Axiom-oriented Reasoning to Deal with Inconsistency Between Ontology and Knowledge Base

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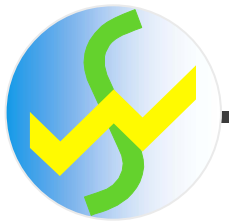
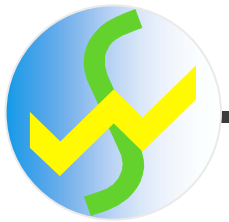


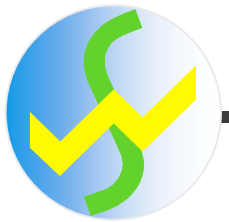
Outline

- Introduction and Motivation
- Ontology and KB
- Inconsistencies in Ontology and KB
- Framework for Diagnosing and Repairing Inconsistency
- Axiom-oriented Reasoning



Introduction

- Semantic Web is developed as a new generation of the current Web
- Ontology & Knowledge Base (KB) are the two significant elements of the Semantic Web
- When used in practical applications, Ontologies and KBs always suffer inconsistencies
- A mechanism to detect and refine inconsistency in Ontology and KB is highly desirable



Ontology and KB

- Ontology represents knowledge
- KB captures knowledge to be represented with respect to an ontology

Football Ontology

C = {football-player, person, club, city }

