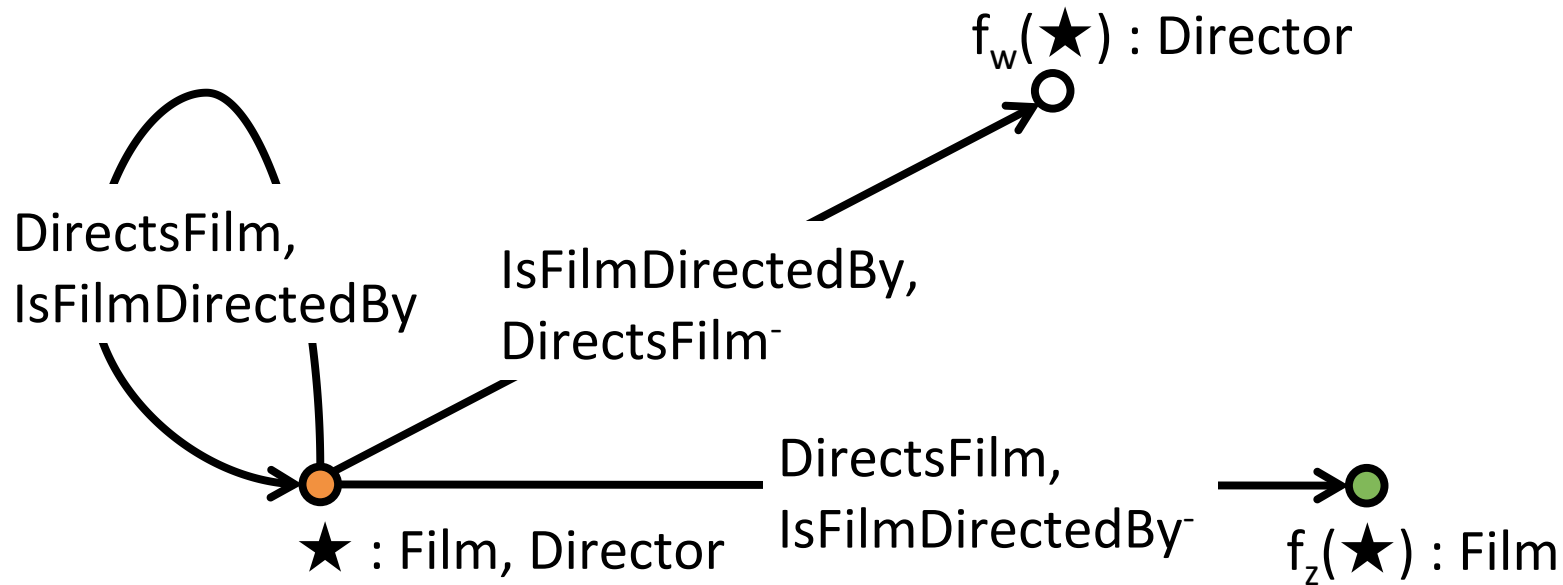
$\text{DirectsFilm}(x, y) \rightarrow \text{IsFilmDirectedBy}(y, x)$



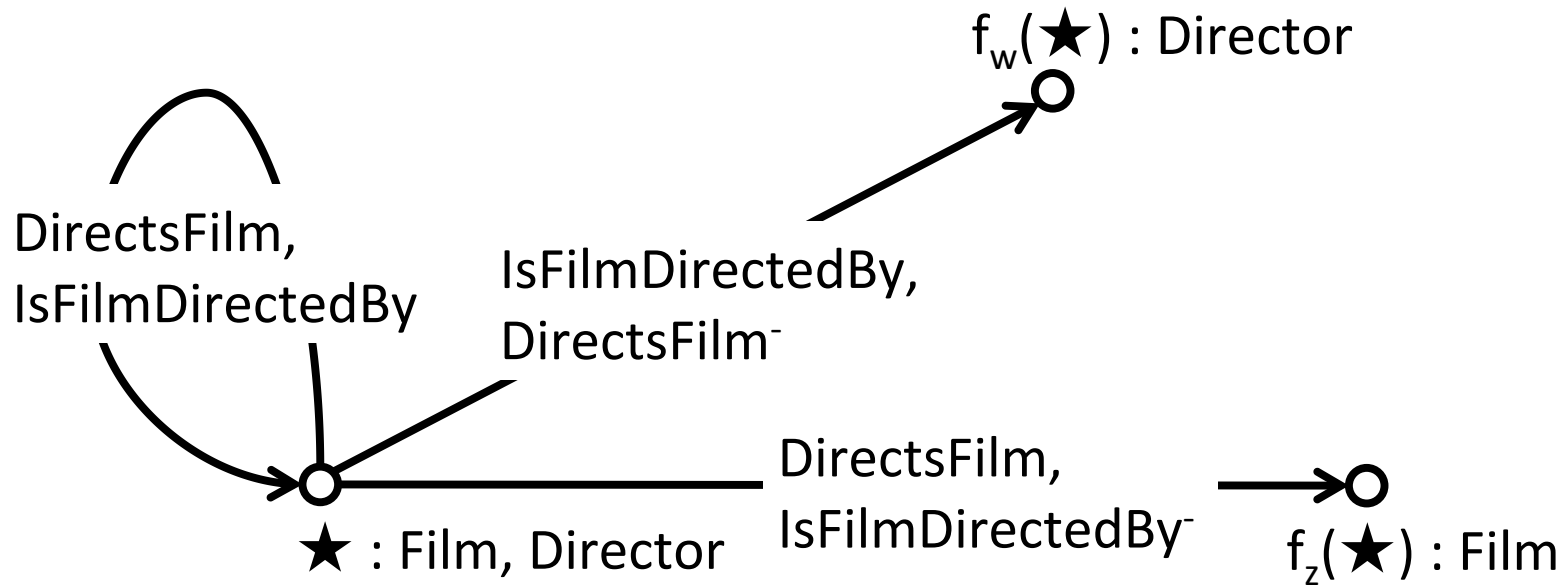
$\text{Film}(x) \rightarrow \exists w . \text{IsFilmDirectedBy}(x, w) \wedge \text{Director}(w)$   
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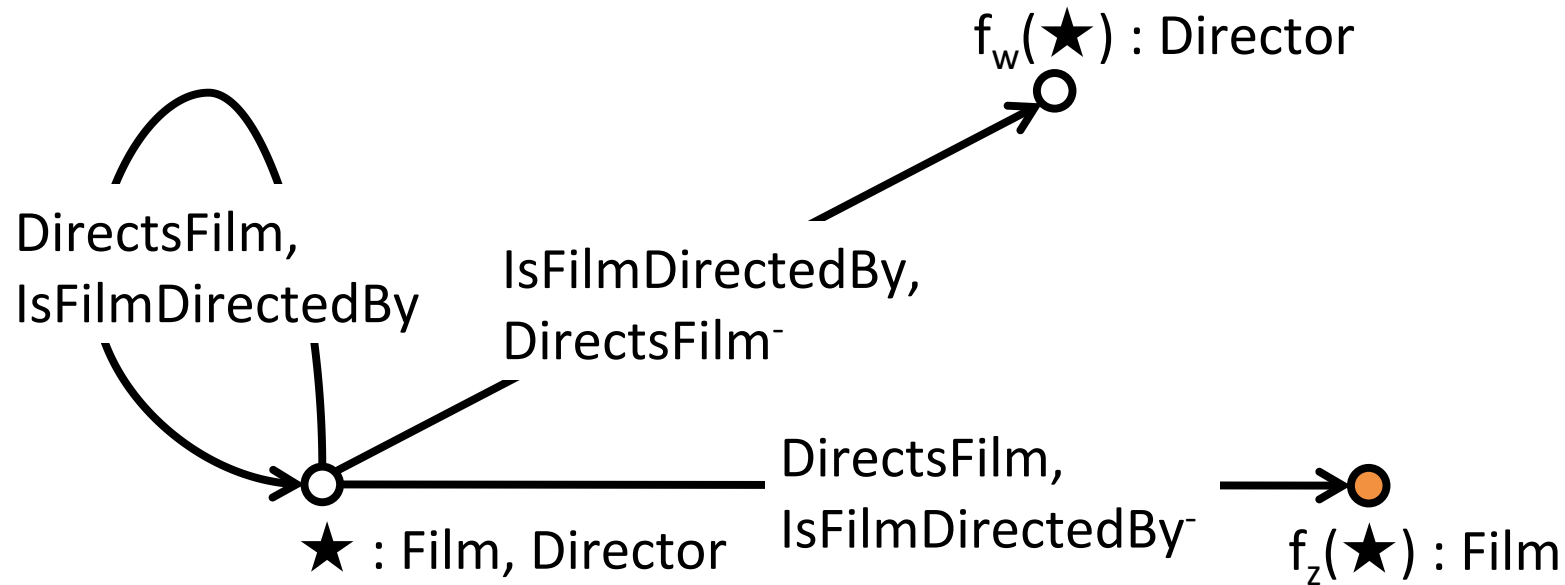


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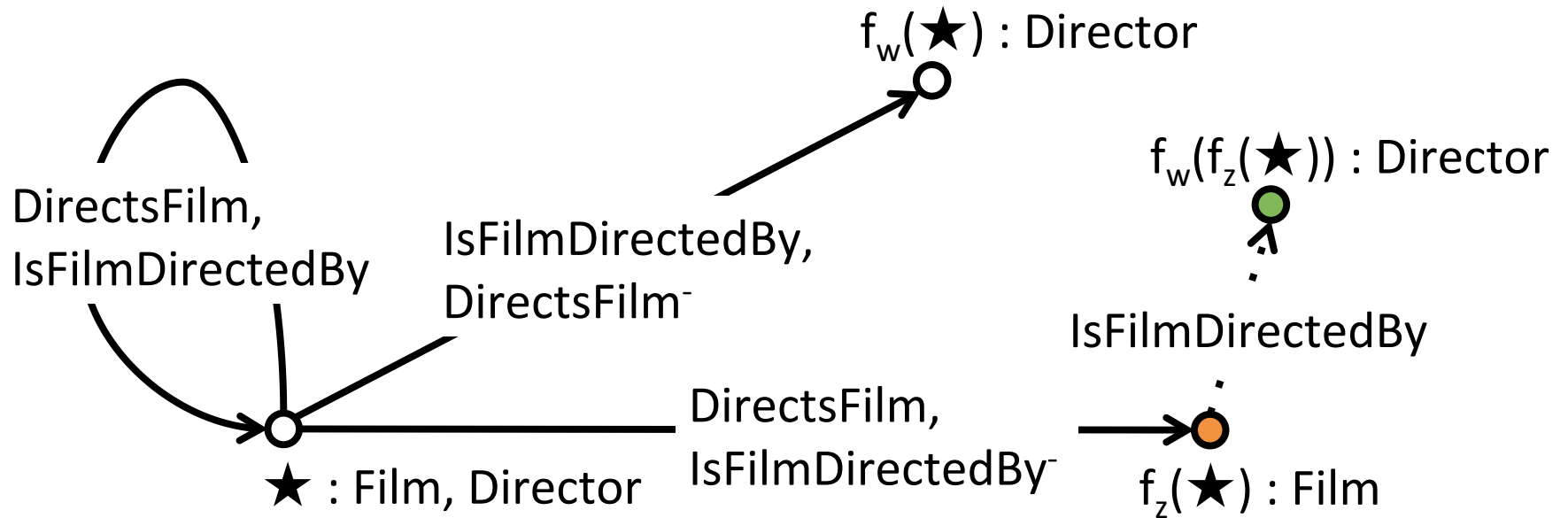
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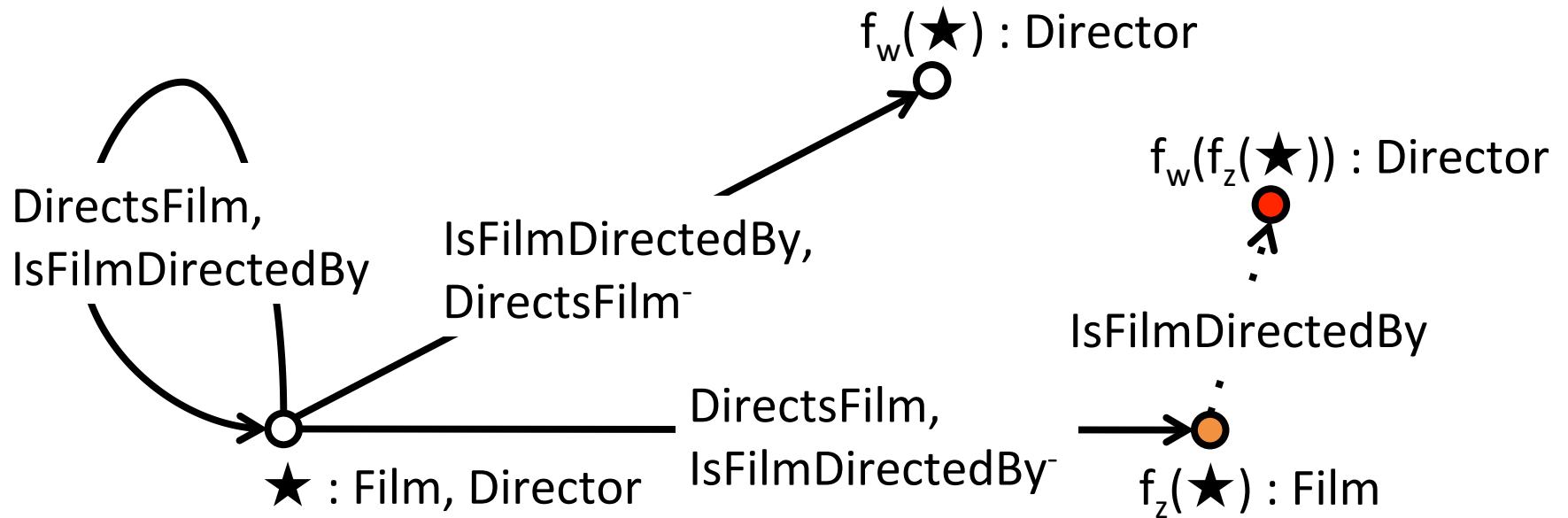




