Modelling of Reasoning Strategies, and Representation through Conceptual Graphs: Application to Accidentology

Laurence Alpay

Unité de recherche INRIA Lorraine, technopôle de Nancy-Brabois, 615 rue du jardin botanique, BP 101, 54600 VILLERS-LÈS-NANCY
Unité de recherche INRIA Rennes, IRISA, Campus universitaire de Beaulieu, 35042 RENNES Cedex
Unité de recherche INRIA Rhône-Alpes, 46 avenue Félix Viallet, 38031 GRENOBLE Cedex 1
Unité de recherche INRIA Rocquencourt, domaine de Voluceau, Rocquencourt, BP 105, LE CHESNAY Cedex
Unité de recherche INRIA Sophia-Antipolis, 2004 route des Lucioles, BP 93, 06902 SOPHIA-ANTIPOLIS Cedex

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```
SR_Non_Hypothese_Relation<Strategie_Raisonnement_Relation;
        Raffinement_de_Probleme_Relation<SR_Non_Hypothese_Relation;
Raffinement_de_Probleme_Relation<IfThen_Addition_Observation_Relation;


// *************************************************************************;
// *************************************************************************;
// IfThenRelation et fils - Relations specifiques a l'utilisatrice Laurence Alpay;
//**************************************************************************;

IfThen_Relation<Relation_from_a_Proposition;
        IfThen_Addition_Relation<IfThen_Relation;
        IfThen_Addition_Hypothese_Relation<IfThen_Addition_Relation;
        IfThen_Addition_Observation_Relation<IfThen_Addition_Relation;
        IfThen_Addition_Diagnostic_Relation<IfThen_Addition_Relation;

        IfThen_Suppression_Relation<IfThen_Relation;
        IfThen_Suppression_Hypothese_Relation<IfThen_Relation;

//**************************************************************************;
```

```
LA_panneauxVirageDangereux<LA_panneaux;
LA_panneauxVirageDangereux<LA_Road_Accident_Analysis_Concept_INFRA1;

LA_etatReseauRoutier<LA_infraStructureRoutiere;
LA_baliseAvecChevrons<LA_etatReseauRoutier;
LA_baliseAvecChevrons<LA_Road_Accident_Analysis_Concept_INFRA1;

LA_voies<LA_etatReseauRoutier;
LA_voies<LA_Road_Accident_Analysis_Concept_INFRA1;

LA_voiesMemesLargeurs<LA_etatReseauRoutier;
LA_voiesMemesLargeurs<LA_Road_Accident_Analysis_Concept_INFRA1;

LA_stationnementGenant<LA_infraStructureRoutiere;
LA_stationnementGenant<LA_Road_Accident_Analysis_Concept_INFRA1;
```

6.3.5. Typology of relations

The typology of relation types specific for representating our reasoning strategies is given below. They are included in the file KB.INRETS used by the CGKAT tool.

```
User_Relation<Relation;

//***************************************************************************;
// Typologie de relations pour l'utilisatrice Laurence Alpay dans le domaine de l'accidentologie;
//***************************************************************************;

LA_Relation<User_Relation;
Strategie_Raisonnement_Relation<LA_Relation;

SR_Hypothese_Relation<Strategie_Raisonnement_Relation;

Recherche_Hypothese_Relation<SR_Hypothese_Relation;
        Generation_Hypothese_Relation<Recherche_Hypothese_Relation;
        Generation_Hypothese_Relation<IfThen_Addition_Hypothese_Relation;
        Suggere_Hypothese_Relation<Recherche_Hypothese_Relation;
        Indique_Hypothese_Relation<Recherche_Hypothese_Relation;

Test_Hypothese_Relation<SR_Hypothese_Relation;
        Confirmation_Hypothese_Relation<Test_Hypothese_Relation;
        Confirmation_Hypothese_Relation<IfThen_Addition_Diagnostic_Relation;
        Elimination_Hypothese_Relation<Test_Hypothese_Relation;
        Elimination_Hypothese_Relation<IfThen_Suppression_Hypothese_Relation;

Filtre_Hypothese<SR_Hypothese_Relation;
        Generalisation_Hypothese_Relation<Filtre_Hypothese;
        Generalisation_Hypothese_Relation<IfThen_Addition_Hypothese_Relation;
        Specialisation_Hypothese_Relation<Filtre_Hypothese;
        Specialisation_Hypothese_Relation<IfThen_Addition_Hypothese_Relation;
```

LA_hypotheseAccoutumanceInfra<LA_Road_Accident_Analysis_Concept_INFRA1;

LA_hypotheseReseauRoutier<LA_hypotheseInfra;
LA_hypotheseReseauRoutier<LA_Road_Accident_Analysis_Concept_INFRA1;

LA_hypotheseZone<LA_hypotheseInfra;
LA_hypotheseZone<LA_Road_Accident_Analysis_Concept_INFRA1;

LA_hypothesePlanOccupation&PlanCirculation<LA_hypotheseInfra;

LA_hypothesePlanOccupation&PlanCirculationtion<
LA_Road_Accident_Analysis_Concept_INFRA1;

LA_conducteurEndormi<LA_Road_Accident_Analysis_Concept_INFRA1;

LA_conducteurFatigue<LA_comportementConducteur;
LA_conducteurFatigue<LA_Road_Accident_Analysis_Concept_INFRA1;
LA_conducteurFatigue<W_driver/n;

LA_effectueTachesAnnexes<LA_comportementConducteur;
LA_effectueTachesAnnexes<LA_Road_Accident_Analysis_Concept_INFRA1;

LA_meconnaissancesTrajets<LA_etatConducteur;
LA_meconnaissancesTrajets<LA_Road_Accident_Analysis_Concept_INFRA1;

LA_pbGeneVisibilite<LA_pbVisibilite;
LA_pbGeneVisibilite<LA_Road_Accident_Analysis_Concept_INFRA1;

LA_GeneVisibilite<LA_etatInfra;
LA_GeneVisibilite<LA_Road_Accident_Analysis_Concept_INFRA1;

LA_pratiqueInhabituelledeConduite<LA_pbVisibilite;
LA_pratiqueInhabituelledeConduite<LA_Road_Accident_Analysis_Concept_INFRA1;

LA_pbGeneCirculation<LA_etatInfra;
LA_pbGeneCirculation<LA_Road_Accident_Analysis_Concept_INFRA1;
LA_pbGeneCirculation<W_trouble__problem;

LA_pbGeneAccoutumanceInfra<LA_etatInfra;
LA_pbGeneAccoutumanceInfra<LA_Road_Accident_Analysis_Concept_INFRA1;
LA_pbGeneAccoutumanceInfra<W_trouble__problem;

LA_adherenceMediocre<LA_etatVehicule;
LA_adherenceMediocre<LA_Road_Accident_Analysis_Concept_INFRA1;

LA_etatPneus<LA_etatVehicule;
LA_etatPneus<LA_Road_Accident_Analysis_Concept_INFRA1;

LA_etatAmortisseurs<LA_etatVehicule;
LA_etatAmortisseurs<LA_Road_Accident_Analysis_Concept_INFRA1;

6.3.4. Typology of concepts for INFRA1

```
// ***************************************************************;
// Typologie specifique a l'expert ingenieur infra INFRA1;
// ***************************************************************;

LA_iVehicule<LA_icvi;
LA_iSignalisation<LA_Road_Accident_Analysis_Concept_INFRA1;

LA_iAccotement<LA_iInfra;
LA_iAccotement<LA_Road_Accident_Analysis_Concept_INFRA1;

LA_iEtatInfra<LA_iInfra;
LA_iEtatInfra<LA_Road_Accident_Analysis_Concept_INFRA1;

LA_iEtatRoute<LA_iInfra;
LA_iEtatRoute<LA_Road_Accident_Analysis_Concept_INFRA1;
        LA_iMarquage<LA_iEtatRoute;
        LA_iAdherence<LA_iEtatRoute;
        LA_iDeformationRevetement<LA_iEtatRoute;

LA_iGeneVisibilite<LA_iInfra;
LA_iGeneVisibilite<LA_Road_Accident_Analysis_Concept_INFRA1;

LA_iGeneCirculation<LA_iInfra;
LA_iGeneCirculation<LA_Road_Accident_Analysis_Concept_INFRA1;

LA_iAccoutumanceInfra<LA_iInfra;
LA_iAccoutumanceInfra<LA_Road_Accident_Analysis_Concept_INFRA1;

LA_iReseauRoutier<LA_iInfra;
LA_iReseauRoutier<LA_Road_Accident_Analysis_Concept_INFRA1;
        LA_iRouteNationale<LA_iReseauRoutier;
        LA_iRouteDepartementale<LA_iReseauRoutier;

LA_iZone<LA_iInfra;
LA_iZone<LA_Road_Accident_Analysis_Concept_INFRA1;
        LA_iZoneTransition<LA_iZone;

LA_donneesFurtives<LA_natureObservationsAccident;
LA_donneesFurtives<LA_Road_Accident_Analysis_Concept_INFRA1;
LA_donneesObjectives<LA_natureObservationsAccident;
LA_donneesObjectives<LA_Road_Accident_Analysis_Concept_INFRA1;
LA_donneesAggravantes<LA_natureObservationsAccident;
LA_donneesAggravantes<LA_Road_Accident_Analysis_Concept_INFRA1;

LA_hypotheseVisibilite<LA_Road_Accident_Analysis_Concept_INFRA1;

LA_hypotheseCirculation<LA_hypotheseInfra;
LA_hypotheseCirculation<LA_Road_Accident_Analysis_Concept_INFRA1;

LA_hypotheseAccoutumanceInfra<LA_hypotheseInfra;
```

```
LA_prisedeMedicaments<LA_Road_Accident_Analysis_Concept_PSY2;
LA_prisedeMedicaments<W_consumption__ingestion__intake__uptake;

LA_repasCopieuxBienArrose<LA_etatConducteur;
LA_repasCopieuxBienArrose<LA_Road_Accident_Analysis_Concept_PSY2;
LA_repasCopieuxBienArrose<W_meal__repast;

LA_effetsSecondairesSurVigilance<LA_etatConducteur;
LA_effetsSecondairesSurVigilance<LA_Road_Accident_Analysis_Concept_PSY2;

LA_effetsSecondairesSurConduite<LA_etatConducteur;
LA_effetsSecondairesSurConduite<LA_Road_Accident_Analysis_Concept_PSY2;

LA_conducteurNonExperimente<LA_Road_Accident_Analysis_Concept_PSY2;

LA_repertoireSituationsLimite<LA_etatConducteur;
LA_repertoireSituationsLimite<LA_Road_Accident_Analysis_Concept_PSY2;

LA_diversiteSolutionsLimitee<LA_etatConducteur;
LA_diversiteSolutionsLimitee<LA_Road_Accident_Analysis_Concept_PSY2;

LA_pertedeControle<LA_erreurConducteur;
LA_pertedeControle<LA_Road_Accident_Analysis_Concept_PSY2;
        LA_PCLorsDepassement<LA_pertedeControle;

LA_manoeuvreImpromptue<LA_erreurConducteur;
LA_manoeuvreImpromptue<LA_Road_Accident_Analysis_Concept_PSY2;
LA_MITourneAGauche<LA_manoeuvreImpromptue;

LA_confusionManoeuvre<LA_erreurConducteur;
LA_confusionManoeuvre<LA_Road_Accident_Analysis_Concept_PSY2;
        LA_CMTourneAGauche&Depassement<LA_confusionManoeuvre;


LA_carrefour<LA_etatInfra;
LA_carrefour<LA_Road_Accident_Analysis_Concept_PSY2;

LA_pbMasqueVisibilite<LA_Road_Accident_Analysis_Concept_PSY2;

LA_elementVehicule<LA_etatVehicule;
LA_elementVehicule<LA_Road_Accident_Analysis_Concept_PSY2;
        LA_retrovisseurs<LA_elementVehicule;
        LA_angleMortRetrovisseurs<LA_etatVehicule;
        LA_angleMortRetrovisseurs<LA_Road_Accident_Analysis_Concept_PSY2;

LA_elementEnvironement<LA_infraStructureRoutiere;
LA_elementEnvironement<LA_Road_Accident_Analysis_Concept_PSY2;
        LA_buissons<LA_elementEnvironement;
```

6.3.3. Typology of concept types for PSY2

```
// ************************************************************;
// Typologie specifique a l'expert psychologue PSY2;
// ************************************************************;

LA_iMasqueVisibilite<LA_iInfra;
LA_iMasqueVisibilite<LA_Road_Accident_Analysis_Concept_PSY2;

LA_iExperienceConducteur<LA_Road_Accident_Analysis_Concept_PSY2;

LA_iHeuresdeRepas<LA_iConducteur;
LA_iHeuresdeRepas<LA_Road_Accident_Analysis_Concept_PSY2;

LA_iTempsdeReaction<LA_iInfra;
LA_iTempsdeReaction<LA_Road_Accident_Analysis_Concept_PSY2;

LA_iEtatSante<LA_iConducteur;
LA_iEtatSante<LA_Road_Accident_Analysis_Concept_PSY2;

        LA_donneesSures<LA_natureObservationsAccident;
        LA_donneesSures<LA_Road_Accident_Analysis_Concept_PSY2;
        LA_donneesPeuSures<LA_natureObservationsAccident;
        LA_donneesPeuSures<LA_Road_Accident_Analysis_Concept_PSY2;


LA_hypotheseVisibilite<LA_Road_Accident_Analysis_Concept_PSY2;

LA_hypotheseExperienceConducteur<LA_hypotheseConducteur;
LA_hypotheseExperienceConducteur<LA_Road_Accident_Analysis_Concept_PSY2;

LA_hypotheseSanteConducteur<LA_hypotheseConducteur;
LA_hypotheseSanteConducteur<LA_Road_Accident_Analysis_Concept_PSY2;

LA_hypotheseTempsdeReaction<LA_hypotheseConducteur;
LA_hypotheseTempsdeReaction<LA_Road_Accident_Analysis_Concept_PSY2;

LA_hypotheseHeuresRepasConducteur<LA_hypotheseConducteur;
LA_hypotheseHeuresRepasConducteur<LA_Road_Accident_Analysis_Concept_PSY2;

LA_conducteurSurpris<LA_comportementConducteur;
LA_conducteurSurpris<LA_Road_Accident_Analysis_Concept_PSY2;
LA_conducteurSurpris<W_driver/n;

LA_conducteurSomnolent<LA_comportementConducteur;
LA_conducteurSomnolent<LA_Road_Accident_Analysis_Concept_PSY2;
LA_conducteurSomnolent<W_driver/n;

LA_conducteurEndormi<LA_Road_Accident_Analysis_Concept_PSY2;