$\leq C$ = {football-player $\subseteq$ person}

T = {integer}

R = {live-in, locate-in, play-for, has-wife}

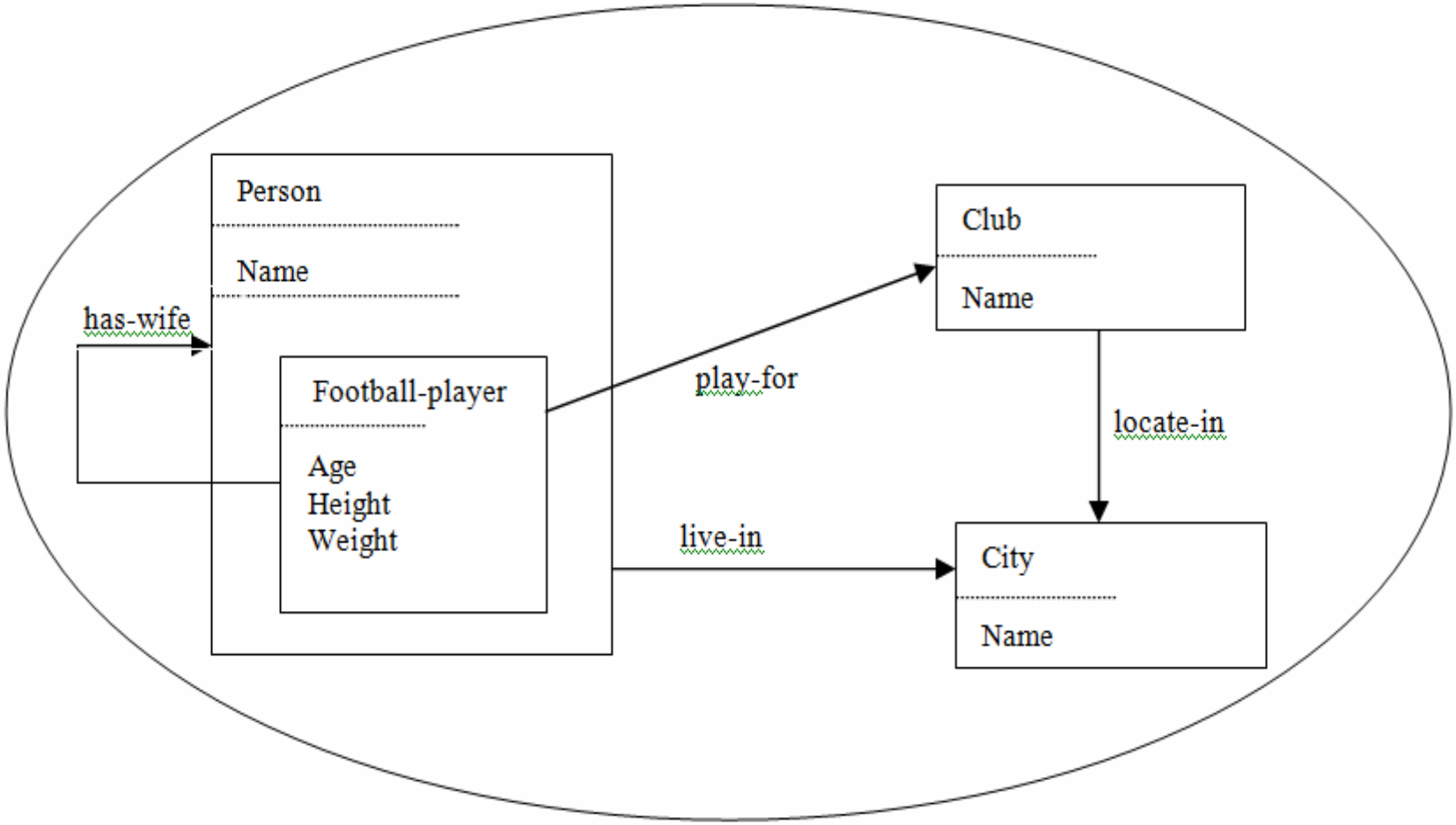
A = {age, height, weight}

δR = {live-in $\rightarrow$ football-player x city,live-in $\rightarrow$ person x city,locate-in $\rightarrow$ club x city,

play-for $\rightarrow$ football-player x club,has-wife $\rightarrow$ football-player x person}

δA = {age $\rightarrow$ football-player x integer,height $\rightarrow$ football-player x integer,

weight $\rightarrow$ football-player x integer}


Person
Name
has-wife
Football-player
Age
Height
Weight
play-for
Club
Name
locate-in
live-in
City
Name

Football KB

I = {Beckham, MU, Manchester, Liverpool, Chelsea, Maria)

τC = {($K5$) football-player (Beckham), ($K6$) club (MU), ($K7$) city (Manchester),

($K8$) city (Liverpool), ($K9$) club (Chelsea)}

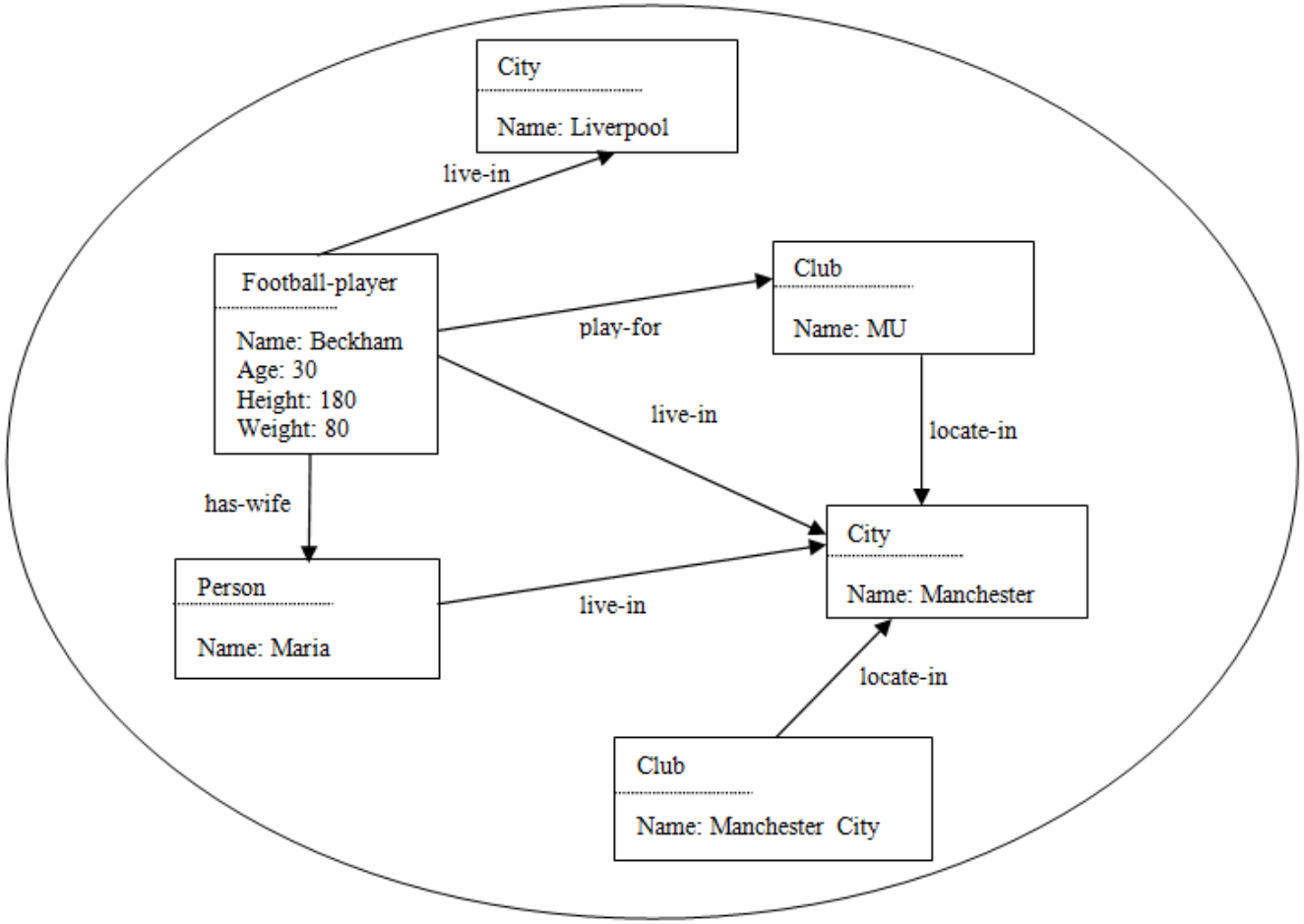
τR = {($K10$) live-in (Beckham, Liverpool), ($K11$) play-for (Beckham, MU),