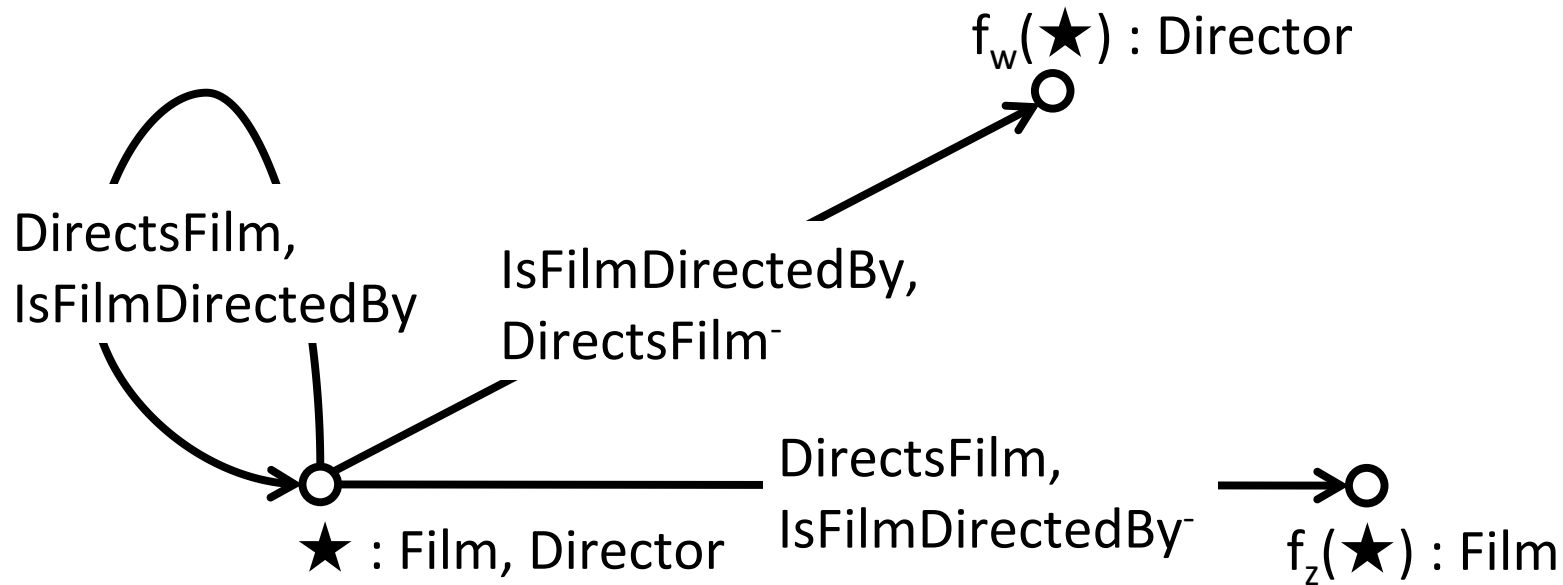
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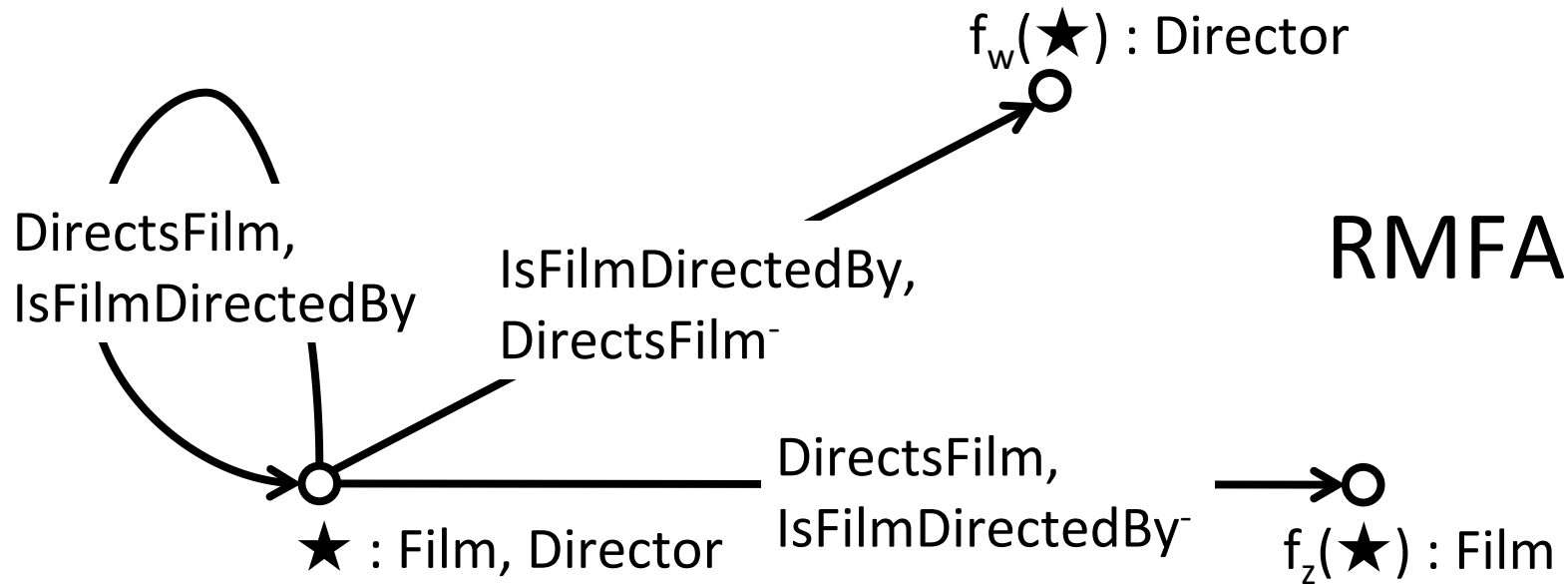
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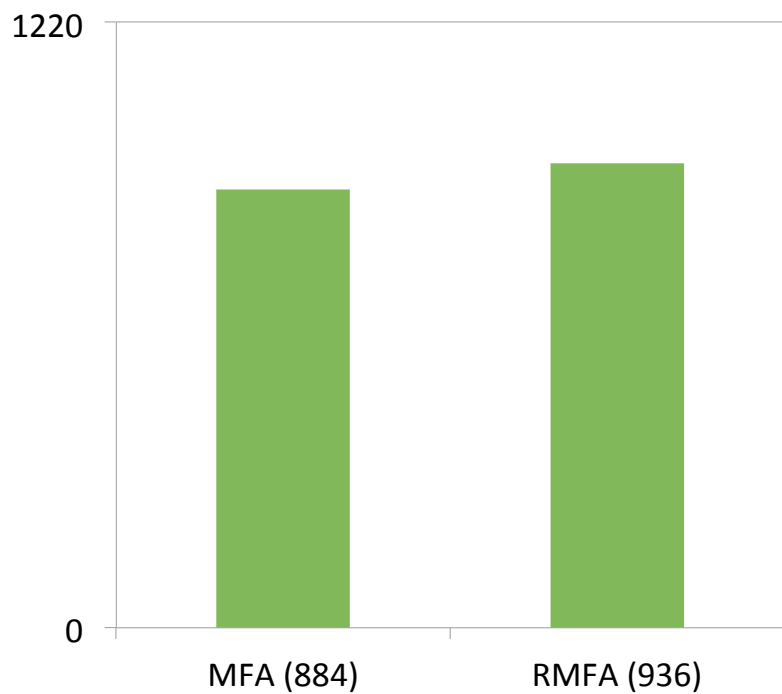


## Membership Check

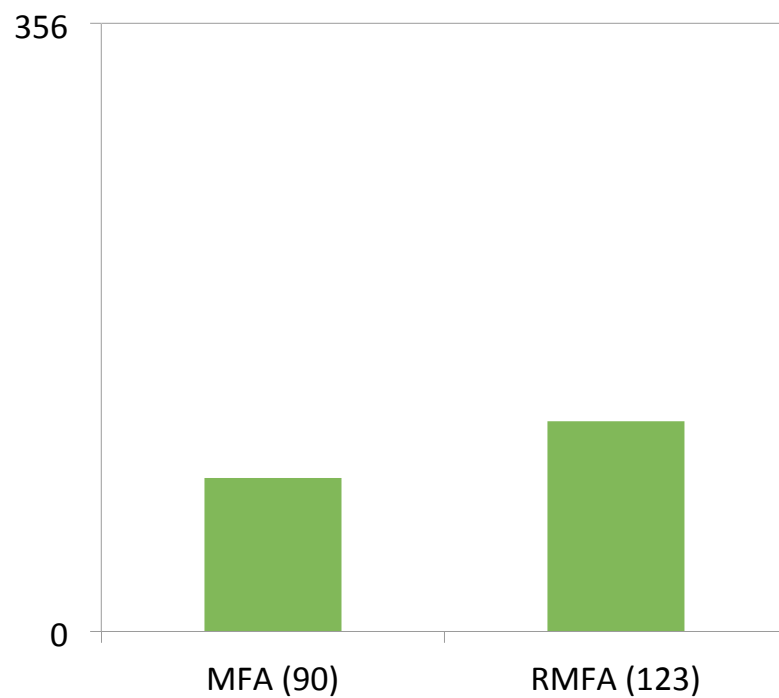
	RJA	RMSA	RMFA
No restrictions	ExpTime	ExpTime	2ExpTime
Variables per rule bounded	P	P	2ExpTime
<1 Frontier Variable per rule	ExpTime	ExpTime	ExpTime