LA_prisedeMedicaments<LA_comportementConducteur;
```

LA_pbMasqueVisibilite<LA_Road_Accident_Analysis_Concept_PSY1;

LA_masqueVisibiliteTemporaire<LA_pbInfra;
LA_masqueVisibiliteTemporaire<LA_Road_Accident_Analysis_Concept_PSY1;

LA_panneauxAmbigus<LA_pbInfra;
LA_panneauxAmbigus<LA_Road_Accident_Analysis_Concept_PSY1;

LA_usurePneus<LA_etatVehicule;
LA_usurePneus<LA_Road_Accident_Analysis_Concept_PSY1;
LA_usurePneus<W_wear/n;

LA_usurePlaquettesFreins<LA_etatVehicule;
LA_usurePlaquettesFreins<LA_Road_Accident_Analysis_Concept_PSY1;
LA_usurePlaquettesFreins<W_wear/n;

LA_usureAmortisseurs<LA_etatVehicule;
LA_usureAmortisseurs<LA_Road_Accident_Analysis_Concept_PSY1;
LA_usureAmortisseurs<W_wear/n;

LA_propretePareBrise<LA_etatVehicule;
LA_propretePareBrise<LA_Road_Accident_Analysis_Concept_PSY1;
LA_propretePareBrise<W_cleanness/n1;

LA_jeuDirection<LA_etatVehicule;
LA_jeuDirection<LA_Road_Accident_Analysis_Concept_PSY1;

LA_reglageRetrovisseur<LA_etatVehicule;
LA_reglageRetrovisseur<LA_Road_Accident_Analysis_Concept_PSY1;

LA_etatdeSurface<LA_infraStructureRoutiere;

LA_bosses<LA_etatdeSurface;
LA_bosses<LA_Road_Accident_Analysis_Concept_PSY1;
LA_bosses<W_bulge__bump__hump__gibbosity__gibbousness__
jut__prominence__protuberance__protrusion__extrusion__excrescence;

LA_creux<LA_etatdeSurface;
LA_creux<LA_Road_Accident_Analysis_Concept_PSY1;
LA_creux<W_hole__hollow;

LA_flaquesdEau<LA_etatdeSurface;
LA_flaquesdEau<LA_Road_Accident_Analysis_Concept_PSY1;
LA_flaquesdEau<W_pool__puddle;

LA_dosdAne<LA_etatdeSurface;
LA_dosdAne<LA_Road_Accident_Analysis_Concept_PSY1;

LA_conducteurNonExperimente<LA_Road_Accident_Analysis_Concept_PSY1;

LA_absorptionDrogues<LA_etatConducteur;
LA_absorptionDrogues<LA_Road_Accident_Analysis_Concept_PSY1;
LA_absorptionDrogues<W_absorption/n2;

LA_meconnaissancesLieux<LA_etatConducteur;
LA_meconnaissancesLieux<LA_Road_Accident_Analysis_Concept_PSY1;
LA_meconnaissancesLieux<W_unknown__unknown_region__terra_incognita;

LA_experienceConduite<LA_etatConducteur;
LA_experienceConduite<LA_Road_Accident_Analysis_Concept_PSY1;
LA_experienceConduite<W_experience/n1;

LA_vitesseConduite<LA_etatConducteur;
LA_vitesseConduite<LA_Road_Accident_Analysis_Concept_PSY1;
LA_vitesseConduite<W_speed__velocity;

LA_risquesObliges<LA_etatConducteur;
LA_risquesObliges<LA_Road_Accident_Analysis_Concept_PSY1;
LA_risquesObliges<W_risk__peril__danger;

LA_pbPriseInformations<LA_etatConducteur;
LA_pbPriseInformations<LA_Road_Accident_Analysis_Concept_PSY1;
LA_pbPriseInformations<W_trouble__problem;

LA_pbInterpretation<LA_etatConducteur;
LA_pbInterpretation<LA_Road_Accident_Analysis_Concept_PSY1;
LA_pbInterpretation<W_trouble__problem;

LA_pbInterpretationSignalisation<LA_pbInterpretation;

LA_mauvaisePriseInformations<LA_erreurConducteur;
LA_mauvaisePriseInformations<LA_Road_Accident_Analysis_Concept_PSY1;

LA_vitesseParAmusement<LA_erreurConducteur;
LA_vitesseParAmusement<LA_Road_Accident_Analysis_Concept_PSY1;
LA_vitesseParAmusement<W_speed__velocity;

LA_vitesseExcessive<LA_erreurConducteur;
LA_vitesseExcessive<LA_Road_Accident_Analysis_Concept_PSY1;
LA_vitesseExcessive<W_speed__velocity;

LA_pointsDurs<LA_etatInfra;
LA_pointsDurs<LA_Road_Accident_Analysis_Concept_PSY1;

LA_pointsdeRupture<LA_etatInfra;
LA_pointsdeRupture<LA_Road_Accident_Analysis_Concept_PSY1;
LA_pointsdeRupture<W_disruption__perturbation;

LA_fPointsDurs<LA_fInfra;
LA_fPointsDurs<LA_Road_Accident_Analysis_Concept_PSY1;

LA_fPointsRuptures<LA_fInfra;
LA_fPointsRuptures<LA_Road_Accident_Analysis_Concept_PSY1;

LA_fPrisedeRisques<LA_fcvi;
LA_fPrisedeRisques<LA_Road_Accident_Analysis_Concept_PSY1;

LA_iEtatdeSurface<LA_iInfra;
LA_iEtatdeSurface<LA_Road_Accident_Analysis_Concept_PSY1;

LA_iMasqueVisibiliteTemporaire<LA_iInfra;
LA_iMasqueVisibiliteTemporaire<
LA_Road_Accident_Analysis_Concept_PSY1;

LA_iSignalisation<LA_Road_Accident_Analysis_Concept_PSY1;

LA_iExperienceConducteur<LA_Road_Accident_Analysis_Concept_PSY1;

LA_iContexteConducteur<LA_iConducteur;
LA_iContexteConducteur<LA_Road_Accident_Analysis_Concept_PSY1;

LA_hypotheseVisibilite<LA_Road_Accident_Analysis_Concept_PSY1;
LA_hypothesePriseInformation<LA_hypotheseConducteur;
LA_hypothesePriseInformation<LA_Road_Accident_Analysis_Concept_PSY1;
LA_hypotheseInterpretation<LA_hypotheseConducteur;
LA_hypotheseInterpretation<LA_Road_Accident_Analysis_Concept_PSY1;
LA_hypotheseComportementConducteur<LA_hypotheseConducteur;
LA_hypotheseComportementConducteur<
LA_Road_Accident_Analysis_Concept_PSY1;

LA_conducteurPresse<LA_comportementConducteur;
LA_conducteurPresse<LA_Road_Accident_Analysis_Concept_PSY1;
LA_conducteurRigide<LA_comportementConducteur;
LA_conducteurRigide<LA_Road_Accident_Analysis_Concept_PSY1;
LA_conducteurPlusFacilementSurpris<LA_comportementConducteur;
LA_conducteurPlusFacilementSurpris<
LA_Road_Accident_Analysis_Concept_PSY1;

LA_pasEvocationConnaissancesAlternatives<LA_comportementConducteur;
LA_pasEvocationConnaissancesAlternatives<
LA_Road_Accident_Analysis_Concept_PSY1;

LA_evacueInfoContreAttenteConducteur<LA_comportementConducteur;
LA_evacueInfoContreAttenteConducteur<
LA_Road_Accident_Analysis_Concept_PSY1;

LA_conducteurExperimente<LA_comportementConducteur;
LA_conducteurExperimente<LA_Road_Accident_Analysis_Concept_PSY1;

```
LA_iExperienceConducteur<LA_iConducteur;
LA_conducteurNonExperimente<LA_comportementConducteur;

LA_pbMasqueVisibilite<LA_pbVisibilite;

// ***************************************************************************;
// Typologie specifique et commune a l' expert psychologue PSY1 et
// a l'ingenieur infra INFRA1;
// These are in fact compound concepts;
/****************************************************************************;

LA_iSignalisation<LA_iInfra;

LA_signalisation<LA_infraStructureRoutiere;
LA_signalisation<W_sign/n;

LA_panneaux<LA_signalisation;


// ***********************************************************************;
// Typologie specifique et commune a l' expert psychologue PSY2 et
// a l'ingenieur infra INFRA1 ;
// These are in fact compound concepts types;
//*************************************************************************;

LA_natureObservationsAccident<LA_observationAccident;

LA_conducteurEndormi<LA_comportementConducteur;
LA_conducteurEndormi<W_driver/n;
```

6.3.2. Typology of concept types for PSY1

```
// *******************************************************************;
// Typologie specifique a l'expert psychologue PSY1;
// These are in fact compound concept types;
// No direct link with Wordnet concepts, only via their parent nodes;
// *******************************************************************;

LA_natureFacteur<LA_facteur;
LA_natureFacteur<LA_Road_Accident_Analysis_Concept_PSY1;
        LA_fAggravant<LA_natureFacteur;
        LA_fPotentiel<LA_natureFacteur;
        LA_fTerminaux<LA_natureFacteur;

LA_fEtatSurface<LA_fInfra;
LA_fEtatSurface<LA_Road_Accident_Analysis_Concept_PSY1;

LA_fSignalisation<LA_fInfra;
LA_fSignalisation<LA_Road_Accident_Analysis_Concept_PSY1;
```

```
                        LA_iConducteur<LA_icvi;

        LA_hypothese<LA_proposition;
        LA_hypothese<W_hypothesis/n;
                LA_hypotheseAccident<LA_hypothese;
                        LA_hypotheseInfra<LA_hypotheseAccident;
                                LA_hypotheseVisibilite<LA_hypotheseInfra;
                        LA_hypotheseConducteur<LA_hypotheseAccident;

                LA_erreurConducteur<LA_etatConducteur;
                LA_erreurConducteur<W_mistake__error__fault;

        LA_interpretation<LA_proposition;
        LA_strategie_de_Raisonnement<LA_proposition;
        LA_diagnostic<LA_proposition;


LA_situation<LA_Road_Accident_Analysis_Concept;
        LA_processus<LA_situation;
        LA_processus<W_process/n;
                LA_evenement<LA_processus;
                LA_evenement<W_event/n;
                        LA_accident<LA_evenement;
                        LA_accident<W_accident__fortuity__chance_event;
                                LA_accidentRoutier<LA_accident;
LA_etat<LA_situation;
LA_etat<W_state/n;
        LA_etatAccident<LA_etat;
                LA_etatConducteur<LA_etatAccident;
                        LA_comportementConducteur<LA_etatConducteur;
                        LA_comportementConducteur<W_behavior__behaviour;

LA_etatVehicule<LA_etatAccident;
        LA_etatInfra<LA_etatAccident;
                LA_pbInfra<LA_etatInfra;
                        LA_pbVisibilite<LA_pbInfra;
                        LA_pbVisibilite<W_trouble__problem;

// ************************************************************************;
// Typologie specifique et commune aux experts psychologues PSY1 et PSY2.
// These are in fact compound concept types;
// No direct link with Wordnet concepts, only via their parent nodes;
// ************************************************************************;

LA_fcvi<LA_facteur;
LA_fInfra<LA_fcvi;
LA_fVehicule<LA_fcvi;
LA_fConducteur<LA_fcvi;

LA_icvi<LA_indice;
LA_iInfra<LA_icvi;
```

verbs are organised into synomym sets (synsets); each synset represents an underlying lexical concept i.e. a word meaning. CGKAT automatically builds a unique concept type with the name in a synset. If there are at least two names in the synset, a simple concatenation of these names is sufficient (e.g. with the synset {object, inanimate, object, physical object}, CGKAT builds the concept type name W_object_inanimate_object_physical_object). If there is only one name, a unique type may be built by adding to this name the initial of this grammatical category (e.g. ‘n’ for noun, ‘v’ for verb) and the sense number of this synset in this grammatical category.

The hierarchy between 2 concepts is expressed as A< B (i.e. concept A is a subtype of concept B).

6.3.1. Common typology

```
// ************************************************************;
// Typologie commune aux experts - PSY1, PSY2 et INFRA1;
// ************************************************************;

LA_entite<LA_Road_Accident_Analysis_Concept;
        LA_objetPhysique<LA_entite;
                LA_vivant<LA_objetPhysique;
                LA_humain<W_earthborn__human;
                        LA_conducteur<LA_humain;
                        LA_conducteur<W_driver/n;
                LA_nonVivant<LA_objetPhysique;
                LA_nonVivant<W_insentient__inanimate;
                        LA_vehicule<LA_nonVivant;
                        LA_vehicule<W_vehicle/n;
                        LA_infraStructureRoutiere<LA_nonVivant;
                        LA_infraStructureRoutiere<W_infrastructure/n1;
                LA_entiteMobile<LA_objetPhysique;
                LA_entiteMobile<W_mobile/a;
                        LA_vehicule<LA_entiteMobile;
                        LA_voiture<LA_entiteMobile;
                LA_entiteNonMobile<LA_objetPhysique;
                        LA_localite<LA_entiteNonMobile;
                        LA_localite<W_vicinity__locality__neighborhood__neighbourhood;

LA_proposition<Proposition;

        LA_observation<LA_proposition;
        LA_observation<W_observation__reflection__reflexion;
                LA_observationAccident<LA_observation;

                        LA_facteur<LA_observationAccident;
                        LA_facteur<W_factor__component;

                                LA_indice<LA_observationAccident;
                                LA_indice<W_hint__clue;
```

```
Test_Hypothese_Relation{Signature:2,Concept,Concept};
Confirmation_Hypothese_Relation{Signature:2,Concept,Concept};
Elimination_Hypothese_Relation{Signature:2,Concept,Concept};

Filtre_Hypothese{Signature:2,Concept,Concept};
Generalisation_Hypothese_Relation{Signature:2,Concept,Concept};
Specialisation_Hypothese_Relation{Signature:2,Concept,Concept};


SR_Non_Hypothese_Relation{Signature:2,Concept,Concept};

Raffinement_de_Probleme_Relation{Signature:2,Concept,Concept};


//***********************************************************************;
Relation_from_a_Proposition{Signature:2,Proposition,Concept}
{@:e.g. InfoSource, Author, Rhetorical_Relation;};
InfoSource{Signature:2,Proposition,Concept};
Author{Signature:2,Proposition,Causal_Entity};

// Relations de Laurence Alpay pour l'accidentologie;
IfThen_Relation{Signature:2,Proposition,Proposition}{@:relation between propositions;};

IfThen_Addition_Relation{Signature:2,Proposition,Proposition}
{@:relation between propositions;};
IfThen_Addition_Hypothese_Relation{Signature:2,Proposition,Proposition}
{@:relation between propositions;};
IfThen_Addition_Observation_Relation{Signature:2,Proposition,Proposition}
{@:relation between propositions;};
IfThen_Addition_Diagnostic_Relation{Signature:2,Proposition,Proposition}
{@:relation between propositions;};

IfThen_Suppression_Relation{Signature:2,Proposition,Proposition}
{@:relation between propositions;};
IfThen_Suppression_Hypothese_Relation{Signature:2,Proposition,Proposition}
{@:relation between propositions;};
```

6.3 Typologies

We have regrouped the typologies specific for each expert, as well as typologies which are common to all three experts, and the concepts that they may share in dual.

The typologies presented here come from the file KB.INRETS which is used by the tool CGKAT. Each concept has a prefix LA_ to identify the person who inserted the concept (in this case Laurence Alpay). The prefix W_ indicates concepts from WordNet. In WordNet, word forms of English nouns verbs, adjectives and ad-

```
LA_meconnaissancesTrajets;

LA_pbGeneVisibilite;
LA_GeneVisibilite;
LA_pratiqueInhabituelledeConduite;
LA_pbGeneCirculation;
LA_pbGeneAccoutumanceInfra;

LA_adherenceMediocre;
LA_etatPneus;
LA_etatAmortisseurs;

LA_panneauxVirageDangereux;

LA_etatReseauRoutier;
LA_baliseAvecChevrons;
LA_voies;
LA_voiesMemesLargeurs;

LA_stationnementGenant;
```

6.2 Relation types

The set of relations specific for representating our reasoning strategies is given below. They are included in the file KB.INRETS used by the CGKAT tool.