($K12$) locate-in (MU, Manchester), ($K13$) has-wife (Beckham, Maria),

($K14$) live-in (Maria, Manchester), ($K15$) locate-in (ManCity, Manchester)}

τA = { ($K16$) age (Beckham, 30), ($K17$) height (Beckham, 180),

($K18$) weight (Beckham, 80)}


City
Name: Liverpool
live-in
Football-player
Name: Beckham
Age: 30
Height: 180
Weight: 80
play-for
Club
Name: MU
live-in
locate-in
has-wife
City
Name: Manchester
Person
Name: Maria
live-in
locate-in
Club
Name: Manchester City

Axioms Defined in Ontology

($O1$) football-player(x) ∧ club(y) ∧ city (z) ∧ play-for(x, y) ∧ locate-in(y, z) → live-in(x, z)

// football player plays for club will live in the city that the club locates.

($O2$) football-player(x) ∧ city(y) ∧ city (z) ∧ live-in(x, y) ∧ live-in(x, z) → y = z

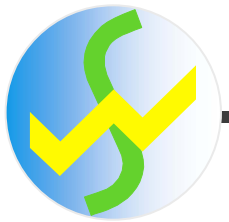
// football player is not living in more than one city.

($O3$) football-player(x) ∧ has-wife(x, y) ∧ city (z) ∧ live-in(y, z) → live-in(x, z)

// football player who has wife will live in the same city as his wife's.

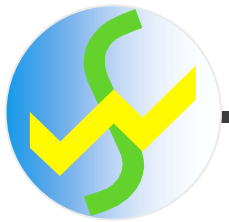
($O4$) club(x) ∧ locate-in(x, z) ∧ club(y) ∧ locate-in(y, z) → x = y

// each city has not more than one club.



Inconsistency in Ontology and KB

- Inconsistency in Ontology
- Inconsistency in KB
- Inconsistency between Ontology and KB



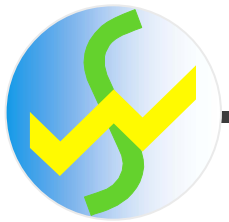
Inconsistency in Ontology

- Bird $\subseteq$ Animal (birds are animals)
- Bird $\subseteq$ Flying-Animal (bird can fly)
- Penguin $\subseteq$ Bird (penguins are birds)
- Penguin $\subseteq \neg$ Flying-Animal (penguin cannot fly)

Inconsistency in KB

- Person (Bob) (Bob is a person)
- Person (Peter) (Peter is a person)
- Same-as (Bob, Peter) (Peter and Bob are the same people)
- Difference-from (Bob, Peter) (Peter and Bob are difference people)

Inconsistency between Ontology and KB



- Football Ontology

  ($O3$) football-player(x) Λ has-wife(x, y) Λ city (z) Λ live-in(y, z) → live-in(x, z)

  // football player who has wife will live in the same city as his wife's.