BCQ entailment: co-N2ExpTime

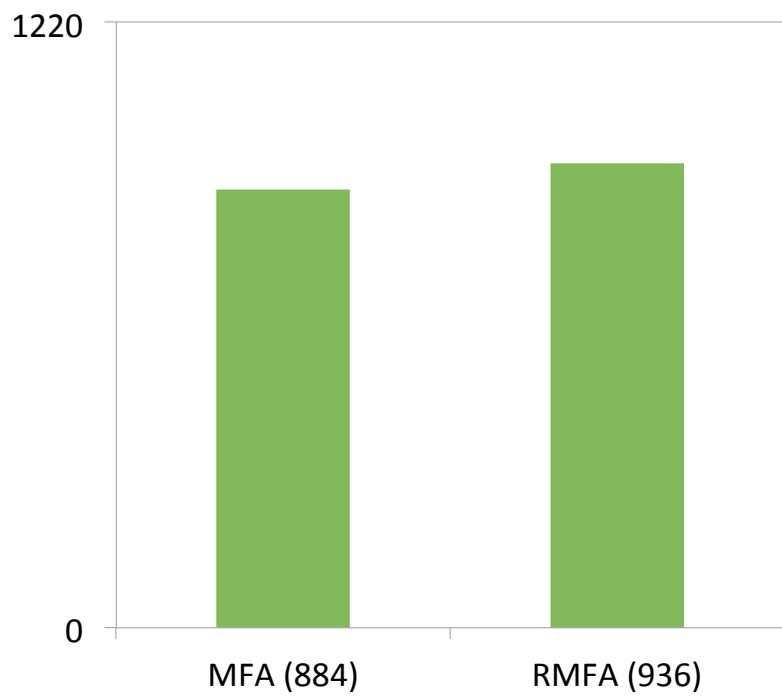
### Deterministic



### Non-Deterministic

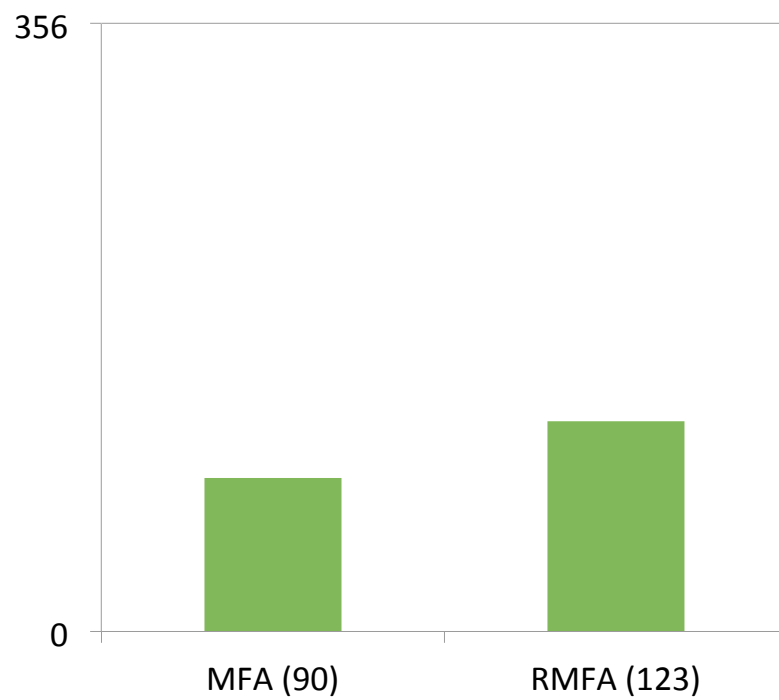


### Deterministic



+6%

### Non-Deterministic

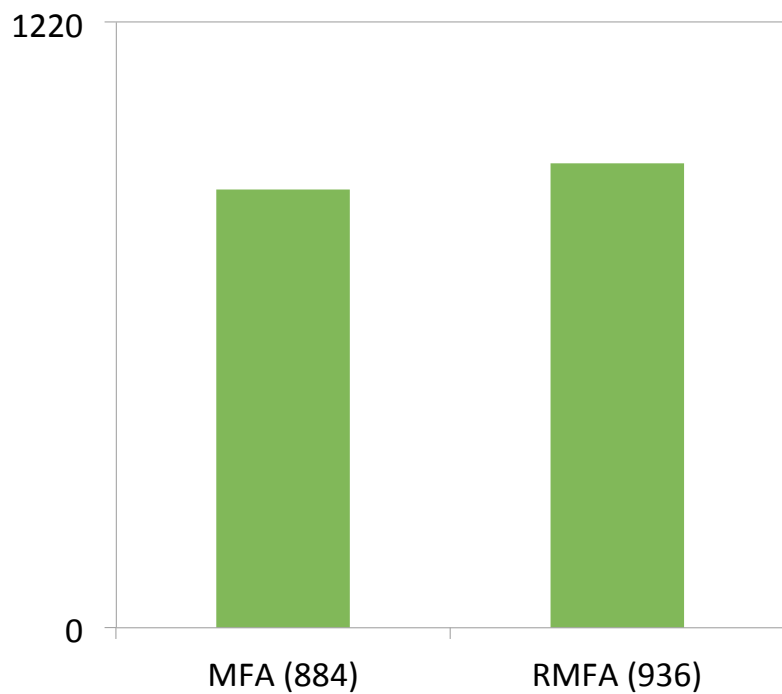


+37%

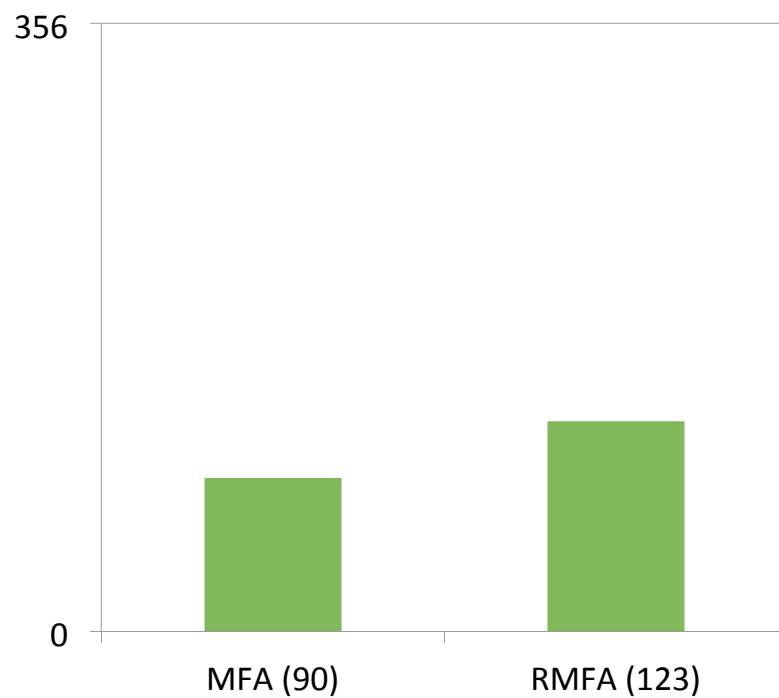
- Model Faithful Cyclicity (MFC)
- Restricted Model Faithful Cyclicity (RMFC)