```
// ***************************************************************************;
// Ce sont les relations specifiques a l'utilisatrice Laurence Alpay
// pour la representation des strategies de raisonnement en accidentologie;
// Les mnemotechniques des relations sont:;
// GNH pour generation d'hypothese;
// CONF pour confirmation d'hypothese;
// ELIM pour elimination d'hypothese;
// GEN pour generalisation d'hypothese;
// SPEC pour specialisation d'hypothese;
// RPB pour raffinement de probleme;
// ***************************************************************************;

User_Relation{Signature:2,Concept,Concept};
LA_Relation{Signature:2,Concept,Concept};

Strategie_Raisonnement_Relation{Signature:2,Concept,Concept};

SR_Hypothese_Relation{Signature:2,Concept,Concept};

Recherche_Hypothese_Relation{Signature:2,Concept,Concept};
Generation_Hypothese_Relation{Signature:2,Concept,Concept};
Suggere_Hypothese_Relation{Signature:2,Concept,Concept};
Indique_Hypothese_Relation{Signature:2,Concept,Concept};
```

LA_pertedeControle;
LA_PCLorsDepassement;
LA_manoeuvreImpromptue;
LA_MITourneAGauche;
LA_confusionManoeuvre;
LA_CMTourneAGauche&Depassement;

LA_carrefour;

LA_elementVehicule;
LA_retrovisseurs;
LA_angleMortRetrovisseurs;

LA_elementEnvironement;
LA_buissons;

6.1.4. Concept types for INFRA1

```
// *****************************************************************;
// Les types de concepts de l'expert ingenieur infra  - INFRA ;
// *****************************************************************;
```

LA_Road_Accident_Analysis_Concept_INFRA1;
LA_iVehicule;
LA_iAccotement;
LA_iEtatInfra;
LA_iEtatRoute;
LA_iMarquage;
LA_iAdherence;
LA_iDeformationRevetement;
LA_iGeneVisibilite;
LA_iGeneCirculation;
LA_iAccoutumanceInfra;
LA_iReseauRoutier;
LA_iRouteNationale;
LA_iRouteDepartementale;
LA_iZone;
LA_iZoneTransition;

LA_donneesFurtives;
LA_donneesObjectives;
LA_donneesAggravantes;

LA_hypotheseCirculation;
LA_hypotheseAccoutumanceInfra;
LA_hypotheseReseauRoutier;
LA_hypotheseZone;
LA_hypothesePlanOccupation&PlanCirculation;

LA_conducteurFatigue;
LA_effectueTachesAnnexes;

```
LA_pbInterpretation;
LA_pbInterpretationSignalisation;
LA_mauvaisePriseInformations;
LA_vitesseParAmusement;
LA_vitesseExcessive;
LA_pointsDurs;
LA_pointsdeRupture;
LA_masqueVisibiliteTemporaire;
LA_panneauxAmbigus;
LA_usurePneus;
LA_usurePlaquettesFreins;
LA_usureAmortisseurs;
LA_propretePareBrise;
LA_jeuDirection;
LA_reglageRetrovisseur;
LA_etatdeSurface;
LA_bosses;
LA_creux;
LA_flaquesdEau;
LA_dosdAne;
```

6.1.3. Concept types for PSY2

```
// ********************************************************************;
// Les types de concepts de l'expert psychologue - PSY2;
// ********************************************************************;

LA_Road_Accident_Analysis_Concept_PSY2;

LA_iMasqueVisibilite;
LA_iEtatSante;
LA_iHeuresdeRepas;
LA_iTempsdeReaction;

LA_donneesSures;
LA_donneesPeuSures;

LA_hypotheseExperienceConducteur;
LA_hypotheseSanteConducteur;
LA_hypotheseTempsdeReaction;
LA_hypotheseHeuresRepasConducteur;

LA_conducteurSurpris;
LA_conducteurSomnolent;
LA_prisedeMedicaments;
LA_repasCopieuxBienArrose;
LA_effetsSecondairesSurVigilance;
LA_effetsSecondairesSurConduite;
LA_repertoireSituationsLimite;
LA_diversiteSolutionsLimitee;
```

```
LA_signalisation;
LA_panneaux;

LA_iSignalisation;


// **************************************************************************;
// Les types de concepts communs a l'expert psychologue PSY2 et a l'ingenieur infra INFRA1; ;
// **************************************************************************;

LA_natureObservationsAccident;
LA_conducteurEndormi;
```

6.1.2. Concept types for PSY1

```
// **********************************************************************;
// Les types de concepts de l'expert psychologue - PSY1;
// **********************************************************************;

LA_Road_Accident_Analysis_Concept_PSY1;
LA_natureFacteur;
LA_fAggravant;
LA_fPotentiel;
LA_fTerminaux;
LA_fEtatSurface;
LA_fSignalisation;
LA_fPointsDurs;
LA_fPointsRuptures;
LA_fPrisedeRisques;

LA_iEtatdeSurface;
LA_iMasqueVisibiliteTemporaire;
LA_iContexteConducteur;

LA_hypothesePriseInformation;
LA_hypotheseInterpretation;
LA_hypotheseComportementConducteur;

LA_conducteurPresse;
LA_conducteurRigide;
LA_conducteurPlusFacilementSurpris;
LA_pasEvocationConnaissancesAlternatives;
LA_evacueInfoContreAttenteConducteur;
LA_conducteurExperimente;
LA_absorptionDrogues;
LA_meconnaissancesLieux;
LA_vitesseConduite;
LA_risquesObliges;
LA_pbPriseInformations;
```

```
LA_hypothese;
LA_hypotheseAccident;
LA_hypotheseInfra;
LA_hypotheseVisibilite;
LA_hypotheseConducteur;

LA_situation;
LA_processus;
LA_evenement;
LA_accident;
LA_accidentRoutier;

LA_etat;
LA_etatAccident;
LA_etatConducteur;
LA_comportementConducteur;
LA_erreurConducteur;
LA_etatVehicule;

LA_etatInfra;
LA_pbInfra;
LA_pbVisibilite;

LA_interpretation;
LA_strategie_de_Raisonnement;
LA_diagnostic;


// **************************************************************;
// Les types de concepts communs a PSY1 et PSY2 - les 2 psychologues ;
// **************************************************************;

LA_fcvi;
LA_fInfra;
LA_fVehicule;
LA_fConducteur;

LA_icvi;
LA_iInfra;
LA_iExperienceConducteur;

 LA_experienceConduite;
LA_conducteurNonExperimente;

LA_pbMasqueVisibilite;


// *******************************************************************;
// Les types de concepts communs a l'expert psychologue PSY1 et à l'ingenieur
// infra (INFRA1);
// *******************************************************************;
```

6 Appendices

6.1 Concept Types

The following sections give the concept types that the experts use, and as extracted from partial analyses of some protocols. As mentioned in section 3.2.2., it is by no means an exhaustive list but rather a first sketch. Furthermore, a number of these concept types are themselves quite complex and are formed of canonical concept types.

The concept types presented here come from the file KB.INRETS which is used by the tool CGKAT. Each concept has a prefix LA_ to identify the person who inserted the concept (in this case the user Laurence Alpay). Each user concept is given in French.

6.1.1. Common concept types

```
// *************************************************************************;
// Types de concepts de la typologie commune aux experts - PSY1, PSY2 et INFRA1;
// Les noms des types de concepts sont en francais;
// ************************************************************************;

LA_Road_Accident_Analysis_Concept_Commun_Experts;

LA_entite;

LA_objetPhysique;

LA_vivant;
LA_humain;
LA_conducteur;

LA_nonVivant;
LA_vehicule;
LA_voiture;
LA_infraStructureRoutiere;

LA_entiteMobile;
LA_entiteNonMobile;
LA_localite;

LA_proposition;

LA_observation;
LA_observationAccident;
LA_facteur;