- Football KB

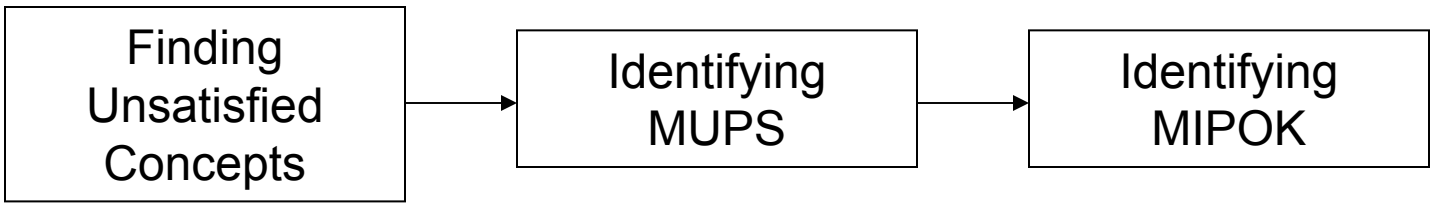
  ($K5$) football-player (Beckham)

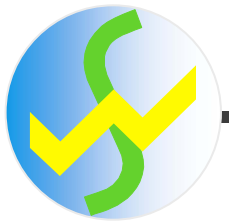
  ($K10$) live-in (Beckham, Liverpool)

  ($K13$) has-wife (Beckham, Maria)

  ($K14$) live-in (Maria, Manchester)

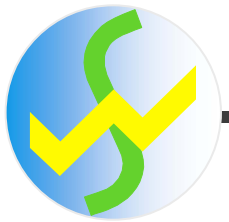
Framework for Diagnosing and Repairing Inconsistency between Ontology and KB





Finding Unsatisfied Concepts

- Unsatisfied concepts:
  - *football-player* (containing unsatisfied individual Beckham who does not live in the same city as his wife does)
  - *city* (because it containing unsatisfied individual Manchester, which has two football clubs).



Identifying MUPS

- MUPS: Minimal Unsatisfied Preserving Sub Ontology and KB - a minimal inconsistent subset, but removal of any single axiom or fact from the set will eliminate the inconsistency.
  - MUPS(*city*) = {*O*4, *K*6, *K*7, *K*8, *K*9, *K*12, *K*15}, MUPS(*football-player*) = {*O*3, *K*5, *K*7, *K*8, *K*10, *K*13, *K*14} or {*O*1, *O*2, *K*5, *K*6, *K*7, *K*8, *K*10, *K*11, *K*12}.