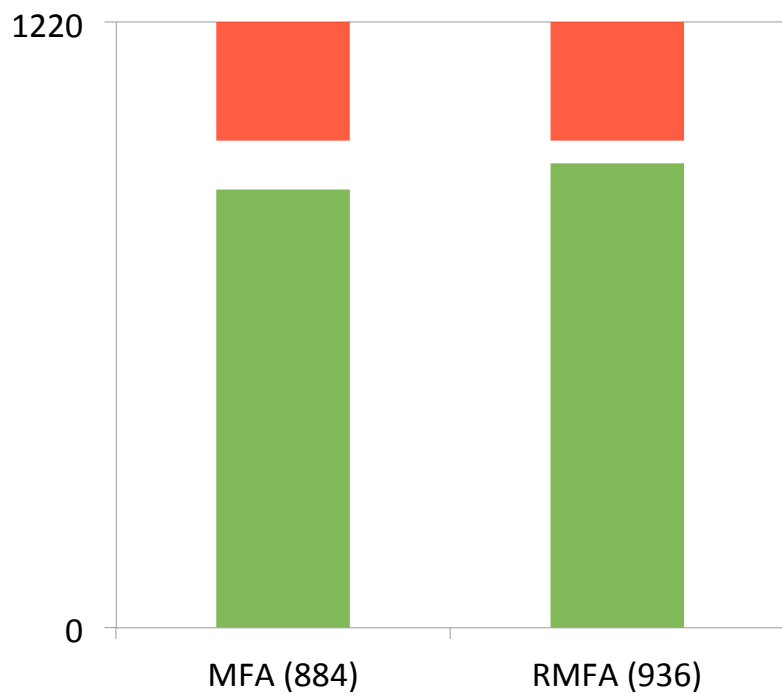
### Deterministic



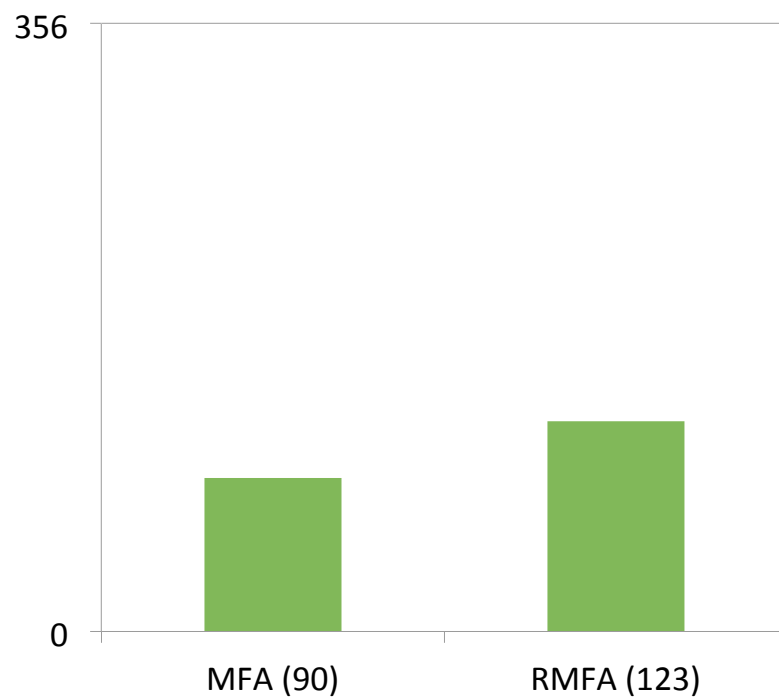
### Non-Deterministic



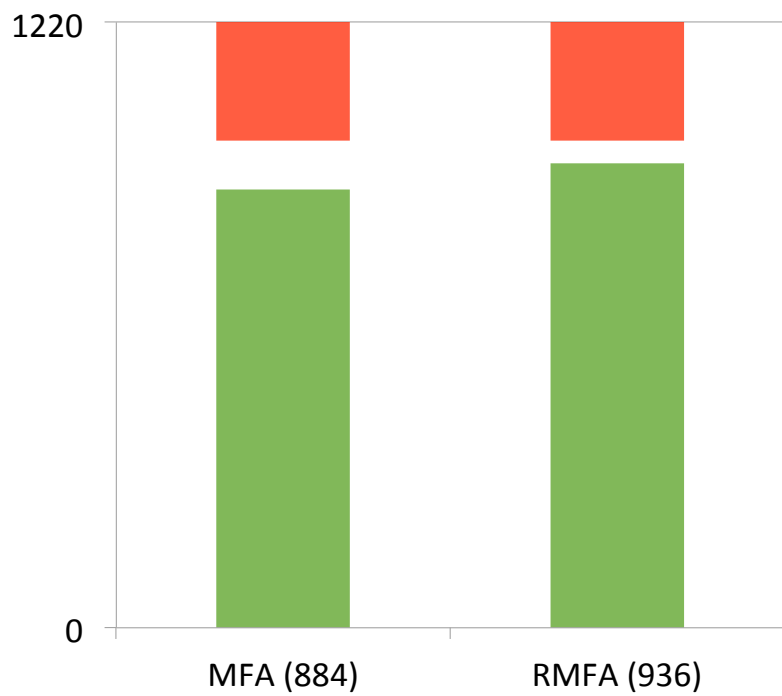
### Deterministic



### Non-Deterministic

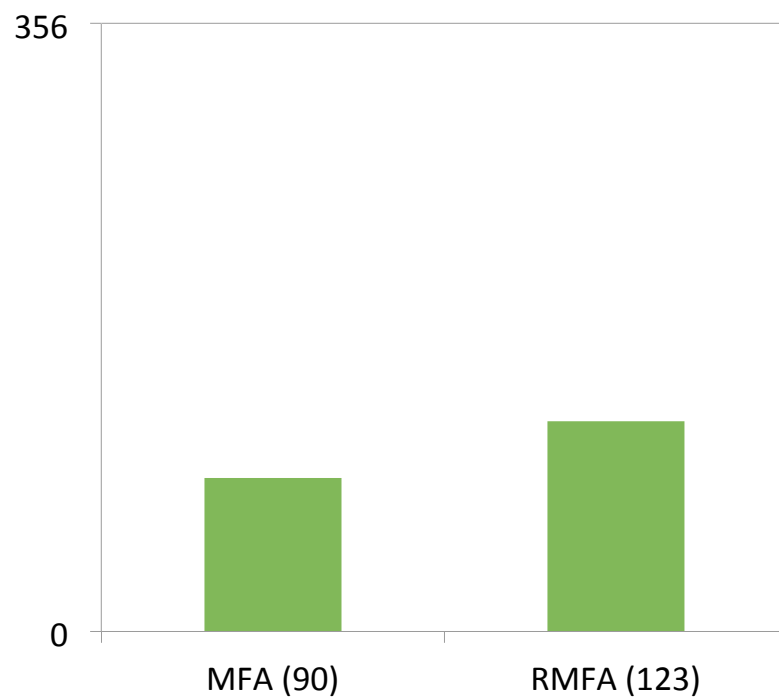


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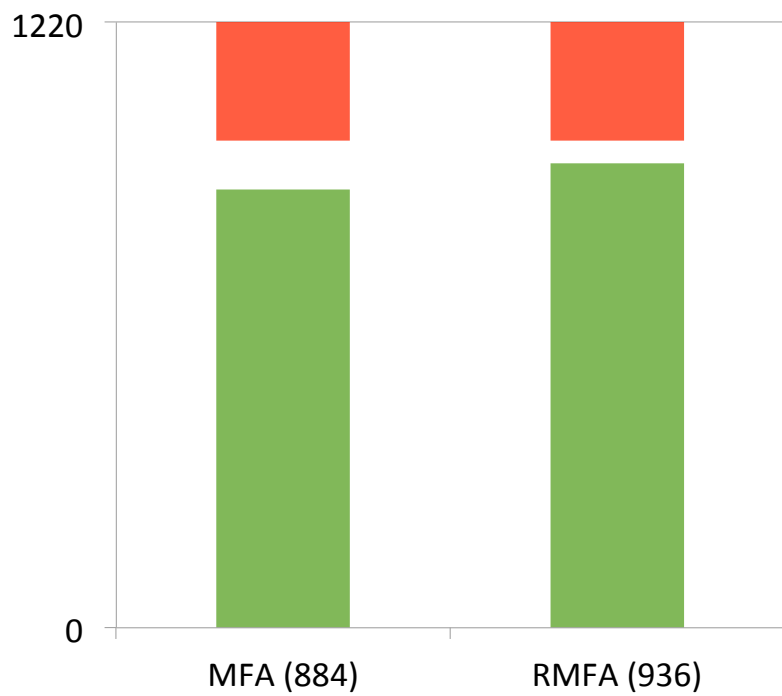


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### Non-Deterministic

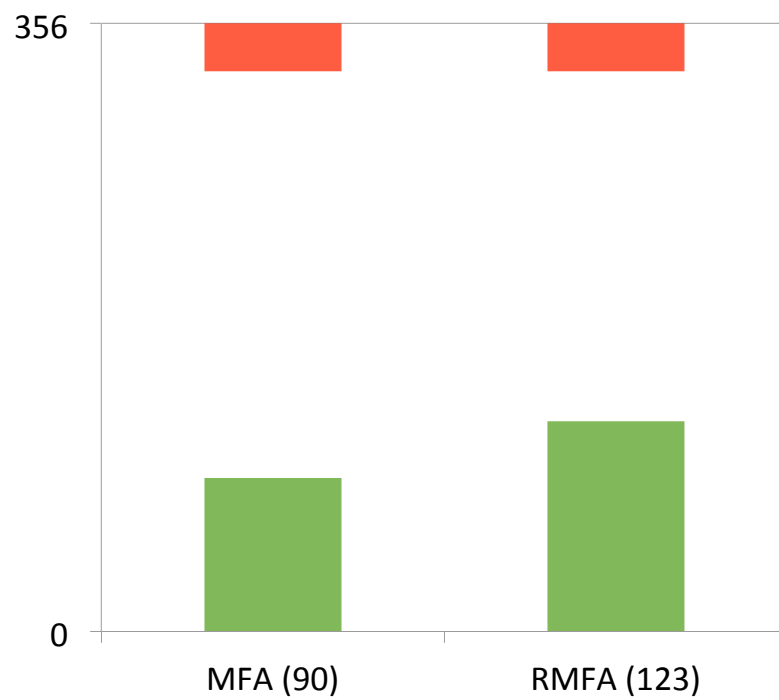


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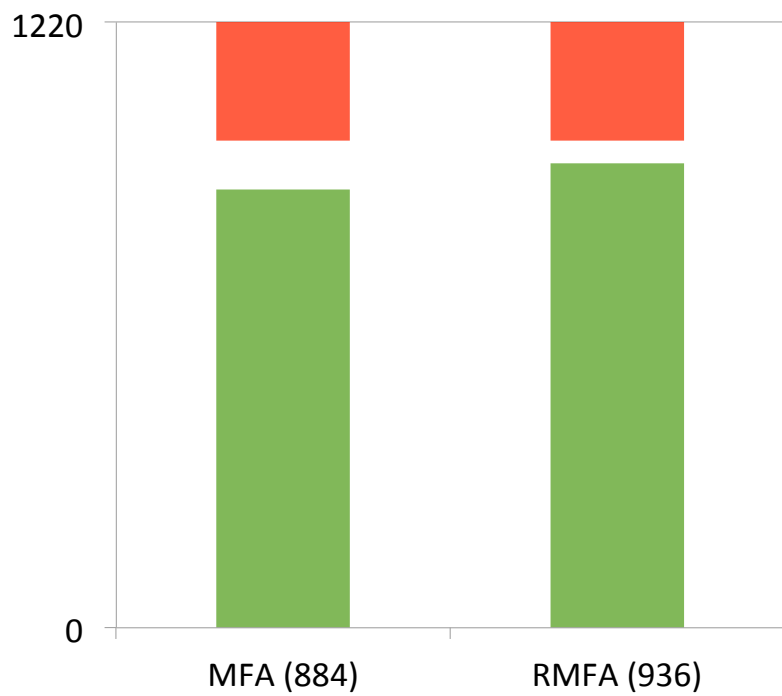


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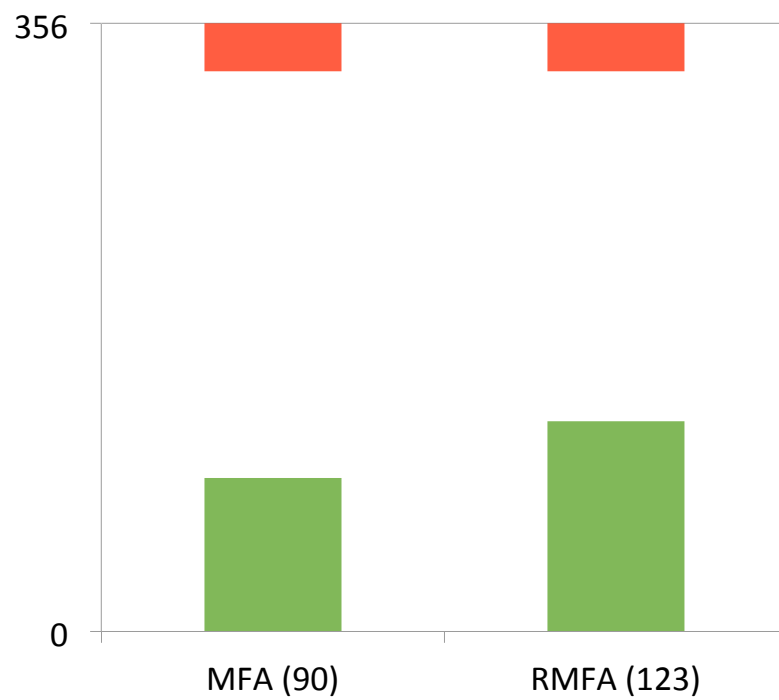