LA_indice;
LA_iConducteur;
```

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representations or whether transformation of these representations has to occur. In this context of multiple expertise, our interest in particular is on in the comparison between experts from the same specialist or from different specialities (e.g. vehicle engineer, psychologist) at the level of their inferences in terms of their reasoning strategies. Our work within the ACACIA project provides a basis for discussion within the working group of the LHM-ESF programme.

GRAFIA:

Our work on conceptual graphs has led us to participate in the CG project called GRAFIA [17], a national action of PRC-GDR IA (Programme de Recherches Coordonnées- Groupe De Recherche in Artificial Intelligence). The accidentology is a good application domain, where issues related to conceptual graphs (such as the building typologies of concept types and relation types and the CGs) are addressed.

INRETS

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do the anchorages, the order in performing the task of creating a concept or a graph and so on.

2. *Types of users:* It would be useful to have two running modes available. 1) An ”authoring” mode for the designer of ontologies. In this case, the user would be able to modify the typologies, and the user’s concept types would be viewed as it is now (e.g. LA_indice). 2) A ”reader” mode for end-user of the tool. In this context, the user would be able to visualise the typologies, without the author of the concept (e.g. concept indice is viewed rather than LA_indice), and with more details (e.g. expert identification, document, context).

On building CGs:

Example set: A few graphs have been implemented with CGKAT, and further work would involve constructing additional graphs.

On exploiting CGKAT:

1. *Link with documents:* CGKAT aims at constructing CGs from documents. We could use extracts of protocols or protocols analysis to link with the CGs of reasoning strategies.
2. *Queries mechanisms:* with the collection of CGs at hand, the next step would be to exploit the queries mechanisms, that is, the information retrieval mechanisms provided by CGKAT.
3. *Use of functionalities:* Further tests should be carried out to explore the various functions provided by the tool (this is related to the above points 1 and 2).

4.3 Related research actions

The work carried out here has been related to two external research programmes, described below:

ESF-LHM programme:

The programme of the European Science Foundation (ESF) called "Learning in Humans and Machines" (LHM) has a subtask on “"Multiobjective learning with multiple representations" [3]. This subtask is concerned with learning processes based on multiple representations in the context of one or more tasks/objectives. One of the sub-group where we belong is interested in particular on “Transformation versus coordination of representations". This sub-working group is concerned with the fact that humans and machines can learn from different sources, resulting in multiple representations. Initially these representations may be independent, resulting in suboptimal performance. The question this sub-task force deals with is whether optimization of performance of a system is the result of coordination of these multiple

2. *Set of reasoning strategies:* We reused an initial set of reasoning strategies from medical problem solving to model cognitive processes in accidentology. However, there are in fact additional strategies which are derived from the initial ones (e.g. over specialisation, under generalisation). Further work could be to exploit those additional strategies for the modelling activity.

3. *Domain-oriented strategies:* It is clear that there is a wider range of reasoning processes used by the experts. For example, we found that "hypothesis generation" can be in fact elaborated as a two step process, an explication of mechanisms and an explication of factors. It could be interesting to investigate how domain-oriented strategies are related to the more generic strategies.

On the models of reasoning strategies:

1. *Dynamics of the models:* The models we proposed are static. That is, at present, there is no temporal criterion to indicate the dynamics of the models. The dynamic aspect is closely linked to the interaction of strategies. This is an issue which we strongly investigated in medical problem solving. Further work could be to use it as a basis to study the interactions of the strategies in accidentology.

2. *Comparison for multi-expertise:* We have built the models within the same framework, and provided initial elements of comparison for these models. Thus, this seems to be a basis for continuing the comparison of expertise in terms of the reasoning strategies.

On building the typologies of concept types:

1. *Compound concept types:* the concept types which are composite need to be refined and decomposed into canonical ones, and definitions need to be provided. For example, LA_usurePneus (wear of the tires) means that the tires are wore, and thus what is expressed here is the property of the tires; the definition graph being [LA_pneus]→(ATTR)→[LA_usure]→(Value)→[True].

2. *Validation of the concept types and typologies:* This is a necessary step that would need to be carried out in order to have accurate and sound typologies.

3. *Integration with existing typologies:* a number of typologies for the experts has been developed [9] e.g. typology of crossroads for PSY2. We need to integrate our typologies within the ones which already exist.

On constructing the typologies with CGKAT:

1. *Specifications:* We reported our experience in using CGKAT and provided some feedback. The next step is to put together specifications to help the user to construct his/her typologies. These specifications should include, for instance, how to

experts. Our basis was a) the protocol analyses performed in ACACIA, for three experts (two psychologists and an infrastructure engineer), and b) our previous work carried out on modelling medical reasoning strategies. For each expert, we built a model of reasoning strategies. The limitations of this modelling work include a) the small number of experts considered and b) the partial use of the protocol analyses. Initial results show that:

1. the set of reasoning strategies selected from the medical problem solving can be successfully reapplied in another diagnostic problem solving task. In other words, this means that these strategies are generic enough to account in the reasoning of two diagnostic tasks. It is clear that the context of applying those strategies differ given the domain and plays a significant role.
2. The models of reasoning strategies indicate that the experts tend to share common reasoning processes. These models provide insights for comparing the expertise of the different specialists.

The second activity was to represent results of our modelling task with the conceptual graph formalism, and to use CGKAT, a CG-oriented tool, developed in ACACIA. We built typologies of concept types and relation types (for the reasoning strategies). Moreover, we specified a set of CGs bases in order to represent, with the graphs, reasoning strategies applied by the experts.

We used CGKAT as a tester/user rather than an end-user. A selected set of functions were tested, including those to browse through the typologies and to build conceptual graphs. The typologies put forward as well as the CGs bases constructed with the tool are not complete. However, they provide the skeletons for future work on extending and improving the typologies and on adding graphs in the CGs bases.

4.2 Further work

Directions for future work include the following:

On the expertise involved:

1. *Types of experts:* We modelled reasoning strategies for 3 experts who represent two kinds of specialists in accidentology (psychologist and infrastructure engineer). This modelling task should be extended to the third type of specialist, namely, the vehicle engineer.

On the reasoning strategies for the accidentology:

1. *Example set:* For some reasoning strategies (like specialisation or confirmation), we found limited examples of application of such strategies. This is due, in part, to the fact that we exploited partial sections of the protocol analyses. Further work would involve extending the set of examples.

”road bump” *(dos d’âne),* it could be any one existing. Moreover, as mentioned before, we have not given type definitions for the compound concept types.

The graphs we built are of the type Proposition. Some of those graphs (see CGs bases of interpretations and of hypotheses) link either:

1. two abstractions, where the abstractions are not data from the brief but generated by the expert e.g. ”problem of hidden visibility” *(problème de masque à la visibilité)* with ”hypothesis of visibility” *(hypothèse de visibilité).* Given some clues, the expert has thought of ”problem of hidden visibility” *(problème de masque à la visibilité).*

2. two abstractions, where one of the abstraction may in fact have already been an interpretation in the brief e.g. ”driver is in a hurry” *(conducteur pressé);* the other abstraction being for instance ”clue for the driver experience” *(indice de l’expérience du conducteur).* For example, the conductor interviewed on the accident site may say that he/she was in a hurry to an appointment, or while asking him/her questions, the person taking notes may conclude that the driver was in hurry and wrote it down in the brief.

3. an element of the real world with an abstraction e.g. “road bump” *(dos d’âne)* with “clue of temporary hidden visibility” *(indice de masque à la visibilité temporaire).*

Other graphs (see CGs base of reasoning strategies) link two abstractions previously built (see points 1 to 3 above).

On manipulation of CGKAT:

In section 3.3.2. and section 3.3.3., we detailed our use of the tool for building the typologies and the graphs. Here, we give a general comment on using CGKAT. Our use of the tool was an interactive process with the developer. Upon starting CGKAT, functionalites are run using the mouse and the keyboard. The browsing of the typologies of concept types and relation types is easy and the response time is acceptable. To search for a concept, the user has to type the full name. The possibility to search separately a concept type in WordNet or in the user’s typologies is useful, especially when the user only works on his/her typologies. The building of conceptual graphs with the tool requires a number of mouse and keyboard manipulations.

4 Conclusions

4.1 Summary of the results

Two main activities have been carried out.

The first activity was to model reasoning processes in accidentology. Within that domain, we selected the task of searching for clues, as this task is shared by the are that the use of the CGKAT typologies will help to document the concept types, to add coherence, and to enrich the user's own typologies (e.g. to name a concept, to define a concept or to structure the typology). In our context, we have been able to validate some of those hypotheses, for example concerning the clarification of concept definitions, the non ambiguity of concept names, and the documentation of typologies. The process of linking some of our concept types with CGKAT concept types led to question some of the concept types (which need to be decomposed or reformulated). It is clear that further testing with the tool would involve checking and exploiting those hypotheses.

2. *Types of anchorages:* The anchorage process takes three aspects into account. i) The user identification (e.g. Laurence Alpay). At the moment, we have put LA_ followed by the concept name, but in the future, there will only be the concept name; the fact that it has been entered by LA would be described somewhere else as a concept type. ii) The kind of expert being represented (e.g. the psychologist or the infrastructure engineer) which was done in the current typologies. iii) The domain of expertise which we represent (e.g. accidentology). We initiated this by adding the concept Road_Accident_Analysis_Concept under the CGKAT concept Concept_Used_in_an_Application.

3. *Validation of the user's typologies:* The typologies of concept types proposed were not validated by the experts. The validation of the concept types and the typologies of concept types will ease the anchorage task.

On building conceptual graphs:

We used conceptual graphs in order to represent static knowledge. We did tackle the problem of reasoning with CGs. The graphs we built represent instantiations of generic inferences with the domain knowledge.

We proposed a set of CGs bases i.e. for intepretation of data, for hypotheses, for diagnoses and for reasoning strategies. These are the starting ones we believe are a core basis for our representation with CGs of reasoning processes in accidentology. Other CGs bases such as CGs base of facts have to be added to contain facts from the brief such as LA_pertedeControle *(loss of control)* (see section 4.2). In the CGs bases of interpretations and of hypotheses, the graphs represent how a datum from the brief is viewed by the expert. The relation ROLE was used to do so. Indeed, a datum is given a role by the expert - as a clue or an hypothesis for instance. The CGs base of reasoning strategies was built using the graphs from other CGs bases. Thus, we took a modular approach in constructing the CGs base of reasoning strategies.

We exploited a restricted part of the CG formalism. For instance, we worked with generic concept types rather than individual concept types. This is due, in part, to the fact that the CGs were built from protocol analysis based on free conversation interview rather than on specific case studies. In the former type of interview, the expert did not usually refer to a specific accident. Thus, when the expert talks about a

3.4 Discussion

We worked towards establishing some of the requirements and specifications for representing reasoning strategies using conceptual graphs. As a computerised CG support, we used the tool CGKAT.

On building the typologies:

For the typology of concept types: we have put forward a set of typologies i.e. a typology common to the three experts, and a typology specific to each expert. We view the typologies of concept types we have built as a skeleton upon which further concept types can get integrated (see section 4.2).

The top level of concept types of our typology is based on the one of Sowa. The number of concept types are limited given the scope of the work here. However, some concept types are compound; this means that by decomposing those concept types in more canonical ones, the typologies can be in fact augmented with additional concept types. One of the difficulties encountered was that of classifying concept types, in particular, complex ones, extracted from the analyses of protocols. It seems that a decomposition of compound concept types into canonical ones will imply to restructure some parts of the typology. In order to do so, it seems important to keep the context in which concepts were extracted.

Furthermore, the building of the typologies of concept types for different experts raise relevant research issues such as the construction of the multiple ontologies, as well as the semantics behind those compound concept types.

For the typology of relation types: we proposed a hierarchy of relation types based on our set of reasoning strategies. This provided us with an initial structure from which other reasoning strategies may be attached (see section 4.2). As to the CGKAT relation types, we mainly used the relation ROLE. We did not use other relations which would help to define compound concepts (such as relations CHRC or LOC among others).

On using CGKAT to construct the typologies:

Regarding the use of WordNet, we linked some of our concept types with its concept types (IS-A link). For others of our concept types, it was not always possible to find a suitable definition.

Regarding the anchorages of the user's typologies of concept types and relation types to CGKAT ontologies, the following remarks need to be made:

1. *Needs for CGKAT anchorage:* The user has the choice between taking into account the already existing typologies or ignoring them. The hypotheses made here