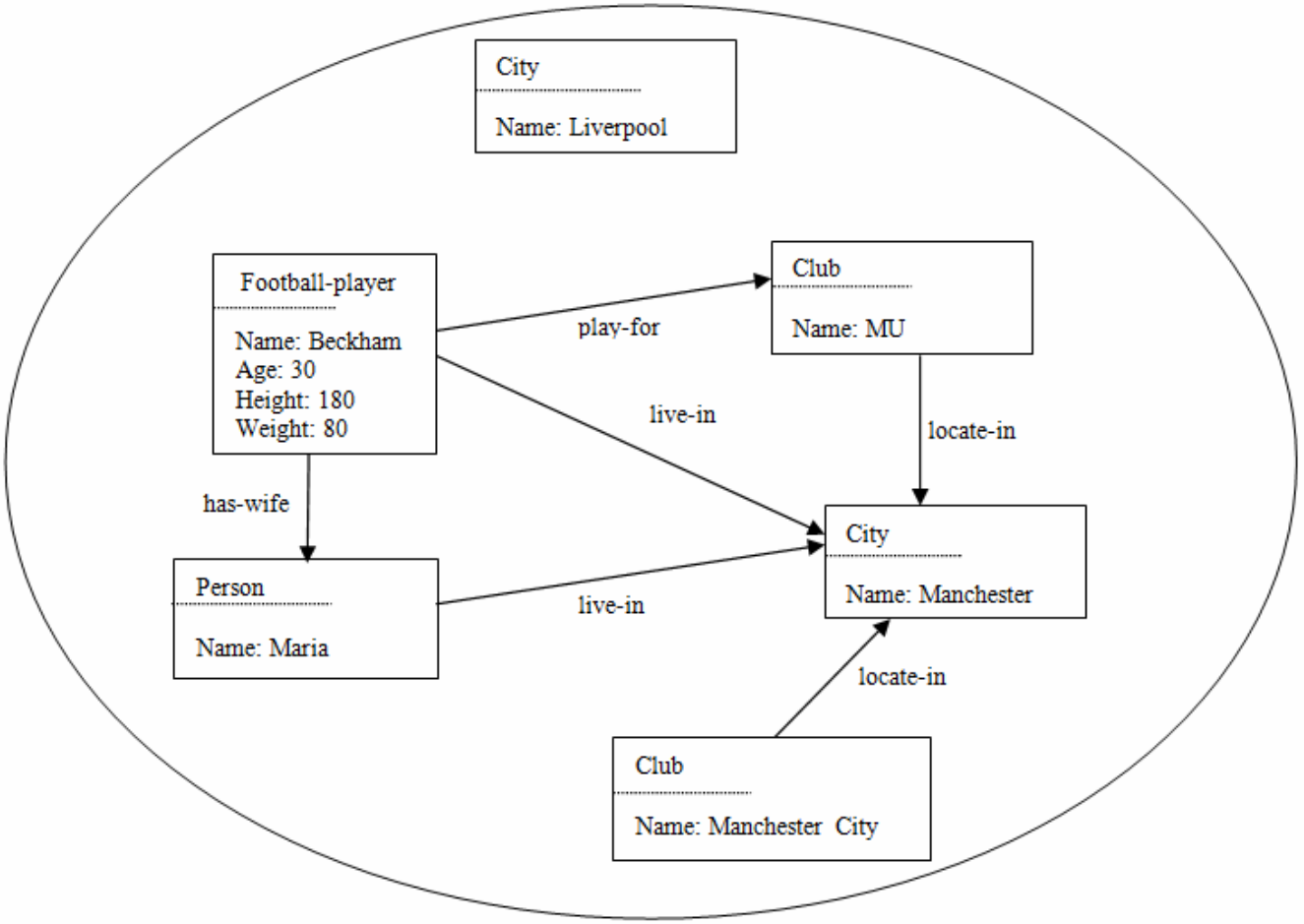
Identifying MIPOK

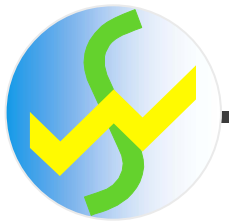
- MIPOK: Minimal Inconsistent Preserving Sub Ontology and KB - the smallest subsets of axioms and facts responsible for all inconsistencies
  - MIPOK = {O4,K10}

(*O*4) club(x) Λ locate-in(x, z) Λ club(y) Λ locate-in(y, z) → x = y *// each city has not more than one club*.

(*K*10) live-in (Beckham, Liverpool)

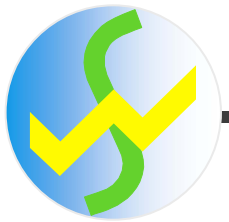
Refined Football KB





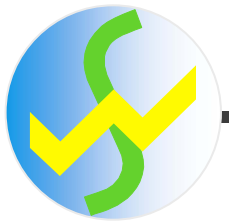
Axiom-oriented Reasoning

- Remove the number of *formulae* considered when calculating MUPS
  - Rule 1: Only consider formulae relevant to at least one axiom
  - Rule 2: Only consider formulae occurring in both Ontology and KB



Axiom-oriented Reasoning

- General formulae:
  - {(*O*1),(*O*2),(*O*3),(*O*4),(*K*5),(*K*6),(*K*7),(*K*8),(*K*9),(*K*10),(*K*11),(*K*12),(*K*13),(*K*14),(*K*15),(K16),(K17),(K18)}



Axiom-oriented Reasoning

- Rule 1 Applying
  - {(*O*1),(*O*2),(*O*3),(*O*4),(*K*5),(*K*6),(*K*7),(*K*8),(*K*9),(*K*10),(*K*11),(*K*12),(*K*13),(*K*14),(*K*15),(K16),(K17),(K18)}

    (*K*16): age (Beckham, 30)

    (*K*17): height (Beckham, 180)

    (*K*18): weight (Beckham, 80)

Axiom-oriented Reasoning

- Rule 2 Applying
  - {(*O*1),(*O*2),(*O*3),(*O*4),(*K*5),(*K*6),(*K*7),(*K*8),(*K*9),(*K*10),(*K*11),(*K*12),(*K*13),(*K*14),(*K*15)}

{*O*1,*O*2,*O*3,*K*5},{O1,O2,O4},{K5,K6,K7,K8,K9}, {*O*1,*O*3,*K*6}, {*O*1,*O*3,*K*7}, {*O*4,*K*10},...

Performance Analysis

- Non axiom-oriented reasoning:
  - N = 2^(n+(a+f)^k)
- Axiom-oriented reasoning:
  - N = 2^((a+f)^k+1) – (2^(a*(a+f)^k)+ 2^(f+(a+f)^k))

where:

a: axioms

f: facts

n: facts not relevant to any axiom

k: number of iteration steps

Thanks for your kind attention

http://www.dit.hcmut.edu.vn/~tru/VN-KIM