### Deterministic

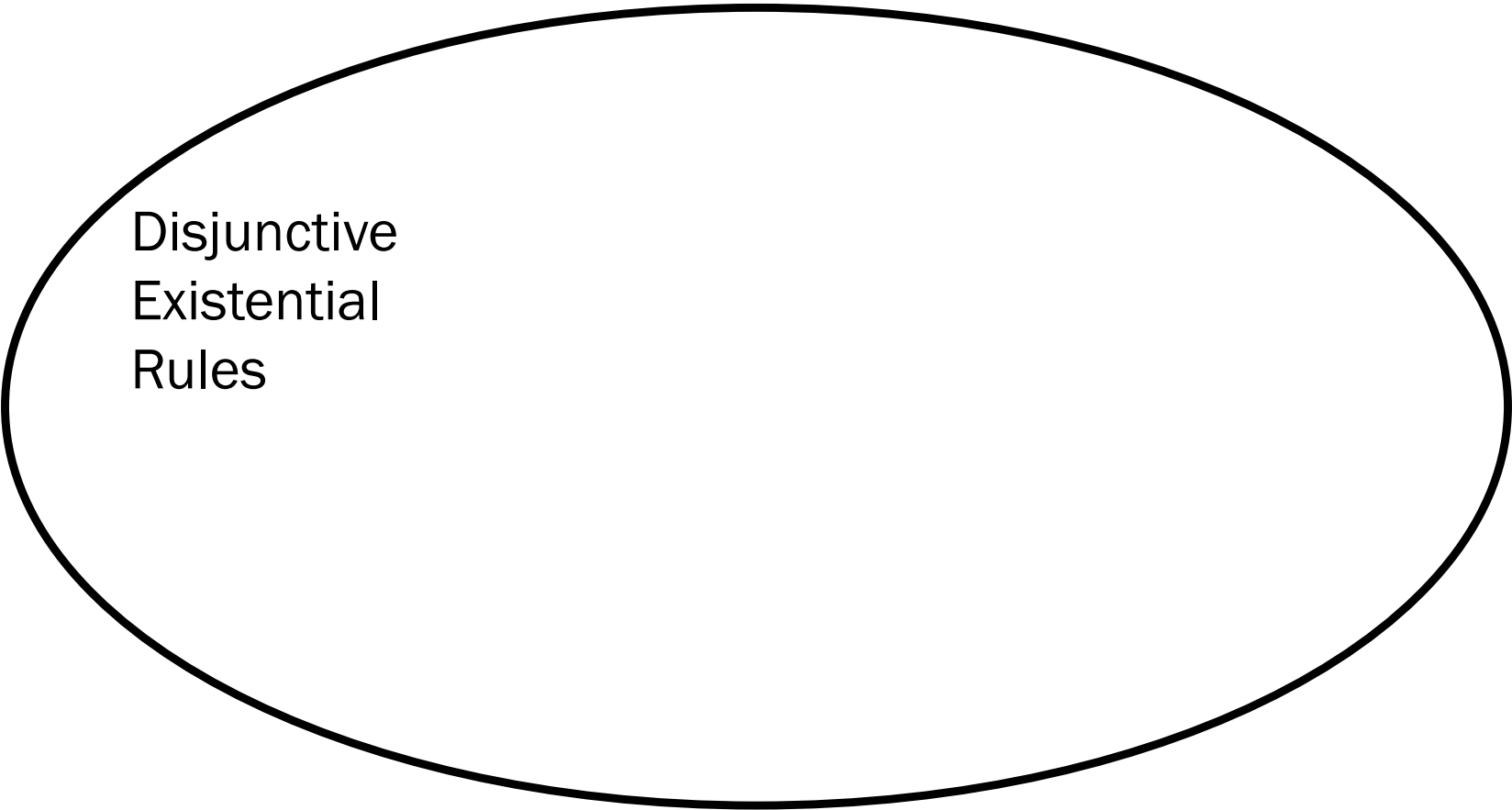


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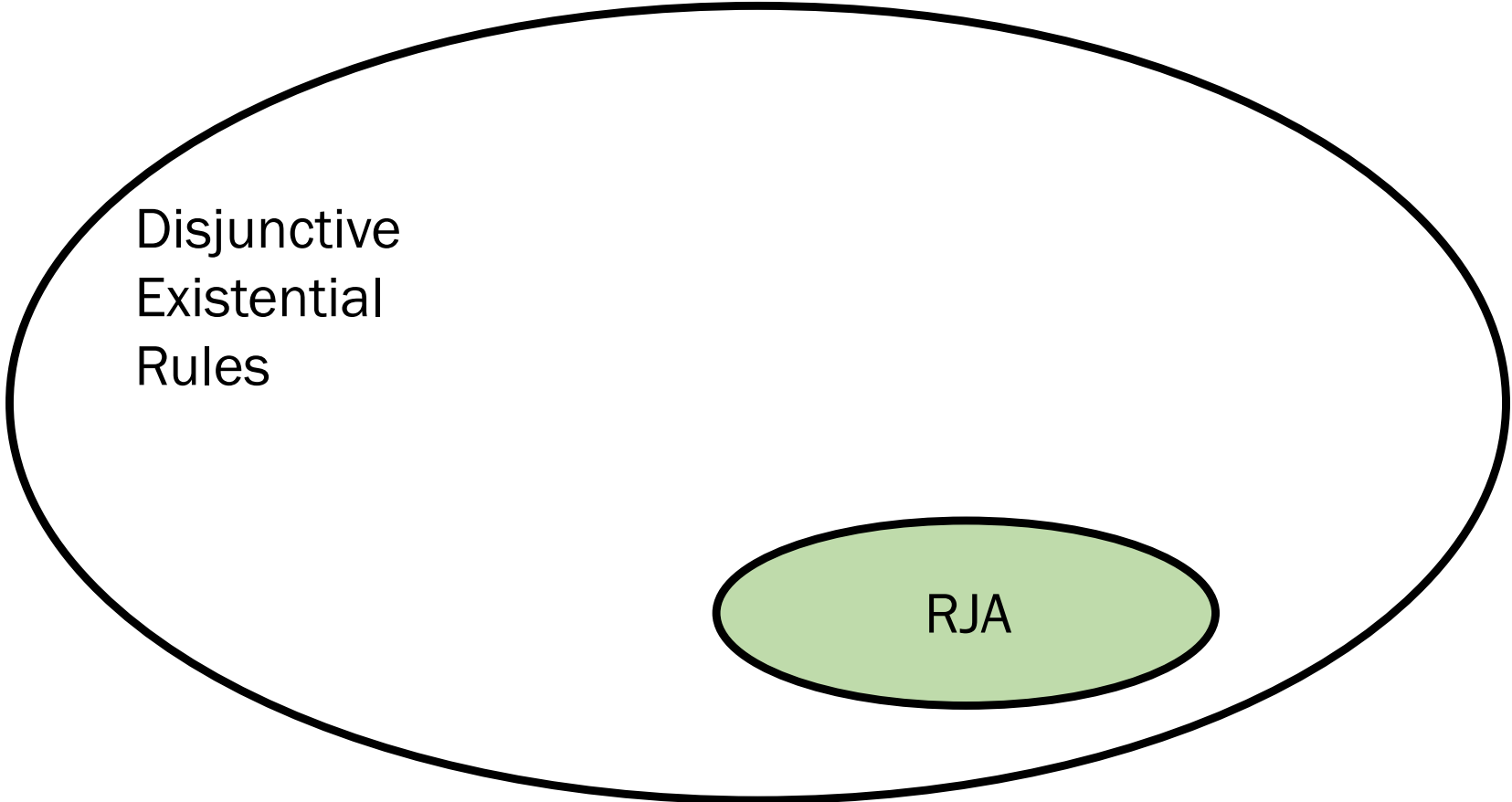
### Non-Deterministic