Example of a graph for the CGs base of hypotheses (see Figure 15.) where “problem of hidden visibility” *(problème de masque à la visibilité)* is considered as an hypothesis for this expert.

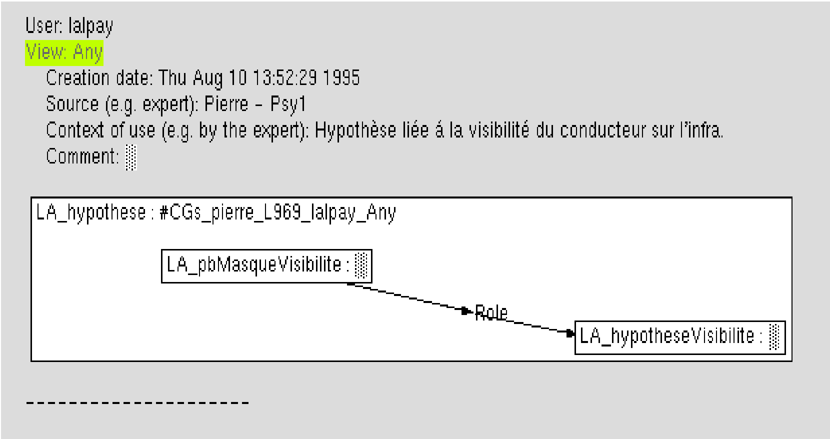


Figure 15. Example of a graph from the CGs base of hypotheses for PSY1

Example of a graph from the CGs base of reasoning strategies (see Figure 16.): we have the strategy of hypothesis generation, with the clue “road bump” *(dos d’âne)* and the hypothesis “problem of hidden visibility” *(problème de masque à la visibilité)*. This graph is in fact composed of a graph from the CGs base of interpretations and a graph from the CGs base of hypotheses (shown above).

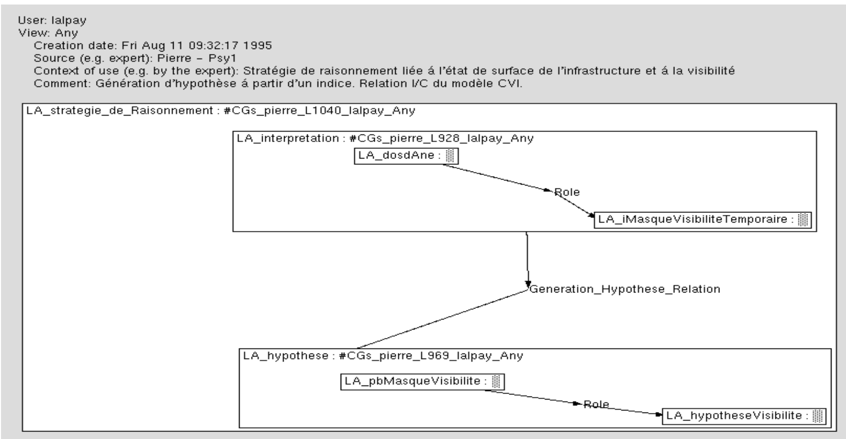


Figure 16. Example of a graph from the CGs base of reasoning strategies for PSY1

Each section of the document represents a CGs base (e.g. CGs base of interpretations). Each CGs base is made of a list of graphs. The user creates new graphs or can also copy an existing graph and paste it into the referent of a concept of the type LA_interpretation for instance.

For each graph that the user built, a number of information are specified (see examples below):

1. *User* to identify the user who created the graph.
2. *View* to indicate which view is chosen (e.g. goals, knowledge categories); the default view is AnyView when the representation is not relative a special view.
3. *Creation date* to specify the datewhen a graph is created.
4. *Source* to indicate for which expert this graph is associated with; *Context of use* to report how this graph is used.
5. *Comment* to enter other information related to the graph. The first three pieces of information are generated automatically. The others are entered as free text by the user.

Moreover, each graph which is created has a unique identification (e.g #CGs_PSY1_L928_lalpay_Any) which is generated automatically and specifies its author, for which expert and which view.

Example of a graph for the CGs base of interpretations (see Figure 14.), where the datum “road bump” *(dos d’âne)* is taken as a clue “clue for hidden visibility” *(indice de masque à la visibilité).*

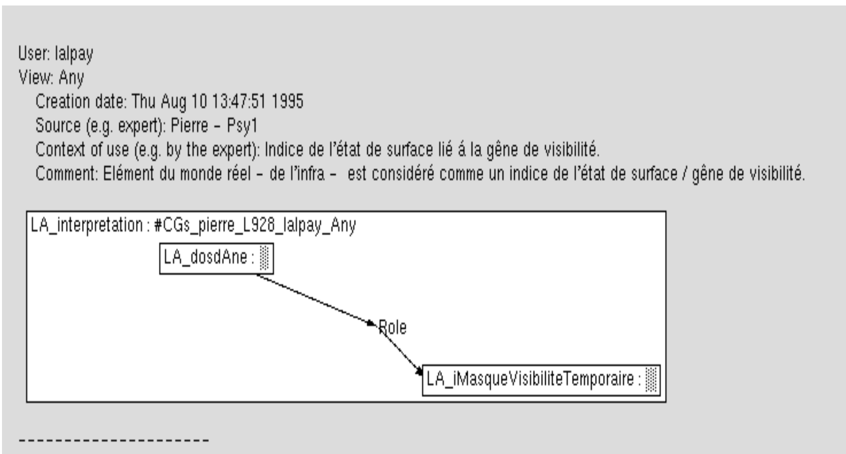


Figure 14. Example of a graph from the CGs base of interpretations for PSY1

we have in the typology the following: LA_flaquesdEau<W_pool__puddle. The link between a CGKAT concept type and the user's concept type is an KIND-OF link.

It should be stressed here that only a limited number of the user's concept types have been linked within the WordNet ontology. The main reason is that a good number of the user's concept types are in fact compound ones (see section 3.2.2.). Thus, without a definition of those concept types with graphs, it is not always possible to find the appropriate WordNet super types for them (see section 4.2).

For the typology of relation types (see Figure 13.): we have linked our top level relation type with the CGKAT relation types. It was linked a) to the CGKAT relation type called User_Relation under which the relation types of the users are put; b) to the CGKAT relation type called Relation_IfThen, concerning the inference mechanism on the graphs (see section 3.2.3.).

Browsing and modifying the ontologies:

Once the typologies of concept types and relation types were built within the editor, we use CGKAT to browse (view and search) for specific concept types or relation types.

For the typology of concept types, the user can search for a concept type from the WordNet ontology or a concept type from her lattice (e.g. all the concept types starting with LA_). The user can easily browse through the hierarchy of concept types and relation types. Given our approach for building the ontologies, any modification of the concept types, relation types is done via the editor (i.e. the file KB.INRETS is modified).

3.3.3. Constructing CGs with CGKAT

Once the typologies of concept types and relation types were entered into CGKAT, the bases of CGs (see section 3.2.4.) were built. These two activities can be done in parallel or on phase. The CGs bases that we have constructed (with the CGKAT tool) contain about seventy graphs as our aim was to put together a framework for the CGs bases, and to give a set of examples as a starting point to build additional conceptual graphs. For each expert, we regrouped all the CGs base into one document. Examples of conceptual graphs built with the tool for the different CGs bases are shown in Figure 14. and Figure 15.

In order to construct the conceptual graphs for an expert, we first created a new document. We took this approach rather than regrouping, for each CGs base, all the graphs of the three experts in a individual document. This is due to the fact that Grif handles better intra-document inclusions than inter-document inclusions. In Grif, an inclusion of an element is a copy of its target element, and an hypertext link connects the inclusion and the target element. This copy is "alive" in the sense that all changes made in the target element are automatically reflected in the copy.

For the typology of concept types (see Figure 12.): We have regrouped concept types common to the three experts and common to experts in peer. At the leaf type level, the user can see the leaf types possessed by the three experts. However, it has not been done for the higher level concept types. For example, when clicking on the concept type LA_pbMasqueVisibilite, the user can see that both PSY1 and PSY2 use that concept, while at present, when clicking on LA_pbVisibilite (a higher level concept), the tool does not indicate which expert knows it. This is an issue for further work in constructing the typologies with CGKAT (see section 4.2).

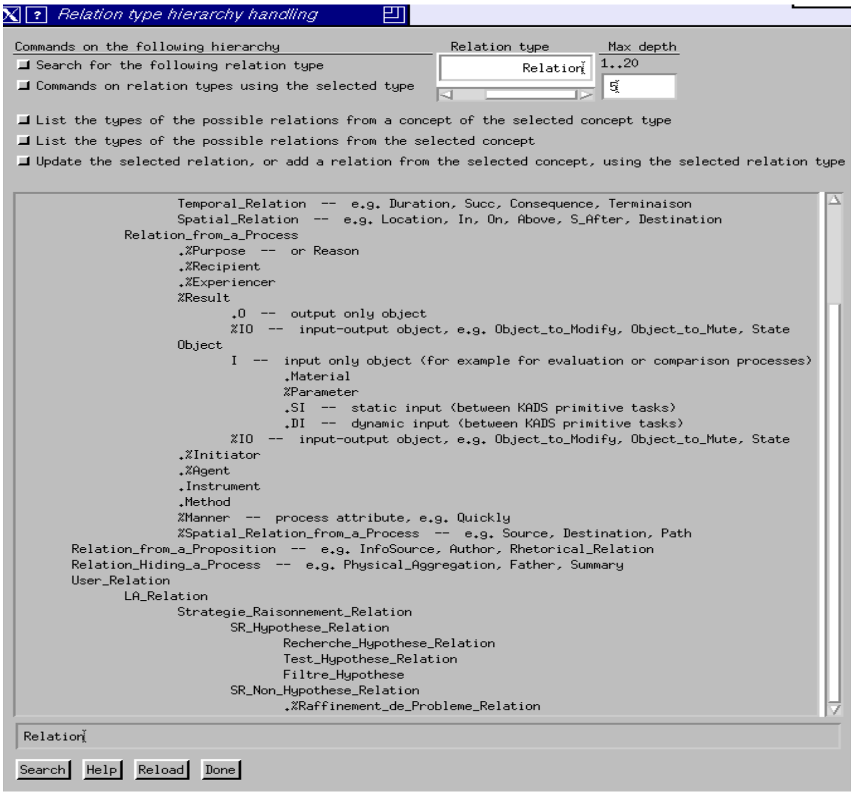


Figure 13. Excerpts of the typologies of relation types from CGKAT and the usert

We also had to link the top level of our typology with concept types proposed by CGKAT. This was done in cooperation with the developer of the tool (this is related to the issue of concept anchorages with CGKAT discussed in section 3.4). Whenever it was possible, we searched for a WordNet concept type to be a super type of one of our concept types. For example, the WordNet concept type W_pool__puddle is set as a super type of our concept type LA_flaquesdEau. Thus,

Approach for building the user's typologies:

In constructing both kinds of typologies (of concept types and of relation types), we had the choice between doing it (a) directly with the commands in the interface, or (b) using an editor (such as emacs) which can be useful for the person testing the tool. The typologies we built are gathered in a file called KB.INRETS.

Building the user's typologies and integration within CGKAT ontologies:

In order to build the typologies (with the editor), we had to specify the concept types and relation types (for each expert), and their order in the hierarchy.

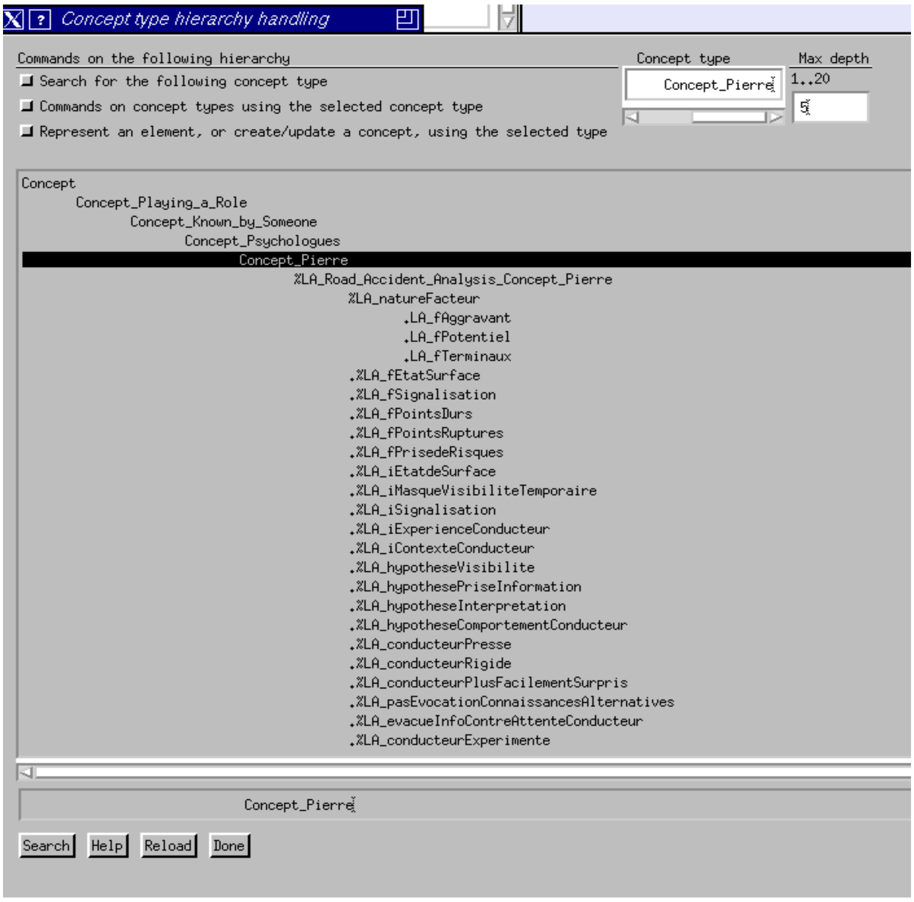


Figure 12. Excerpt of the user's typologies of concept types

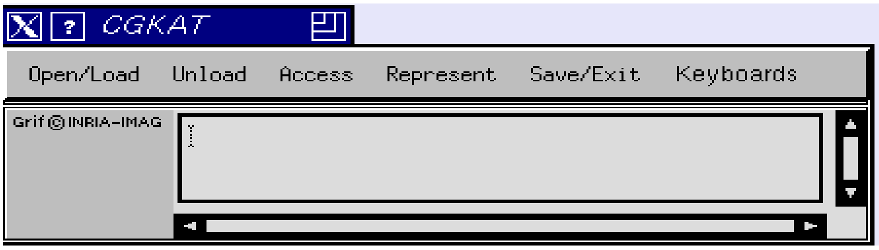


Figure 11. Main menus of CGKAT

Testing Criteria:

Our approach to test the tool was informal with the developer of the tool. As said, the tool helps the user to build conceptual graphs exploiting electronic documents. A first task is to construct the typologies (of concept types and relation types), and the graphs. A second task is to set the links between the documents and the graphs. These two tasks can be carried out in parallel or in phase. Our focus has been on the first task. Thus, we limited ourselves to use a specific and numbered set of functionalities. We did not exploit the links between a document and the graphs, although it was tested independently by the developer.

Our requirement was that the tool should provide functionalities a) to build the typologies of concept types and relation types, and to be able to view and manipulate those typologies, and b) to build and manipulate conceptual graphs based on those typologies. Furthermore, we were interested in providing initial feedback on some ”ergonomical aspects” of the software. This relates, for instance, to the naming of the functions, the easiness of using the tool, and so on.

3.3.2. Constructing typologies with CGKAT

CGKAT ontologies:

Our aim was to build the typologies of concept types for the three experts, and the typologies of relation types for the reasoning strategies (see section 3.2). CGKAT proposes to the user a top-level ontology which includes important high level concept types useful for natural language and knowledge acquisition. For the typology of concept types, the skeleton is mainly made of the top level concept types of Sowa. This skeleton is complemented by the top level concept types of WordNet; additional concept types coming from other ontologies (e.g. CYC [30]) have been integrated into the CGKAT ontology. Similarly, for the typology of relation types, relations from Sowa have first been taken and structured, complemented by additional relations from other ontologies (e.g. from CYC). There are about two hundreds of concept types and the same number of relations.

[LA_Diagnostic:

[LA_Hypothese:

[LA_pbInterpretation]→(ROLE)→[LA_hypotheseInterpretation]]

].

3.3 Using the CGKAT tool

3.3.1. The CGKAT tool

Presentation:

CGKAT (Conceptual Graph Knowledge Acquisition Tool) has recently been developed in the ACACIA project [31], [32]. The purpose of this tool is to help the user build conceptual graphs exploiting electronic documents (e.g. documents of expertise in accidentology). The tool lets the user manipulate and represent elements of a document (such as a word, a group of words, a paragraph, a section and so on). CGKAT manages links between elements of a document and the associated conceptual graphs. These links can then be exploited, for instance, for a hypertext navigation between knowledge based systems and documents.

CGKAT reuses and exploits existing software packages: 1) GRIF, a structured document editor developed at INRIA [38]; 2) CoGITo, a platform to build conceptual graphs, developed at LIRMM (France) [16], [28]; 3) WordNet, a public domain on-line lexical reference system developed at Princeton University [34].

Scope in using the tool:

The reasons for using such a tool in our study include the following:

1) CGKAT is a dedicated tool for conceptual graphs, and we were in need of a software to support the building of our CGs bases and typologies.

2) CGKAT has only been recently developed (including design and implementation). We used that tool as a a ”user/tester” rather than that as an ”end-user”; our position was an intermediate between the developer and a future knowledge engineer.

Upon starting CGKAT, the user gets a set of main menus (see Figure 11.): some of them allow to browse through the typologies of concept types and relation types, and to view the expert’s document containing graphs.

hypothesis generation, CGs base for problem refinement and so on).

[LA_StrategiedeRaisonnement:
[LA_Interpretation:
[LA_dosdAne]→(ROLE)→[LA_iMasqueVisibiliteTemporaire]]
→(Relation_Generation_Hypothese)→
[LA_Hypothese:
[LA_pbMasqueVisibilite]→(ROLE)→[LA_hypotheseInfra]]
].

This above graph contains other graphs. The graph [LA_Interpretation: [LA_dosdAne]→(ROLE)→[LA_iMasqueVisibiliteTemporaire]] comes from the CGs base of interpretations, and the graph [LA_Hypothese: [LA_pbMasqueVisibilite]→(ROLE)→[LA_hypotheseInfra]] from the CGs base of hypotheses. The whole graph [StrategieRaisonnement: ...] belongs to the CGs base of reasoning strategies.

A graph which contains the relation types

- (Relation_Generation_Hypothese), (Relation_Specialisation_Hypothese) or (Relation_Generation_Hypothese) means that an hypothesis will be added to the CGs base of hypotheses.

- (Relation_Confirmation_Hypothese) means that the hypothesis will be added to the CGs base of diagnostics.

- (Relation_Elimination_Hypothese) means that an hypothesis will be supressed from the CGs base of diagnostics.

- (Relation_Raffinement_de_Probleme) means that an observation (taken in the general sense) will be added to the CGs base of interpretations.

For example, let us take the reasoning strategy given above: the relation Relation_Generation_Hypothese, being a subtype of the relation Relation_IfThenAddition_Hypothese, indicates that an hypothesis (the target one of the relation) needs to be added to the CGs base of hypotheses.

4. ***Base of Diagnoses*** which contains graphs representing hypotheses/mechanisms which have been confirmed by the expert as part of the accident scenario. For example, the expert may consider the hypothesis of ”problem of interpretation” *(problème d’interprétation)* to be included in the accident scenario. In this base, we also keep trace of the hypotheses which have been eliminated.

pes* are detailed in the appendix 6.2 and the appendix 6.3.5. The hierarchy of relation types is based on classification presented in section 2.3.1. The actual construction using the CG based tool in presented in section 3.3.2.

3.2.4. Bases of CGs

The conceptual graphs we want to manipulate expressed two different things: :

1. A CG which represents a complex concept such as for instance ”driver is in a hurry” *(conductor pressé)*. Thus, we have the graph [ConducteurPressé] or [Conducteur] → (MANR) → [Pressé]. This raises the issue of providing definitions for complex concept types. As said before, this task has not been carried out yet and it is certainly an area for further work (see section 4.2).
2. A CG which represents a reasoning strategy (see below the example for hypothesis generation - point 3 ”Base of Reasoning Strategies”).

We have defined a number of bases of CGs. Each kind of CGs in the bases are subtypes of the concept type Propositiom. These are:

1. ***Base of Interpretations*** which contains graphs representing data from the brief and taken as clues or factors. For example, we can have the graph

   [LA_Interpretation:

   [LA_dosdAne]→(ROLE)→[LA_iMasqueVisibiliteTemporaire]].

to express the fact that the datum ”road bump” *(dos d’âne)* is considered by the expert as a clue ”clue for hidden visibility” *(indice de masque à la visibilité).*

2. ***Base of Hypotheses*** which contains graphs representing hypotheses/mechanisms generated by the expert. For example, we can have the graph

   [LA_Hypothese:

   [LA_pbMasqueVisibilite]→ (ROLE)→[LA_hypotheseInfra]].

to express that ”problem of hidden visibility” *(problème de masque à la visibilité)* is considered by this expert as an hypothesis concerning Infrastructure.

3. ***Base of Reasoning Strategies*** which contains graphs representing reasoning strategies applied by the expert. For example, we can have the strategy of hypothesis generation, with the clue ”road bump” *(dos d’âne)* and the hypothesis ”problem of hidden visibility” *(problème de masque à la visibilité).* This CGs base is divided into sub-bases, each corresponding to a reasoning strategy (e.g. CGs base for

* Like for the concept types, the relation types are named in French.

the concept types ObservationAccident, HypothesesAccident, EtatAccident and InfraStructureRoutiere. We used the results of the modelling activity to integrate this expert's concept types within the more generic types. The construction of the typologies for the experts PSY2 and INFRA1was similar to the construction of the typology of PSY1.

A few relevant remarks need to be made regarding the building of the typologies.

1. **Basic vs compound concept types:** A number of concept types are compound concept types (e.g. LA_meconnaissancesLieux). Intuitively we can easily decompose them into canonical concept types. As a first sketch to build these typologies, it seems important to remain as close as possible to what the expert wanted to express. For instance, a compound concept may in fact indicate an interaction within the CVI system. As a further work, it is evident that it will be necessary to decompose those complex concept types. Building typologies of concept types is an ongoing research problem as exemplified in [4], [14], or for the validation process in [22].
2. **Multiple ontologies:** By building more than one typology for several experts, the problem which is raised is that of the construction of multiple ontologies, and of the matching between those typologies. Our approach has been incremental as we have first built the typology of PSY1 and from that one we have subsequently built the typologies of PSY2 and INFRA1. The issue of multiple ontologies has not been addressed in our present work. This is a research problem for further work, already investigated in ACACIA [20], [21] and in the GRAFIA project [27].

3.2.3. Typology of relations

We have two kinds of relation types:

1) Conceptual relations given by Sowa [43] which help to describe compound concept types. This includes the relations such as characteristic (CHRC), location (LOC).

2) Conceptual relations which help to describe the reasoning strategies that we have modelled. This includes relation types such as hypothesis generation, specialisation and so on. The conceptual relations for reasoning strategies are directly linked to rules of expertise that we represent with CGs (i.e. the reasoning strategies). The goal is that in the future a mechanism of inferences will be integrated in order to activate those rules. Thus, in anticipation to that, we also created conceptual relations, subtypes of the relation Relation_IFThen to indicate to the inference mechanism whether to add or suppress CGs in the various CGs bases (e.g. whether to add or suppress an hypothesis from the CGs base of hypotheses). The typology of relation ty-

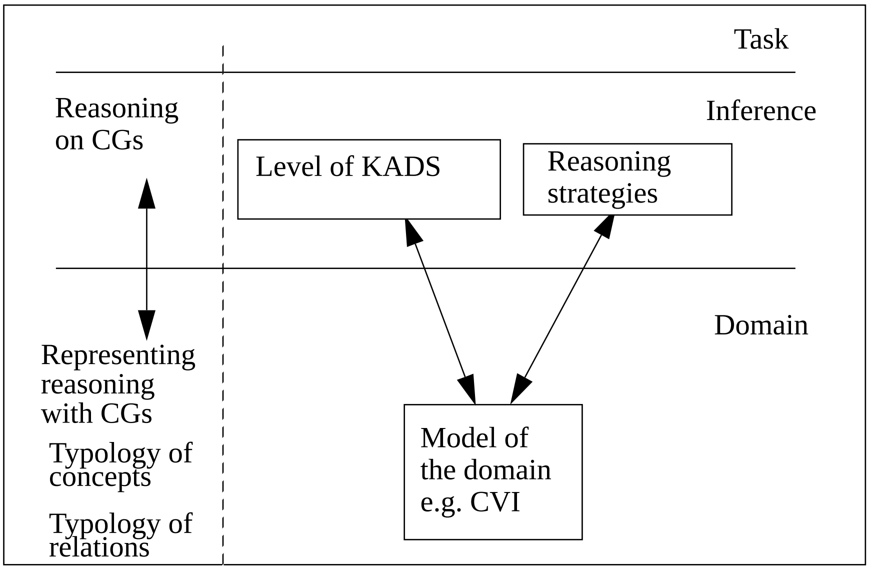


Figure 10. Reasoning and CGs

3.2.2. Typology of concepts

We have constructed typologies of concept types for the three experts. These typologies are by no means exhaustive, but rather reflect the concepts encountered during our modelling of reasoning strategies, in the context of the search for clues. The typologies of concept types are detailed in the appendix 6.1 and the appendix 6.3; the construction of the typologies using the CG-based tool is described in section 3.3.2.

Our approach to build the typologies of concept types has been as follows:

1. **Common typology:** We have constructed a top level hierarchy of concept types, common to the three experts. For the concept types not specific to the domain, the common typology stems from the one given by Sowa (e.g. include types such as PhysicalObject, MobileEntity, State, Event and so on). Using top-level typology of Sowa has provided us with a framework for developing the typologies.

For the general concept types related to the domain of accidentology (such as vehicle, conductor), we took a rule-of-thumb approach. For more specific concept types related to the domain (such as LA_erreurConducteur) shared by the three experts, this was an iterative process closely related to the building of the experts' typologies.

2. **Typology of PSY1:** The typology of PSY1 was the first of the three specific typologies to be built. The starting point was to take some of the generic types of the common typologies and to specialise them. The set of generic types includes

constraints on graphs and to eliminate absurd graphs. The possibility to use the canonical graphs to construct new ones is performed by applying operations such as ”copy of a graph”, ”restriction of certain concepts in a graph”, ”joining two graphs”, or ”simplifying a graph”.

Conceptual graphs have been applied in various domains [35], [45], among others at the Geneva University Hospital for the treatment in natural language from medical texts [11], [40], [41]. This formalism has unified and formalised in a rigorous way, ideas in the research on semantic networks, frames and scripts. The strong points of the representation of conceptual graphs include the good expressiveness, and the naturalness of the formalism which facilitates the reading and the visual understanding of the information expressed through the formalism.

3.2 CGs for the accidentology

3.2.1. Scope

In ACACIA, conceptual graphs have been used to formalise techniques of comparing several knowledge graphs at the domain level of KADS model of expertise [18], [21]. Moreover, CGs are also used for knowledge acquisition exploiting documents [32], [33].

In the context of the work reported here, one of the research problem addressed is whether one can formalise problem solving methods such as reasoning strategies with the representation of conceptual graphs. The basis for this task is the result from our modelling work (see section 2). Our approach to use conceptual graphs to formalise reasoning strategies in accidentology includes the following tasks:

1. Building a typology of concepts, for the three experts PSY1, PSY2 and INFRA;
2. Building a typology of relations for the reasoning strategies;
3. Specifying the bases of conceptual graphs;
4. Constructing the typologies and the graphs using CGKAT.

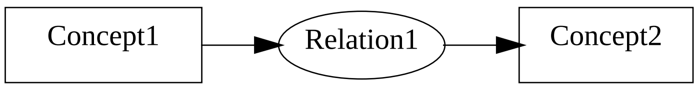
It is worth stressing that the work we report here on conceptual graphs is centred around representing reasoning *with* CGs and not reasoning *on* CGs (see Figure 10.). The problem of reasoning on CGs is studied by other members of ACACIA. The following sections present the specifications for developing the typologies and conceptual graphs. Their actual construction using a CG-based tool is described in section 3.3.

sented. Section 3.3 reports on the utilisation of the CGKAT tool for our representation activity. Discussion on representing reasoning strategies with CGs is found in section 3.4.

3.1 The conceptual graph formalism

The theory of conceptual graphs was developed by Sowa [43] and finds its foundations in linguistics and psychology. It is a system of logic based on the existential graphs of Pierce [37], and on semantics networks of Artificial Intelligence. The purpose of the system of conceptual graphs is to express meaning in a form that is logically precise, humanly readable and computationally tractable. In particular, the theory is important for natural language processing.

A conceptual graph is a finite, connected, bipartite graph. That is, there are two kinds of nodes: concepts and conceptual relations. Concepts and relations are based on language-independent semantic principles. Concept nodes represent entities, attributes, states and events, while relations nodes show how these concepts are interconnected. The graphical and linear representations of a graph are shown in Figure 9.



[Concept1] →
(Relation1) → [Concept 2]

Figure 9. Graphical and linear representation of a conceptual graph

The direction of the arrows indicates how to read the graph. In Figure 9., it is done by reading the relation name and the concepts attached to it as the english phrase ”Relation1 of Concept1 is Concept2” or as ”Concept1 has a relation1 which is Concept2”.

A concept has two fields: a type and a referent, to distinguish a “class” from an “instance of a class” (e.g. class BOY from Tom the boy). Notations in the referent field allow to take into account certain linguistic aspects such as the definite article. Concept types are organised in a hierarchy according to levels of generality. The theory assumes that this hierarchy is a lattice with a universal type at the top T and an absurd type ⊥ at the bottom.

Moreover, a number of operations on canonical graphs have been defined. Canonical graphs represent possible situations in the real world. This allows to put

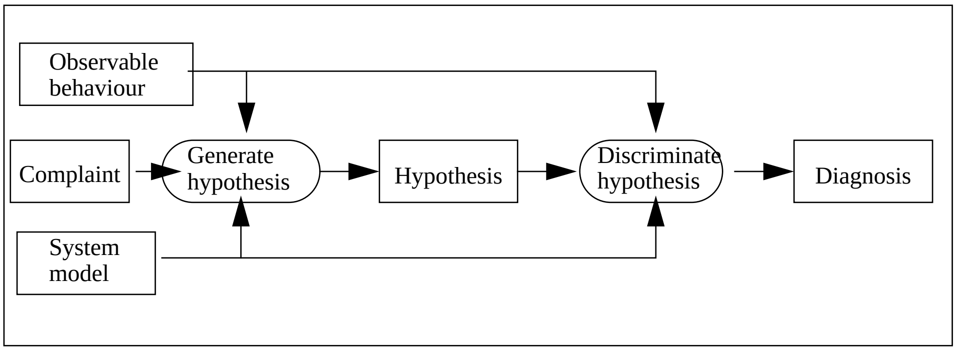


Figure 8. KADS model of expertise:
Diagnosis by generating and discriminating hypotheses

In [12], [13], the diagnostic task is decomposed into three subtasks which can be realised using problem solving methods: 1) symptom detection, 2) hypothesis generation, and 3) hypothesis discrimination. This decomposition is called ”prime diagnostic method”. The author defines the following: A task (i.e. what needs to be achieved) is realized by problem solving methods (i.e. how the goal of a task can be achieved). A method consists of primitive inferences (i.e. an inference that can be carried out using domain knowledge to achieve a goal). A strategy is constituted by a particular configuration of inferences and control knowledge.

The definition of a strategy is more complex than the one we used. Following this above terminology, we view our reasoning strategies as primitive inferences. The input and output roles of such inferences are related to our coding categories (e.g. clue, hypothesis, factor). We have not specified the tasks which reflect the contexts in which reasoning strategies are applied (e.g. analyse the conductor’s interview, analyse the infrastructure checklist). A set of tasks for the accidentology has been defined in [9], and could be used to put in context our reasoning strategies. The interactions of reasoning strategies (not addressed here) would represent part of the control knowledge over those strategies.

3 Representing reasoning strategies using conceptual graphs

This section describes how we represented our reasoning strategies with conceptual graphs, and how we used CGKAT, a CG-oriented tool developed in ACACIA, to support this activity. Section 3.1 briefly presents the formalism of conceptual graphs. Section 3.2 describes the use of CGs to the domain in accidentology. In particular, the typologies of concepts and relations as well as the bases of CGs are pre-

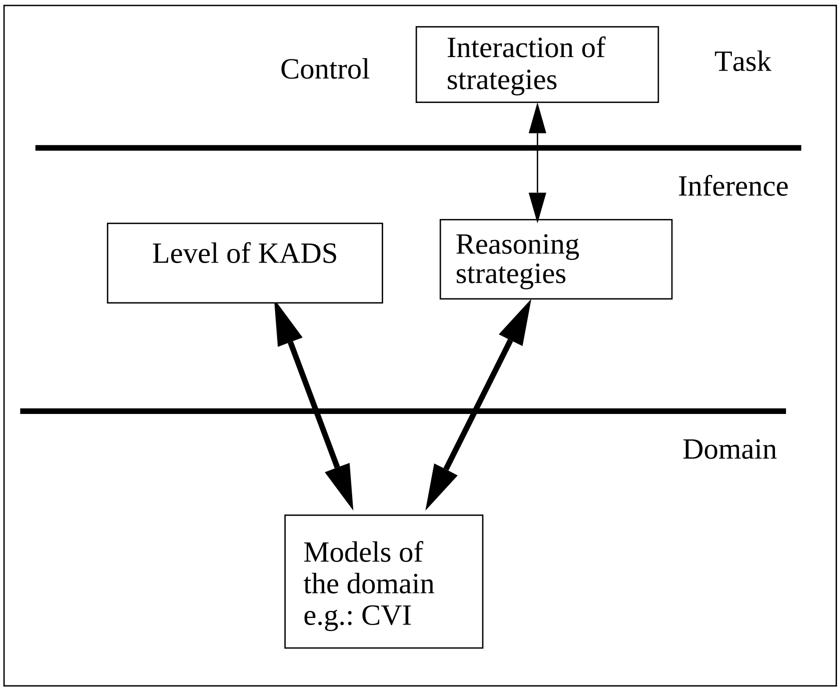


Figure 7. Link between the levels of KADS expertise model and our reasoning strategies

The model of expertise of CommonKADS [15] for diagnosis by “generation and discrimination of hypotheses” provides a frame to support our analogy between the two diagnostic tasks (see Figure 8.). This model gives a good basis within which we can integrate some of our reasoning strategies. From our view point, the knowledge source “generate hypothesis” is similar to our hypothesis generation strategy (from an observation to an hypothesis), whereas the knowledge source “discriminate hypothesis” can be in fact subdivided into the strategies of confirmation and elimination of hypotheses. We see the strategies of specialisation and generalisation of hypotheses to occur as an additional step between “generate hypothesis” and “ discriminate hypothesis”. The CommonKADS model is hypothesis-oriented, and thus problem refinement strategy does not seem to suit within this particular model.

is not of prime concern for the psychologists.

4. The interrelations within the CVI system. Using the schema of interrelations put forward by [9], we can say for instance, that both psychologists tend to favour the relation C/C and I/C, while the infrastructure engineer seems to search more for relations of the types I/I and I/C. This is shown when applying an hypothesis generation strategy. A relation C/C indicates that the expert identifies the state of the driver, and looks for links between the conductor and him/herself, his/her history and so on. A relation I/C reflects the information available through the infrastructure (e.g. road signs). A relation I/I indicates that the expert identifies the type of infrastructure and looks for the influence of any change of the infrastructure on another part of the infrastructure.

According to the type of protocols i.e. free-conversation vs accident-case interview:

1. In the free-conversation based protocol, the strategies are applied on generic elements such as clues, factors and hypotheses. Examples we have in hand are probably typical ones that the experts refer to at first. In the case-based accident protocol, the expert used a mixture of elements from the specific accident as well as from his knowledge on generic ones.
2. One needs to be aware of differentiating between a diagnosis coming from the problem solving task, and a diagnosis generated from a "performance task" (i.e. the expert shows what he knows). This is a distinction that we have found in interviewing physicians during their medical problem solving task.

On the relation to KADS:

Since CommonKADS techniques are used in ACACIA, and CommonKADS offers models for diagnostic task, it seems interesting to compare our approach with KADS.

By using CommonKADS, the knowledge engineer builds a model of expertise by describing three layers. The domain layer represents static knowledge of the expert and includes the concepts of the domain, their structures, and relations between these concepts. The inference layer is described by inference structures, that is, by networks which link knowledge sources and their roles and show which inferences can be made in this domain. The task layer describes the structures of the task and their decomposition in order to control the inferences of the inference layer.

We have contributed to modelling expertise knowledge at the domain level of CommonKADS expertise model. We propose to view our models of reasoning strategies at the inference level of CommonKADS expertise model (see Figure 7.). The instantiations of the reasoning strategies are done at the domain level. We have not dealt with the task level where we foresee the interactions of the reasoning strategies.

On the models of reasoning strategies:

The characteristics and restrictions of the models of reasoning strategies which we have built include the following:

The models of reasoning strategies are in fact models of inferences for a specific context within accidentology. They have been constructed on a partial analysis of protocols. Moreover, the models are at present *static*. In other words, the models do not describe the dynamics of those strategies. There is no temporal or ordering criterion which would indicate how the strategies are applied, each one in relation to other ones. Nevertheless, we have highlighted some dynamic aspects of the experts' reasoning (see section 2.5.2., section 2.5.3. and section 2.5.4.). The reason for this limitation is that as a first step, we were interested in investigating the application of those strategies to another domain. The interactions of those strategies which would reflect aspects of the dynamics of the models have not been looked at, given the limited time scale for our study. It is certainly one direction for further work (see section 4.2).

In the process of building and validating the models, we have been able to reach a certain common ground of the models for the three experts. This is also an encouraging result for further work on the multi-expertise aspect of the models.

On the multi-expertise:

While we have evidence through the different examples that the three experts apply the selected reasoning strategies, it is also important to investigate the context of application of the strategies, that is, the components of the CVI system which are concerned for each instantiation of a strategy. This is a key point as it may describe or reflect aspects of what makes up the expertise for a given speciality in accidentology. In medical problem solving, we found that the context in which the strategies are applied (and how these strategies interact) is an important criterion in identifying levels of expertise. The variations of the models in accidentology include the following.

According to the type of expert i.e. his speciality, we noticed differences regarding:

1. Categorisation of data. For example, PSY2 classifies data into reliable and unreliable ones, while INFRA1 looks at them as objective or furtive.
2. Focus i.e. the reference (or the non reference) to one of the components of the CVI system. For example, regarding the classification of the clues, the psychologist PSY1 will focus on clues on the conductor and on the infrastructure, whereas INFRA1 will also take into consideration the vehicle component.
3. Level of details i.e. the contents of each component of the CVI system. For example, not surprisingly, INFRA1 provides detailed clues for the road network which

hypothesis there is a set of mechanisms. Thus, this global hypothesis encompasses the mechanisms and their associated factors. The search for clues which leads to the generation of hypothetical mechanisms helps in confirming or eliminating those mechanisms.

2.5.5. Discussion

We have applied a set of generic reasoning strategies found in medical diagnosis to the domain of accidentology, in particular, to the diagnostic of the CVI system. It is clear that given our limited study we cannot draw solid conclusions. Nevertheless, our work can offer further evidence to existing results, and provide interesting insights to complement the general work on the modelling in accidentology. Some initial conclusions are described below.