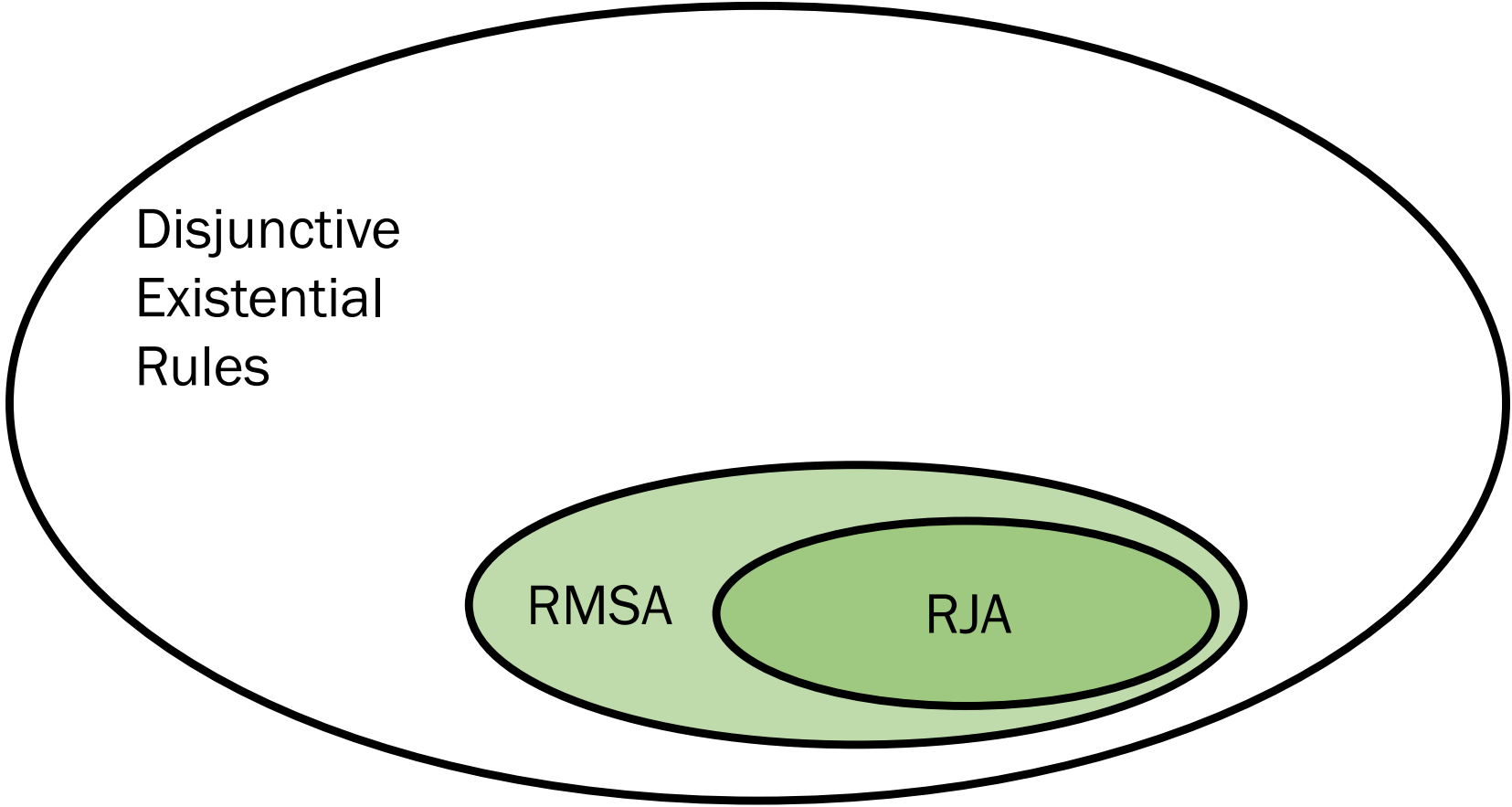


-14%



Disjunctive  
Existential  
Rules



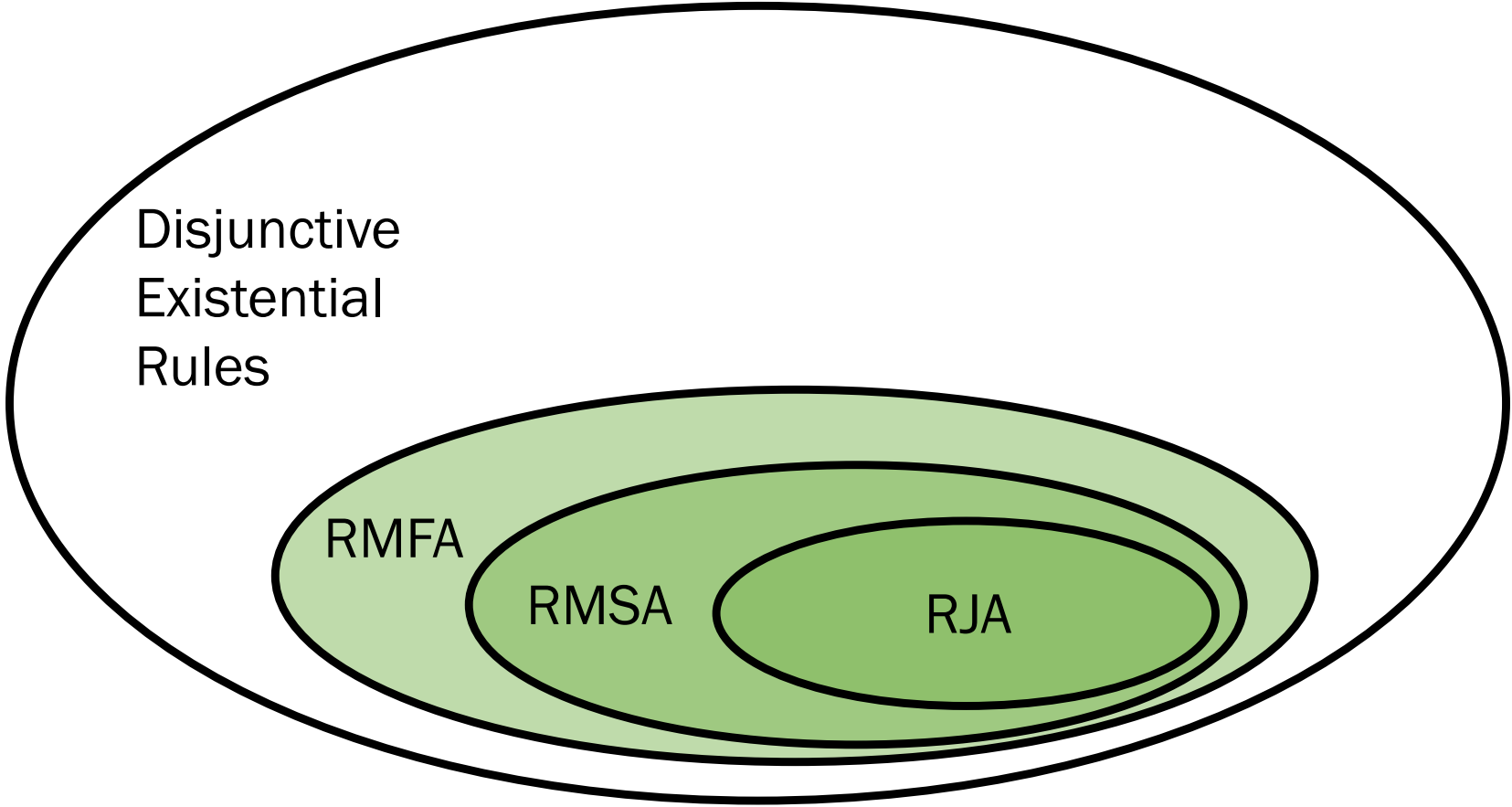


Disjunctive  
Existential  
Rules

RMSA

RJA



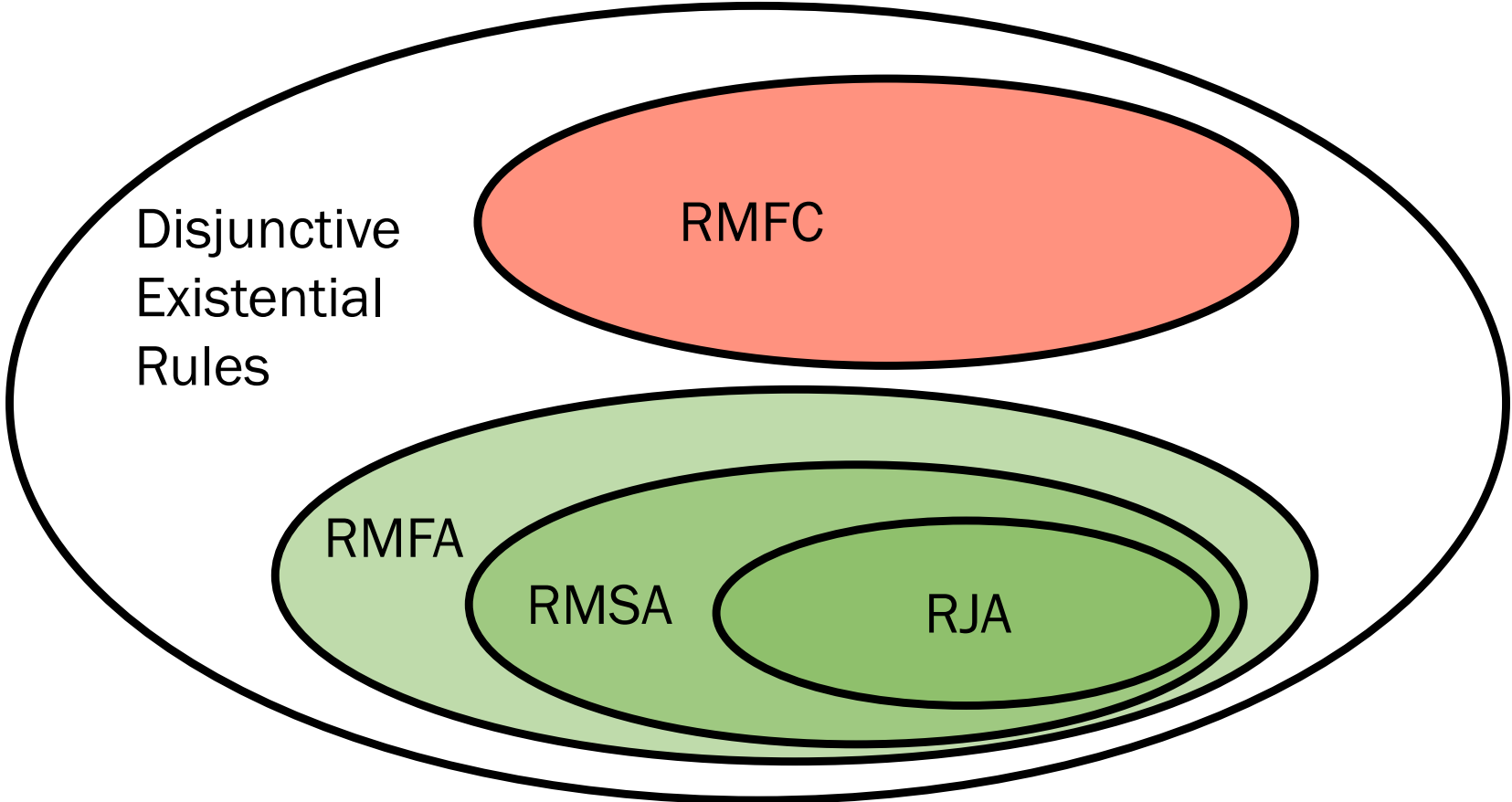


Disjunctive  
Existential  
Rules

RMFA

RMSA

RJA



Disjunctive  
Existential  
Rules

RMFC

RMFA

RMSA

RJA

# JOIN US IN DRESDEN

- Open position from fall 2017
- Ph.D. students & postdocs
- 100% English & International
- KR / Databases / AI

**CONTACT**

Markus Krötzsch [markus.kroetzsch@tu-dresden.de](mailto:markus.kroetzsch@tu-dresden.de)

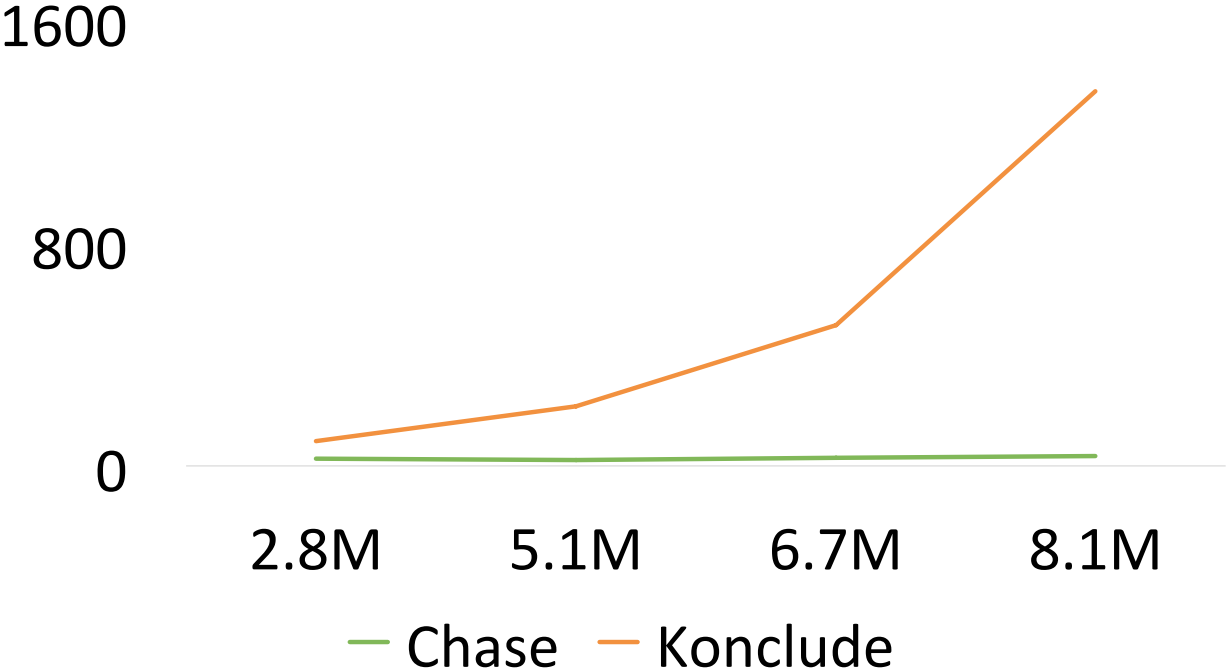
# **Restricted Chase (Non)Termination for Existential Rules with Disjunctions**

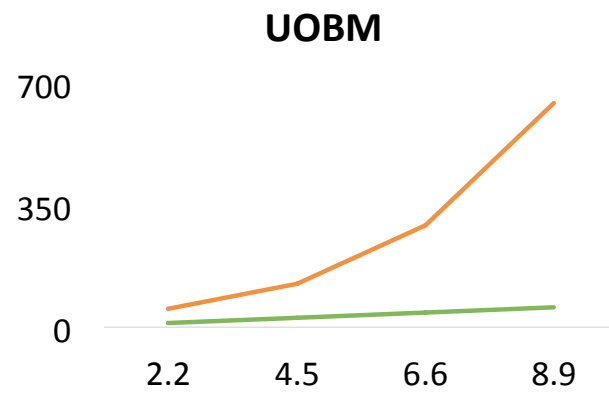
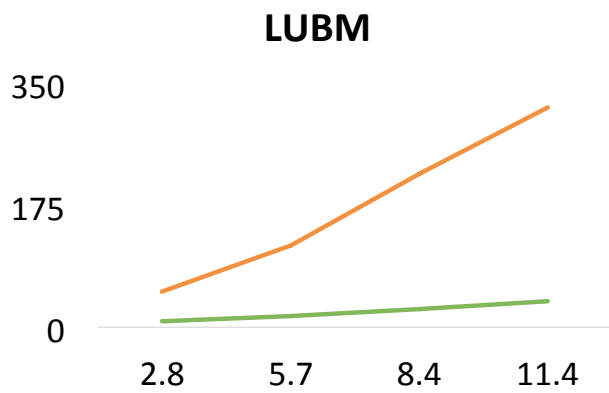
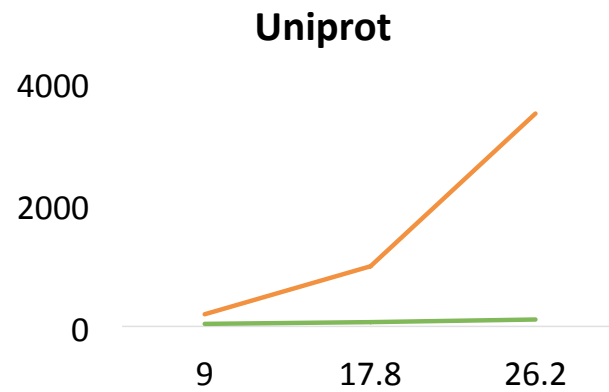
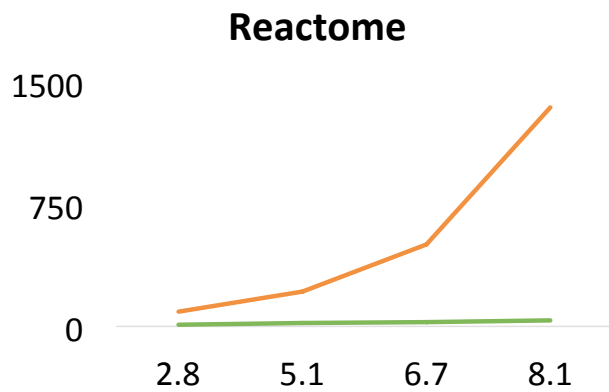
Extended Abstract (IJCAI 2017)

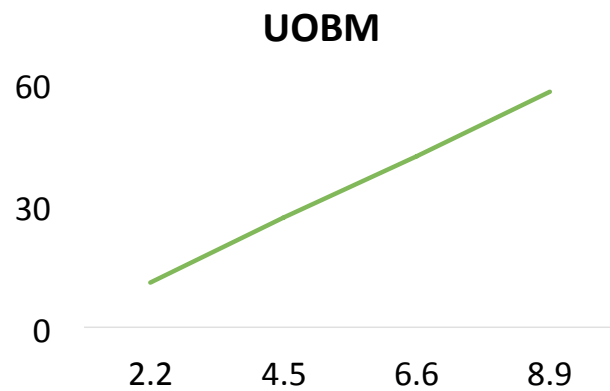
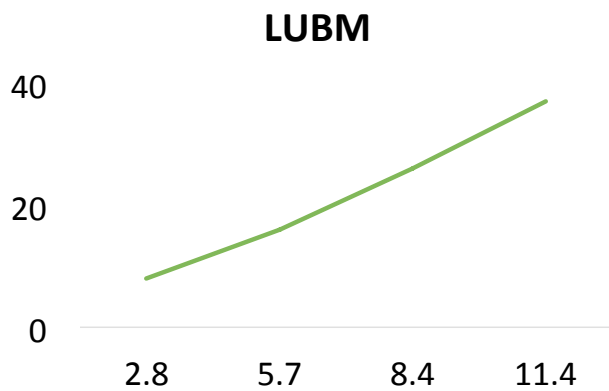
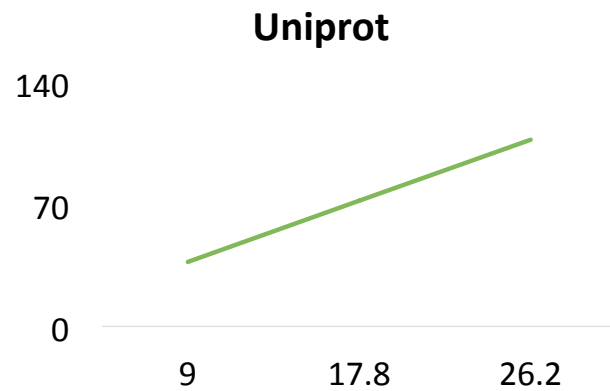
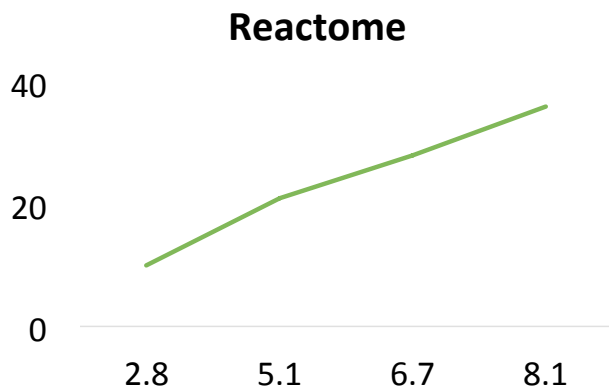
David Carral, Irina Dragoste, Markus Krötzsch  
TU Dresden

	# $\exists$	#	MSA	MFA	RMSA	RMFA	RMFC	open
determin.	1–4	443	293	293	314	314	127	2
	5–69	368	243	243	272	272	72	24
	70–1K	409	348	348	350	350	40	19
	<b>1–1K</b>	<b>1220</b>	<b>884</b>	<b>884</b>	<b>936</b>	<b>936</b>	<b>239</b>	<b>45</b>
non-det.	1–9	128	48	48	53	53	3	72
	10–59	110	19	19	39	40	5	65
	60–1K	118	23	23	30	30	20	68
	<b>1–1K</b>	<b>356</b>	<b>90</b>	<b>90</b>	<b>122</b>	<b>123</b>	<b>28</b>	<b>205</b>

# Reactome









$\text{RDFResource} \sqsubseteq \exists \text{RDFType}.\text{RDFClass}$

$\text{RDFClass} \sqsubseteq \text{RDFResource}$

$\exists \text{RDFType}.T \sqsubseteq \text{RDFResource}$

$\text{RDFResource} \sqsubseteq \exists \text{RDFType}.\text{RDFClass}$

$\text{RDFClass} \sqsubseteq \text{RDFResource}$

$\exists \text{RDFType}.\text{T} \sqsubseteq \text{RDFResource}$

$\text{RDFResource}(\star)$

$\text{RDFClass}(\star)$

$\text{RDFType}(\star, \star)$

$\text{RDFResource} \sqsubseteq \exists \text{RDFType}.\text{RDFClass}$

$\text{RDFClass} \sqsubseteq \text{RDFResource}$

$\exists \text{RDFType}.T \sqsubseteq \text{RDFResource}$



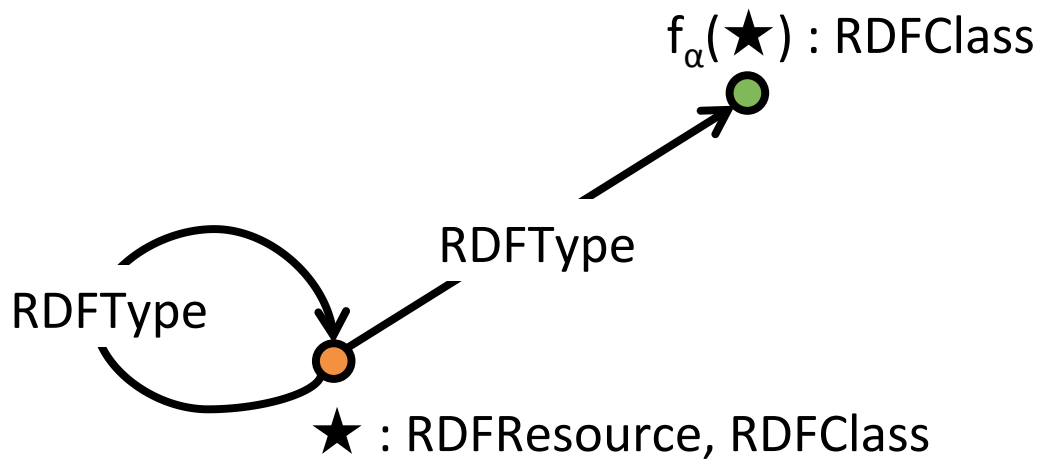
$\text{RDFResource}(x) \rightarrow \exists y [\text{RDFType}(x, y) \wedge \text{RDFClass}(y)] = \alpha$   
 $\text{RDFClass}(x) \rightarrow \text{RDFResource}(x)$   
 $\text{RDFType}(x, y) \rightarrow \text{RDFResource}(x)$



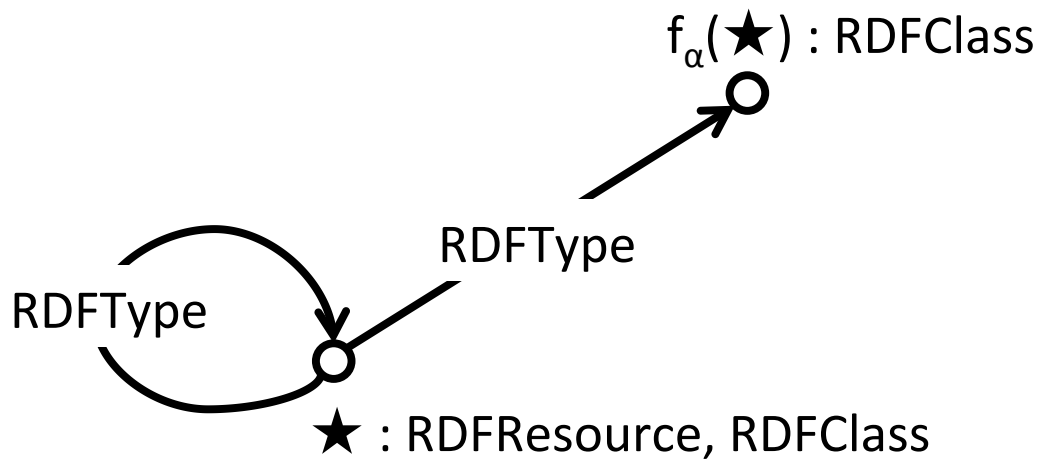
$\text{RDFResource}(x) \rightarrow \exists y [\text{RDFType}(x, y) \wedge \text{RDFClass}(y)] = \alpha$   
 $\text{RDFClass}(x) \rightarrow \text{RDFResource}(x)$   
 $\text{RDFType}(x, y) \rightarrow \text{RDFResource}(x)$



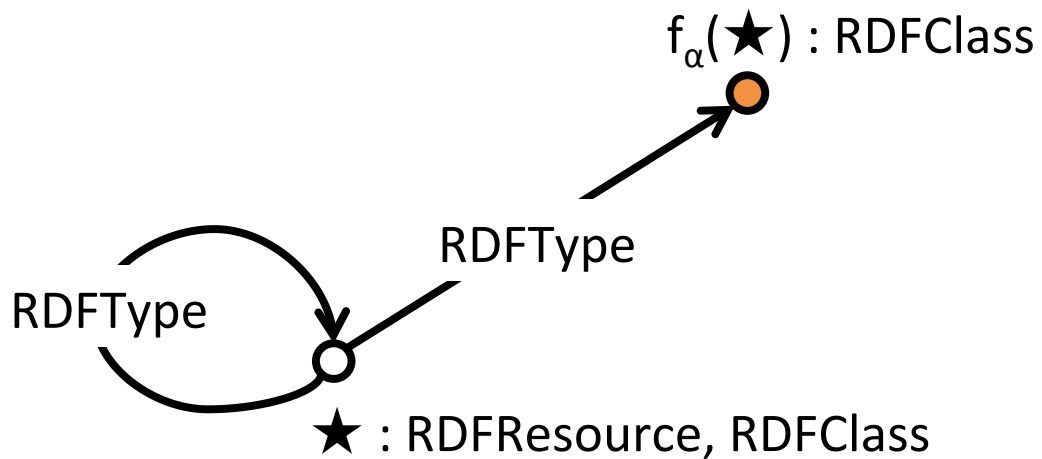
$\text{RDFResource}(x) \rightarrow \exists y [\text{RDFType}(x, y) \wedge \text{RDFClass}(y)] = \alpha$   
 $\text{RDFClass}(x) \rightarrow \text{RDFResource}(x)$   
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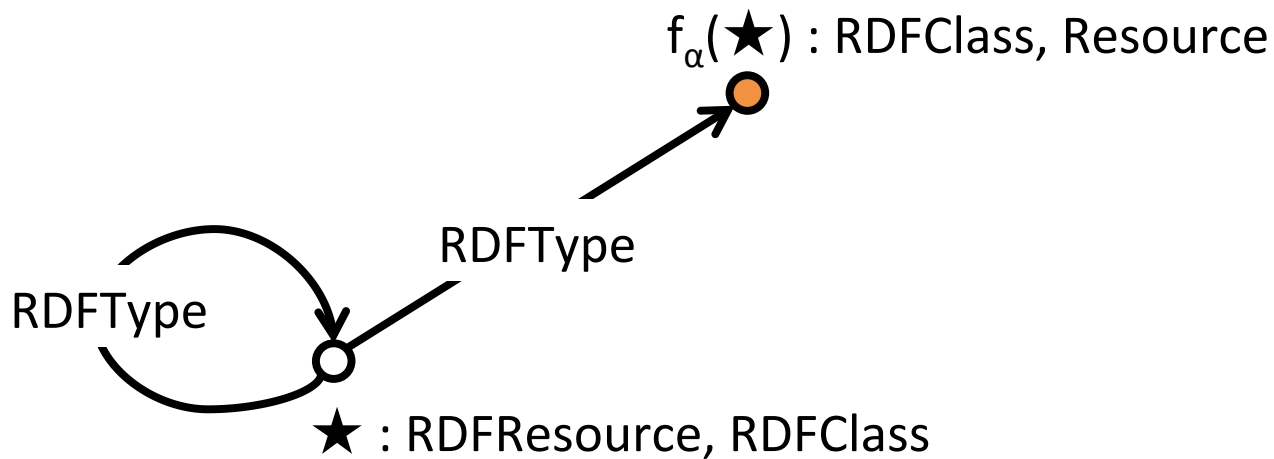


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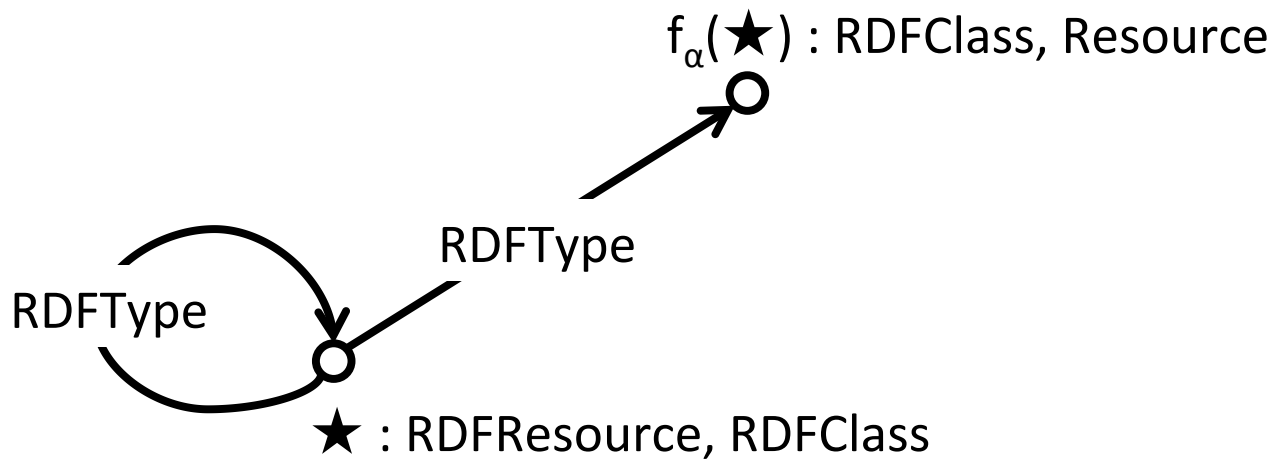




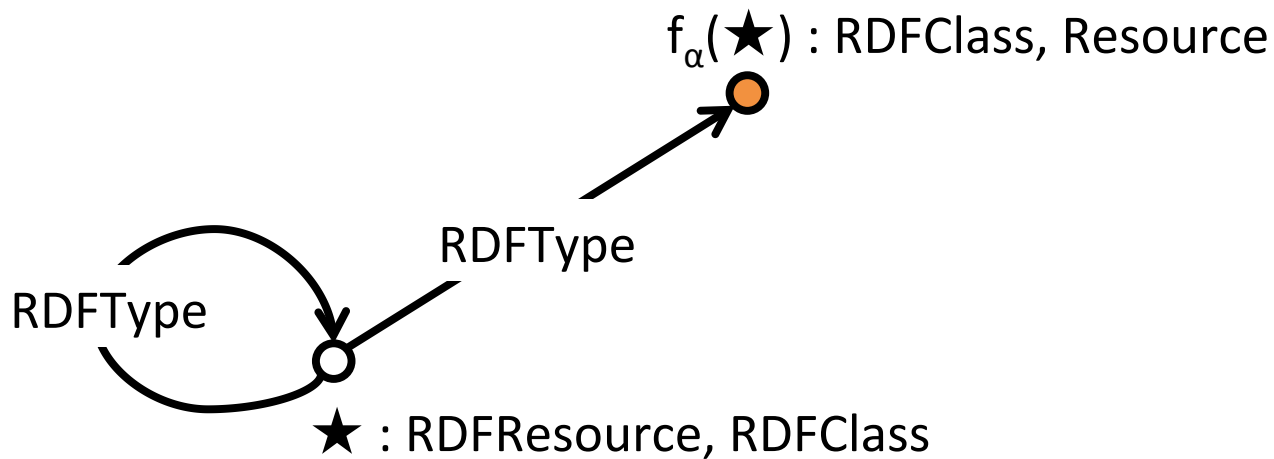
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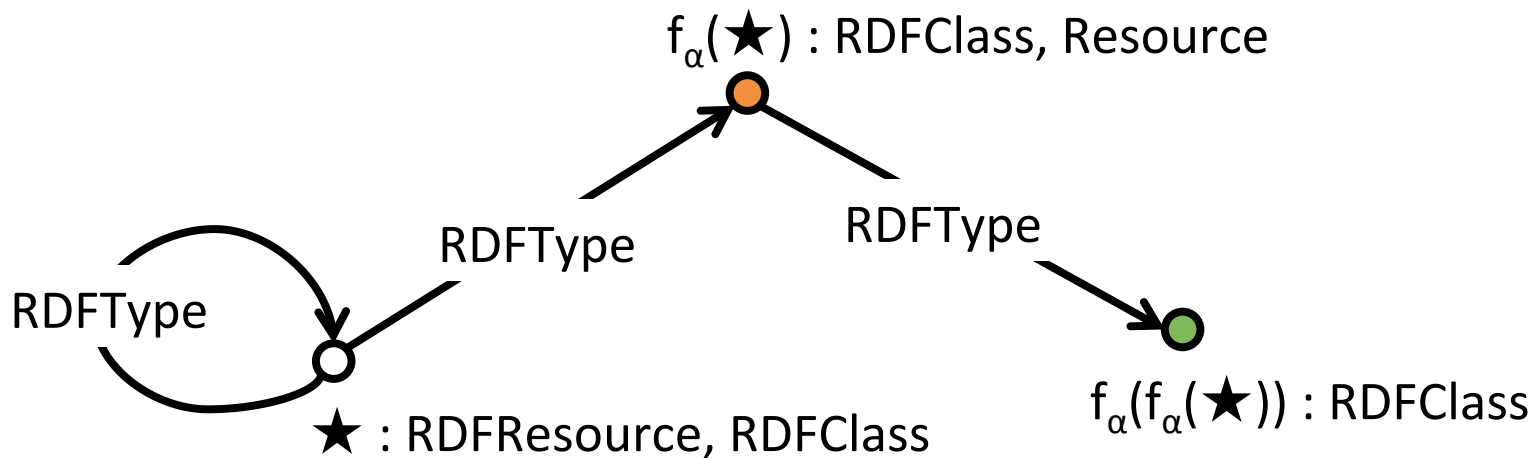
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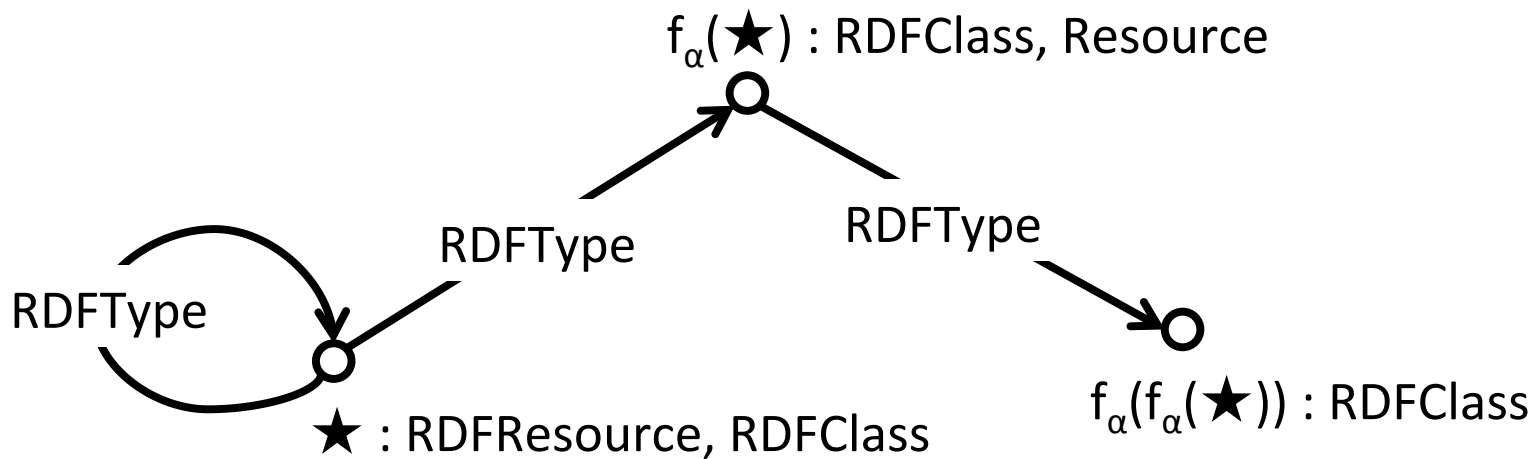
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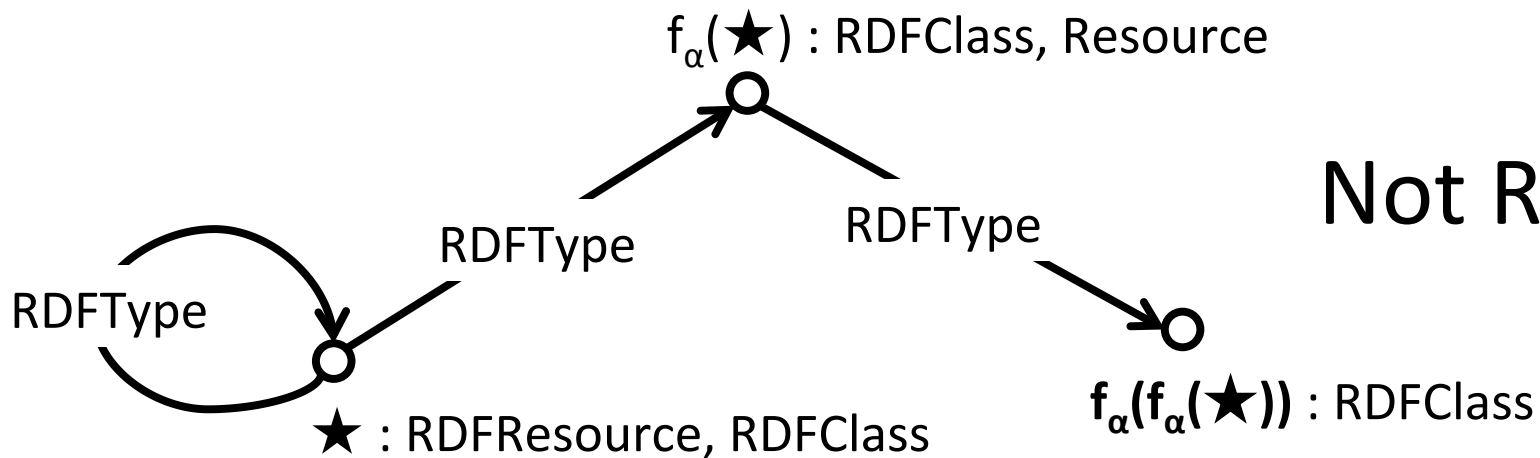
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Not RCA