On the utilisation of the reasoning strategies:

Based on the analyses of protocols that we have used, we have found a number of examples for which those strategies can be applied in accidentology. The *hypothesis generation* is the strategy which is the most applied. This is expected as the hypothesis generation is part of the diagnostic activity. Furthermore, this strategy is divided into sub-processes: a) an explicitation (generation) of mechanism (ExplMecha) and an explicitation (generation) of factors (ExplFact). The relation between those two sub-strategies is variable, depending on the type of the expert. For example, the generation of factors is not so much of concern for PSY1, but is rather a stronger focus for INFRA1.

In addition, it is worth stressing that under the category ”reasoning strategies for search for hypothesis” (see section 2.3.2.), there are variations of hypothesis generation such as ”indique”, suggère” (indicate, suggest), which would need to be taken into account.

Problem refinement occurs at the level of the clues and is triggered by the filtering process shared by the three experts. Even though very few explicit examples of *confirmation* and *elimination* were found, it is evident from the validation sessions with the experts that these two reasoning strategies are not only used but are also necessary for their chain of reasoning. As for the *generalisation* and *specialisation*, we have a few examples. Modelling those strategies was not elaborated as we had at our disposal a limited classification of hypotheses/mechanisms.

We can say that those strategies have been successfully applied for two diagnostic tasks. Given the generic nature of those strategies, this is not a surprising and an unexpected result. However, the further interesting aspect is to investigate the contexts of applying the strategies, that is, for instance, to check the focus of hypothesis generation for PSY1 compared to PSY2 (see discussion below “on relation to multi-expertise”).

- with the focus on the interaction I/C, for example, problem of visibility *(problème de visibilité)* such as difficult visibility, driver not accustomed to drive on this infrastructure, discomfort in driving flow *(gêne à la visibilité, pratique inhabituelle de conduite, gêne à la circulation).*

Strategies applied by INFRA1: we have found examples of

- Hypothesis generation (HGN): generating the hypothesis ”discomfort in visibility” from the clue ”awkward/cumbersome parking” *(gêne de visibilité* from *stationnement gênant).*

- Specialisation (SPEC): generating the hypothesis ”unusual driving habit” from a more general one ”discomfort in visibility” *(pratique inhabituelle de conduite* from *gêne à la visibilité).*

Generalization (GEN): generating the hypothesis ”problem of managing access to roads” from a more specific one “problem of relation between land-use plan and traffic plan” *(problème de gestions des accés* from *problème de correspondance entre le plan d'occupation des sols et plan de circulation).*

- Problem refinement (PREF): refining ”state of the road” with ”types of tracks on the road” *(état de la route* with *types de marquage).*

- Confirming (CONF) and Eliminating (ELIM): confirming or eliminating the hypothesis ”absence d'homogénéité du réseau routier” *(absence of an homogeneous road network).*

Model of reasoning strategies:

Figure 6. presents the model of reasoning for INFRA1 in terms of specific strategies (for examples of clues, hypotheses and factors, see above). The *filtering process* to identify the clues is present as found in the models of PSY1 and PSY2. The starting point is similar to that found in the models of PSY1 and PSY2, with the brief as the source of data, and the expert having at hand a set of predefined scenarios, clues and factors. For INFRA1, a datum is a neutral element, while a clue is part of the coherence of a hypothesis, and a factor which is rarely an isolated element is intrinsically linked to a mechanism. Incidentally, INFRA1 like PSY1 and PSY2 indicates that a clue can become a factor.

The hypothesis generation strategy is also viewed by this expert as taking into account *an explicitation of mechanisms* with *an explicitation of factors.* For INFRA1, a mechanism is a malfunctioning of the CVI system. Mechanisms are almost chronological, that is, they reflect a chain of events with factors linked to such mechanisms. Furthermore, for this expert, there is a global hypothesis, and for this

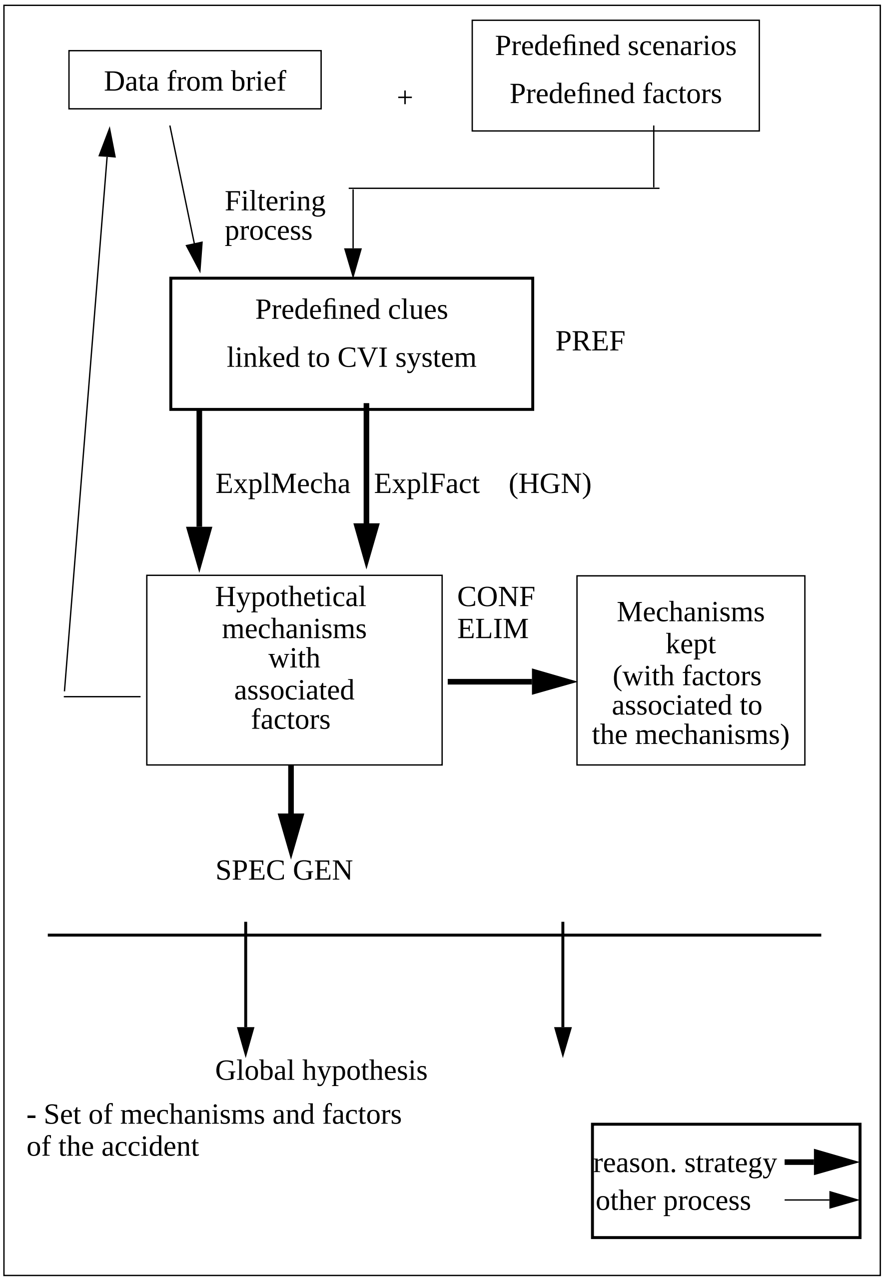


Figure 6. Model of reasoning strategies for INFRA1

2.5.4. Model of reasoning strategies of the infrastructure engineer INFRA1

Context: For INFRA1, the search for clues by the expert is related to the context of the driver, located in his/her own car, in terms of his/her motivations, his/her driving experience and the type of journey.

Coding categories for the strategies:

Clues:

- Clues on driver, for example, driver being tired, driver being sleepy, driver doing something else while driving, conductor does not know his/her journey *(conducteur fatigué, conducteur endormi, conducteur effectuait une tâche annexe, méconnaissance du trajet).*

- Clues on the infrastructure, for example, the characteristics of the sides of the roads, the state of the infrastructure, the state of the road, discomfort in visibility, discomfort in driving flow, road signs, bad grip of tire on road *(caractéristiques /problèmes de l'accotement, état de l'infrastructure, état/problème de la route, gêne à la visibilité, gêne à la circulation, signalisation, adhérence médiocre).*

- Clues on road networks *(réseau routier)*, for example, the characteristics of a national road, chevron boards, road signs indicating a dangerous turn, road tracks of the same width, characteristics of secondary road network *(caractéristiques d'une route nationale, balises avec des chevrons, panneaux qui préviennent du virage dangereux, voies de même largeur, caractéristiques d'un réseau départemental).*

- Clues on areas *(zones)*, for example, transition area - exit from town *(zone de transition - en sortie d'agglomération).*

- Clues on vehicle, for example, state of the tires, state of the shock absorber - used *(état des pneus, état des amortisseurs - usés).*

Factors:

- Types of factors - furtive, objective such as speeds , aggravating such side of the road *(données furtives, données objectives -vitesses pratiquées, données aggravantes - accotement).*

Hypotheses:

- Hypotheses on the infrastructure

- with a focus on the interaction I/I, for example, relation between land-use plan and traffic plan *(correspondance entre plan d'occupation des sols et plan de circulation).*

Strategies applied by PSY2: As in the case of the free-conversation interview, for the accident case-study, we have found examples of :

- Hypothesis generation (HGN) with different focus:

- focus on driver: generating ”different appreciation of speeds” from the clue ”night” *(appréciation des vitesses différentes* from *nuit).*

- focus on the interaction driver/vehicle: generating ”no stop-light on” from the clue ”change of gears downwards without braking” *(pas de feux stop s'allumant* from *rétrograder sans freiner).*

- focus on the interaction infrastructure/conductor: generating the hypothesis ”hidden view of the gas station” from the clue ”set of trees before the gas station” *(masque vue de la station* from *bouquet d'arbres devant station essence).*

- Generalisation (GEN): generating the hypothesis ”comfortable infrastructure” from a more specific one ”large straight roads” *(infrastructure confortable* from *grandes lignes droites).*

- Elimination (ELIM): eliminating the hypothesis ”driving in lines” with the clue ”the Sunny arrives behind the truck and the R21 catches up with it from behind” *(déplacement en file* from *la Sunny déboîte, derrière le poids lourd, et la R21 la rattrape par l'arrière).*

- Confirmation (CONF): confirming the hypothesis ”manoeuvre of turning left” from the clue ”the Sunny hurt on the side” *(manoeuvre de tourne à gauche* from *la Sunny heurtée sur la flanc).*

There was no direct evidence that in the case of accident case-study, PSY2 used specialisation (SPEC) and problem refinement (PREF). Again, given the limited portion of analysis of protocols upon which we have worked, it was not found for the accident case-study but it was found for the free-conversation interview. Furthermore, examples of ELIM and CONF were found in this case.

Model of reasoning strategies (in thinking-aloud case study)*:

PSY2 very quickly generates an hypothesis corresponding to a scenario, given the specific type of infrastructure of the accident and then searches for clues to confirm or eliminate his hypothesis.

The model of reasoning for PSY2 in the thinking-aloud case study is similar to the one in Figure 5. However, differences are shown in the fact that data from the brief, and clues come directly from the specific accident.

* This model was not validated by the expert.

hypothesis is a mechanism which is not confirmed. A mechanism which is confirmed loses its status of hypothesis and becomes a diagnosis. Clues can reveal factors. For PSY2, the process of confirmation and elimination is iterative. There is a loop back to the data from the hypothetical mechanisms which indicates that in the reasoning of the expert there are less hypotheses and thus more confirmed mechanisms.

ACCIDENT CASED-STUDY THINK-ALOUD

The accident case:

The accident happened on a national road, with three lanes; the central lane being non allocated i.e. cars coming from both directions can use the central lane. The accident occurred at night between a Sunny, R21 and a Micra.

The conductor of the Sunny was driving on the right lane. He needed urgently to get gasoline. When he saw a petrol station on the left side of the road, he crossed the three lanes to get to the station. The conductor of the R21, who was at that moment overtaking a car and thus was on the central lane, crashed into the Sunny. The conductor who was coming from the opposite side of the road, also crashed into the Sunny.

Coding categories for the strategies:

Clues:

- Clues on the infrastructure such as night *(nuit).*

- Clues on the vehicle such as ”speed” *(vitesse).*

Hypotheses:

- Hypotheses on the driver e.g. his/her mistakes such as confusion between manoeuvre of turning left and over taking, wrong appreciation of speeds, error of evaluation, no perception of the danger, search for inadequate information, hidden angle from the rear-view mirror not taken into account, unexpected manoeuvre of turning left without warning *(confusion entre manoeuvre tourne-à-gauche et manoeuvre de dépassement, mauvaise appréciation des vitesses, erreur d'évaluation, pas de perception du danger, recherche d'informations inadéquates, angle mort des rétroviseurs non pris en compte, manoeuvre impromptue de tourne à gauche sans avertissement).*

- Hypotheses on the vehicle.

- Hypotheses on the interactions between infrastructure and driver, infrastructure and vehicle, vehicle and driver, vehicle and the driver's actions.

Strategies applied by PSY2: we have found examples of

- Hypothesis generation (HGN): generating the hypothesis ”side-effects on vigilance and on driving” from the clue ”conductor under medication” (*effets secondaires sur la vigilance, sur la conduite* from *prise de médicaments).*

- Specialisation (SPEC): generating the hypothesis “vehicle control loss during over taking” from a more general one “control loss” (*perte de contrôle à l’occasion d’un dépassement* from *perte de contrôle).*

- Problem refinement (PREF): refining “elements of environment” with “bushes” *(élément d’environnement* with *buissons).*

There was no direct evidence that PSY2 used a confirmation and elimination (CONF, ELIM) and generalisation (GEN) strategies. However, like for PSY1, during the validation phase, it appears that those strategies are part of the expert’s reasoning. The greater number of strategies applied belonged to the HGN category.

Model of reasoning strategies:

Figure 5. presents the model of reasoning for PSY2 in terms of specific strategies (for examples of clues, hypotheses and factors, see above). This model shows that from the data, there is a *filtering process* to identify the clues (like with PSY1).

For PSY2, the data are the ones which are available from the brief. The filtering process indicates a meaning of the data. PSY2 makes the distinction between ”reliable” and ”unreliable” data according to the degree of confidence and interpretation of these data. For example, the datum ”length of time that the driver has his/her license” is a secure data, however its interpretation is less reliable as the conductor may have his/her license for a few years but does not drive much or drives on the motorway only once a year.

Unlike in the model of PSY1 (Figure 4.), there is a doubled arrow for the filtering process which indicates a direction of data to clues and back to data to generate more clues. Of course, it does not mean that PSY1 does not perform this process; it rather means that here it was not highlighted by PSY1 in our study. From the clues there is a return to the data for a refinement process. Similarly to PSY1, PSY2 has in his mind a set of predefined scenarios and a set of predefined factors. As we are working here on the analysis from a free-conversation session rather than on an accident case-study, the model contains a set predefined clues (rather than clues coming from one specific brief).

For PSY2, hypothesis generation is a two step process: an *explicitation of mechanisms* and then *an explicitation of factors.* For PSY2, the aim is to look for mechanisms. A mechanism indicates a dynamic interaction within the CVI system. A

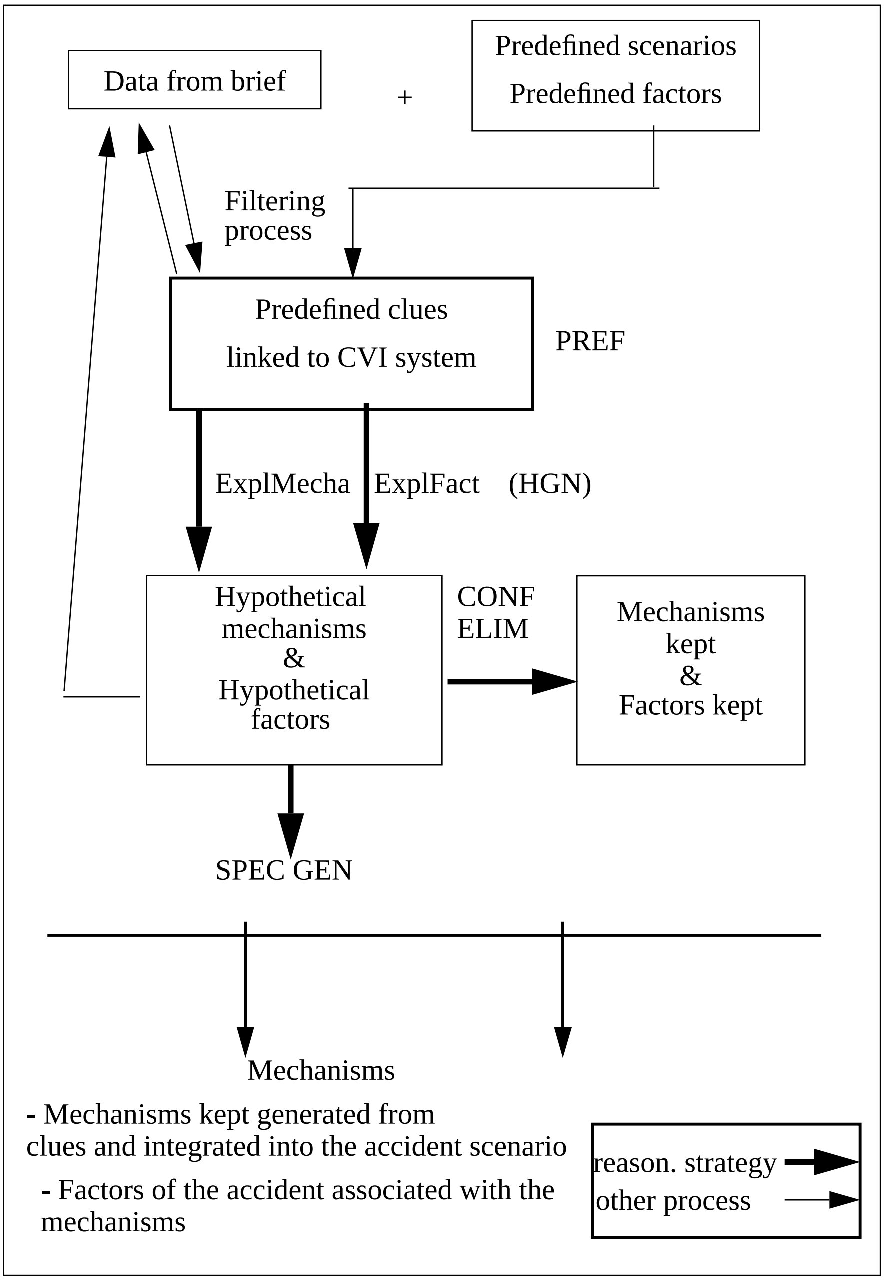


Figure 5. Model of reasoning strategies for PSY2

FREE-CONVERSATION INTERVIEW:

Coding categories for the strategies:

Clues:

- Clues on the driver, for example, the driver's experience, the driver's health - under medication -, mealtimes and eating habits *(l'expérience du conducteur, l'état de santé - prise de médicaments, l'heure des repas).*

- Clues on the infrastructure, for example, hidden visibility, elements of the environment *(masque à la visibilité, éléments de l'environnement).*

- Clues on the place and time of the accident.

- Clues on reaction time *(le temps de réaction).*

Factors:

The factors below, classified within the CVI system as C or V or I, are in fact interactions such as C/I or C/V.

- Factors on the conductor, for example, the driver is drunk *(conducteur en état d'ébriété).*

- Factors on the infrastructure, for example, infrastructure conditions favouring possible confusion between left-turning and over-taking *(conditions infra réunies pour possibilité confusion entre manoeuvre tourne-à-gauche et manoeuvre de dépassement),*

- Factors on the vehicle, for example, hidden angle from the rear-view mirror *(angle mort des rétroviseurs).*

Hypotheses:

- Hypotheses for discomfort in visibility *(gêne de visibilité),* for example, hidden visibility *(masque à la visibilité).*

- Hypothese on the driver's experience *(expérience du conducteur),* for example, the driver not having a large set of situations *(pas grand répertoire de situations).*

- Hypotheses on the driver's health *(l'état de santé),* for example, the driver being somnolent *(somnolence).*

- Hypotheses on mealtimes and habits *(l'heure des repas),* for example, the driver being sleepy after a heavy meal *(endormissement).*

- Hypotheses on the reaction time *(le temps de réaction).*

expert consider those strategies as important in his reasoning. The more numerous strategies applied belonged to the HGN category.

Model of reasoning strategies:

Figure 4. presents the model of reasoning for PSY1 in terms of certain strategies (for example of clues, hypotheses and factors, see above). This model shows that from the data, there is a *filtering process* to identify the clues. The expert has in his mind a set of predefined scenarios and a set of predefined factors (e.g. factors on the driver such as risk taking, on the infrastructure, on the vehicle). As we are working here on the analysis of protocols from a free-conversation session rather than on an accident case-study, we have a set of predefined generic clues (rather than particular clues coming from one specific brief).

For PSY1, working hypotheses are generated from clues. A refinement process takes place with the clues at hand. The interesting point here is that strategy of hypothesis generation is in fact *an explicitation of mechanisms*. This is closely linked to *an explicitation of factors.* The mechanism is a causal link between an initiator element and a malfunctioning (human error, lack of perception). Initiator elements can be factors as well as clues, and are entry elements of the mechanisms. Clues can reveal factors. Factors have an influence on the malfunctioning of the CVI system. In other words, a mechanism concerns the hypotheses (on the malfunctioning) and the factors which led to them. PSY1 does not focus on the factor generation (hence the dotted line on the figure).

Working hypotheses are eliminated and only the strong hypotheses remain (are confirmed). Working hypotheses can be generic as well as more specialised. Given some working hypotheses, there can be a return back to the data from the brief to get more clues and generate further hypotheses.

The diagnostic contains the set of strong hypotheses which are kept. A set of factors is generated along with the confirmed hypotheses on mechanisms, It is worth stressing here that, the scope of our study is the search for clues and the generation of hypotheses related to it. Thus, in the context of our reasoning strategies, we have not investigated further the process of generating factors and scenarios.

2.5.3. Model of reasoning strategies of the psychologist PSY2

Context: For PSY2, the search for clues is centred around mental activities of the conductor.

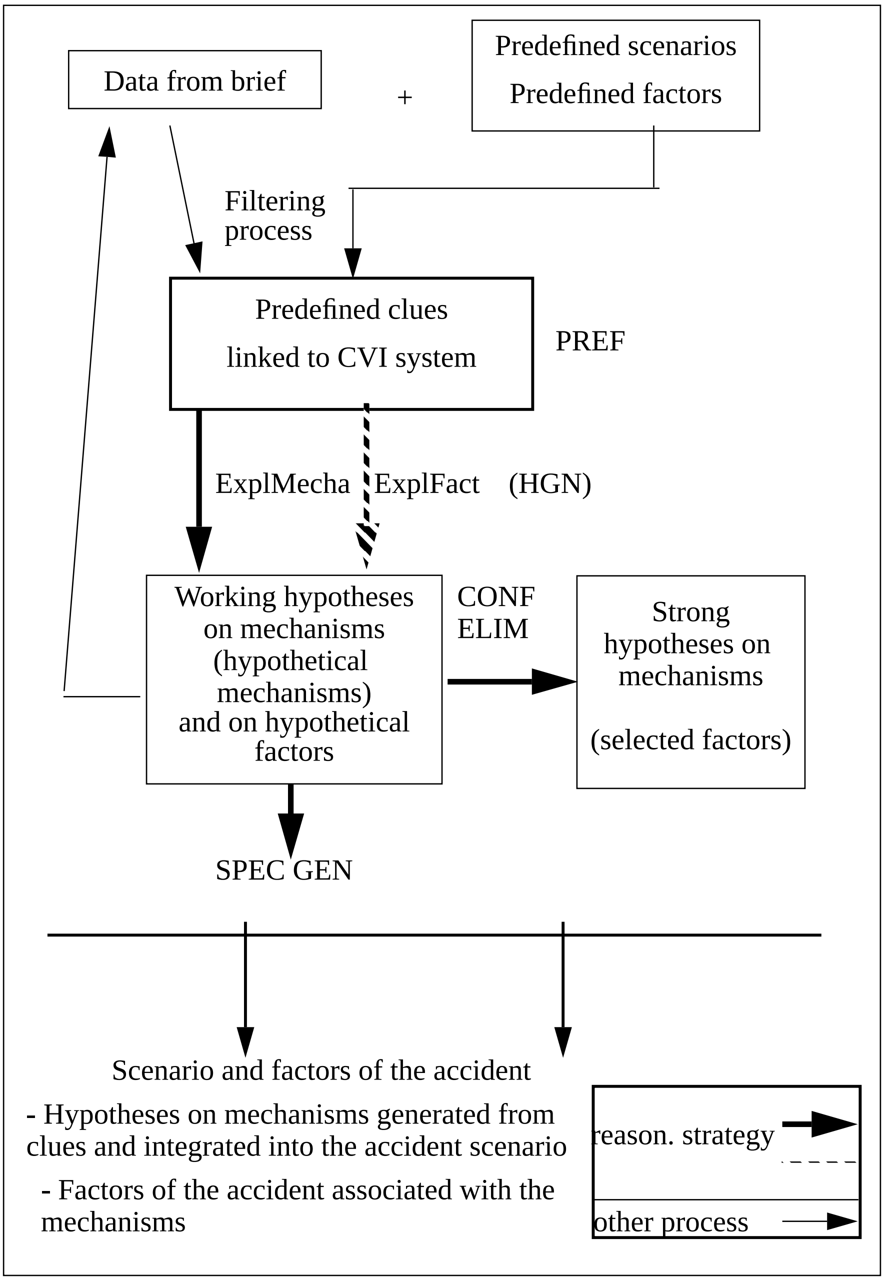


Figure 4. Model of reasoning strategies for PSY1

There was no direct evidence that PSY1 used confirmation and elimination (CONF, ELIM) strategies. However, during the validation phase, it was clear that the

- Factors related to the vehicle, for example, wear of the brake blocks, wear of the tires, wear of the shock absorber, steering looseness, dirtiness of windscreen, adjustment of rear-view mirror *(usure des plaquettes de frein, usure des pneus, usure des amortisseurs, jeu dans la direction, saleté du pare-brise, réglage du rétroviseur).*

- Types of factors such as potential, final, aggravating *(potentiels, terminaux, aggravants).*

Hypotheses:

- Hypotheses of the conductor's behaviour *(comportement du conducteur*), such as the conductor being rigid, the conductor is in hurry, no evocation of alternative knowledge, the driver leaves out information going against his/her expectations *(rigide, pressé, pas d'évocation des connaissances alternatives, évacue des informations qui vont à l'encontre de ses attentes).*

- Hypotheses of problem of visibility *(problème de visibilité)* such as hidden visibility *(masque à la visibilité).*

- Hypotheses of information taking *(prise d'informations)* such as wrongly information taken by the conductor *(mauvaise prise d'informations effectuée par le conducteur).*

- Hypotheses of problem of interpretation *(problème d'interprétation)* such as problem of interpretation related of the road signs *(problèmes au niveau de l'interprétation de la signalisation).*

Strategies applied by PSY1: we have found examples of

- Hypothesis generation (HGN): generating the hypothesis "problem of hidden visibility" from the clue "road bump" (*masque à la visibilité* from *dos d'âne*)

- Specialisation (SPEC): generating the hypothesis "driver did not evoke alternative knowledge" from a more general one "rigid behaviour of the conductor" *(pas d'évocation de connaissances alternatives* from *conducteur rigide).*

- Generalisation (GEN): generating the hypothesis "problem of visibility" from a more specific one "problem of hidden visibility" *(problème de visibilité* from *problème de masque à la visibilité).*

- Problem refinement (PREF): refining "driver factors" with "driver has taken drugs" *(facteurs conducteurs* with *absorption de drogues).*

provide expectations for additional clinical manifestations that should be present if a hypothesis is true for the patient's case, and the findings of the patient are compared to expectations to select among the alternatives. Hypotheses can be restructured or changed as the diagnosis progresses.

2.5.1. Validation of the models of reasoning strategies

The models of reasoning strategies for PSY1, PSY2 and INFRA2 which are presented in the following sections have been validated by the experts. In the validation session, each expert was presented with his model of reasoning strategies, and with examples at hand. Each expert was asked to comment, and the model was modified accordingly. The validation sessions also serve the purpose of examining with the experts some of their concepts (see section 3).

2.5.2. Model of reasoning strategies of the psychologist PSY1

Context: For PSY1, the search for clues is centred around the malfunctioning of the driver on the CVI system. The aim is to check whether clues were detected by the driver, detected but not understood, not taken into account, or not understood.

Coding categories for the strategies*:

Clues:

- Clues of the driver, for example , the driver's experience, the driver's context *(l'expérience du conducteur, le contexte du conducteur).*

- Clues of the infrastructure, for example, the state of the road surface, the temporarily hidden visibility, the road signs *(l'état de la surface, masque à la visibilité temporaire, signalisation).*

Factors:

- Factors concerning the driver, for example, the driver is in hurry, the driver is being under drug absorption, the driver's experience, the driver is not familiar with the place *(être pressé, absorption de drogues, expérience du conducteur, méconnaissance des lieux).* This category of factors also includes risk-taking factor *(prise de risque)* e.g. speeding for fun, risk taken given the constraints of the situation *(vitesse pour amusement, risque obligé compte tenu des contraintes de la situation).*

- Factors related to the infrastructure, for example, the state of the road surface, bumps, holes, puddles, road bumps, road signs, ambiguous signposts *(l'état de surface, bosses, creux, flaques d'eau, dos d'âne, signalisations, panneaux ambigus, points durs, points de ruptures).*

* We have worked with French experts and thus we have kept in French references to the clues, the factors and the hypotheses. We have given a translation, trying to keep as close as possible to the semantics.

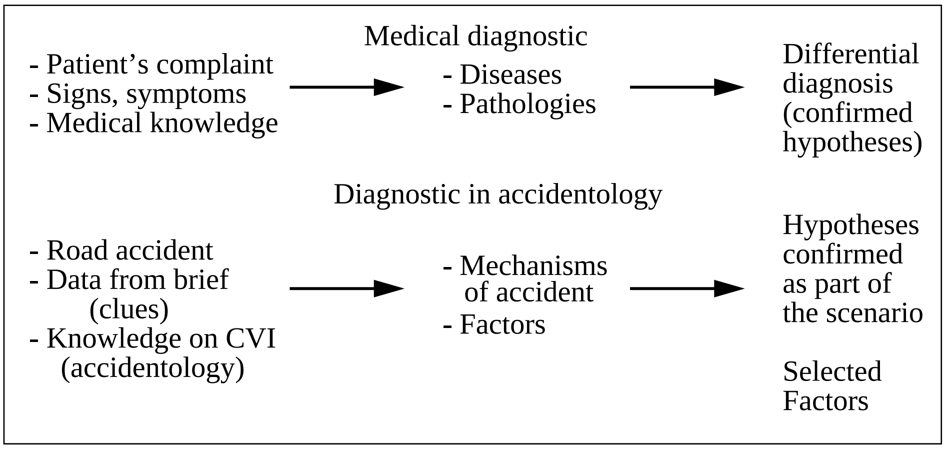


Figure 3. Diagnostic in medicine and in accidentology

2.5 Building models of reasoning strategies in accidentology

Problem solving methods, specifically the reasoning processes represent an important aspect of the experts's cognitive resources. In this context, different research work has been carried out and in various domains such as physics [42] or medicine [2]. Within the framework of the work reported here, we will refer to the medical domain and to our previous work on modelling medical reasoning processes.

Medical problem solving refers to processes by which physicians make medical diagnoses. It has been studied from different approaches. Numerical models have provided ways in which medical information can be manipulated to reach the most likely diagnosis. In contrast, psychological models have provided a better way to understand and describe the medical diagnosis process. Within the psychological approach, medical problem solving has been studied from four perspectives: 1) the generic form of medical problem solving which corresponds to a hypothesis generation and testing type of model [23], 2) the contents of medical problem solving which emphasizes on the medical knowledge used in the reasoning [24], 3) the medical problem solving viewed as an interactive process of case understanding [26], [36], and 4) the development of medical problem solving which focuses on the evolution of problem-solving given the level of expertise [29], [39], [2] (for full discussion see [2]).

The generic form of medical problem solving is an interesting model for our study in accidentology. In this model it is suggested that clinicians use early clues to generate sets of tentative hypotheses for the patient's condition. These hypotheses are then used to structure and guide further interrogation on the case. Hypotheses and looks for clues about the driver’s behaviour and history which may be linked to the origins of the accident.

Experts have at their disposal *data from the brief* (e.g. the accident happened at night), some of which will be viewed as *clues*. The goal is to generate possible explanations (or *mechanisms/hypotheses*) to identify the causes of the accident.

We view the diagnostic task as part of the overall activity of analysing the accident. Thus, in complement to the hypotheses generated during the diagnostic task, the expert aims at the end at identifying a *scenario* which can account for the accident, along with a possible set of *factors* upon which actions can be taken in order to avoid such accident in the future.

2.4.2. Diagnostic in medicine

Medical problem solving refers to the physician solving his/her own diagnostic problem. The *patient case* (also referred to as the patient's problem) contains the initial complaint of the patient.

The physician handles *observations* (also called *findings*) i.e. medical facts about a patient which can be viewed as the direct evidence from which hypotheses about possible diagnoses are generated and tested. This evidence can be either a sign, a symptom or a test result.

The physician generates *hypotheses* as part of his/her medical problem solving task, that is, a disease or a more general disease category or any pathological problem. Any problem that the physician thinks is the cause of the patient's pain (e.g inflammatory problem) can be considered as a hypothesis.The *differential diagnosis*. constitutes the list of hypotheses that the physician is considering as a possible solution to the diagnostic problem. *Medical knowledge* includes knowledge about the diseases, signs, symptoms as well as reasoning knowledge.

2.4.3. Diagnostic in medicine vs diagnostic in accidentology

Figure 3. summarises the two diagnostic tasks: In medical diagnosis, the starting point is the patient’s complaint, the patient’s signs and symptoms, whereas in accidentology, it is the accident and some data in the accident. Both diagnostic tasks rely upon knowledge, either medical or accidentology knowledge as well as strategic/reasoning knowledge. The physician will search for diseases or pathologies explaining the patient’s condition, and the expert in accidentology will look for mechanisms, clues and factors which account for the accident. The physician will select hypotheses which he/she has generated as part of his/her differential diagnosis, while the expert in accidentology will select hypotheses of mechanisms and of possible factors as part of the overall scenario of the accident.

history of the patient, check palpation of the back); and 2) Phases of the consultation which include history, physical examination, investigations.

2.3.4. Re-use of coding categories for the accidentology:

We listed above some of the coding categories which were used to encode medical protocols and thus to extract and model the reasoning strategies in medical problem solving. In accidentology, we also need to code categories to model the reasoning strategies. However, the difference is that, 1) as explained in section 2.2.1., we used analyses of protocols rather than the protocols themselves. Re-use of coding categories includes the categories Hypothesis, Sign and Symptom (the last two closely relate to Datum and Clue), whereas additional categories specific to the accidentology include Factor and Mechanim.

The set of coding categories that we put for our reasoning strategies in accidentology is shown below:

1. Datum: an element/information from the brief. More generally speaking, a datum is taken as an observation (whatever role it is given for the specific accident).
2. Clue: a datum from the brief, viewed by the expert as pertinent.
3. Factor: a datum, the presence of which was necessary for the accident to happen and upon which actions are possible for safety purposes.
4. Mechanism: malfunctioning / functioning which plays a role in the accident (closely related to factors).
5. Hypothesis: a candidate for explaining the causes of the accident. Related to mechanism.
6. Diagnosis: a set of hypotheses (mechanisms) which has been selected to explain the accident.

2.4 Diagnostic

Both medical diagnosis and diagnosis in accidentology belong to the class of diagnostic task and as such tend to share common aspects. In the following, we will draw similarities with both diagnostic tasks.

2.4.1. Diagnostic in accidentology

The diagnostic task in accidentology consists of determining the malfunctioning within the three components of the CVI system, the conductor, the vehicle and the infrastructure (see section 2.1). Depending on the speciality of the expert (e.g. psychologist vs vehicle engineer), the links and their interpretations between the three components vary in nature and importance. For example, the expert psychologist may tend to focus on the property of the driver (i.e. relation C/C of the CVI system). This relation C/C exists when the expert tries to identify the state of the driver, Generating a specific hypothesis from a more general one e.g. “driver lost the control of his/her vehicle during overtaking” *(perte de contrôle durant un dépassement)* from “driver lost the control of his/her vehicle” *(perte de contrôle).*

1.3) Reasoning strategies for testing hypothesis:

• Confirmation (CONF): (hypothesis, evidence)

Validating a hypothesis based on evidence and including it in the set of confirmed hypotheses within the accident scenario e.g. “loss of control of the vehicle” *(perte de contrôle)* with the evidence of “tracks of the vehicle on the road” *(traces du véhicule sur la route).*

• Elimination (ELIM): (hypothesis, evidence)

Ruling out an hypothesis based on evidence, and excluding it from the accident scenario e.g. “problem of hidden visibility” *(problème de masque à la visibilité)* if no presence of “elements of infrastructure masking the visibility” *(élements de l’infrastructure masquant la visibilité).*

Evidence here can be a data from the brief, taken as a clue for that accident (e.g. it was a night accident).

2) Non hypothesis-oriented reasoning strategies:

• Problem refinement (PREF): (observation, refined-observation)

Refining the event of the accident by gathering more details (e.g. refining the state of the car at the time of the accident). No hypothesis is generated using this reasoning,

2.3.3. Coding categories in medical problem-solving:

In our previous study in medical problem solving, the reasoning strategies were extracted from the experts’ protocols, using a set of coding categories. We list a few of them here:

1. Hypotheses which correspond to diseases of back pain and any problem that the physician considers as the cause of the patient's pain (e.g inflammatory problem).
2. Symptoms (e.g. pain) which are subjective sensations reported by the patient, or any other information that the patient gives to the physician.
3. Signs (e.g. patient’s age, patient is a smoker, patient looks pale) which are objective and observable by the physician.
4. Differential Diagnosis contains the current hypotheses (i.e. the working set of diagnoses) generated by the physician for the patient’s case.

There are two additional coding categories which are: 1) Goals which are decisions taken during the consultation (e.g. check about location of the pain, check pothesis generation. Each strategy is defined as follows (the examples are from the domain of back pain):

• Generalisation (GEN): generating a general hypothesis from a more specific one (e.g. *mechanical cause of back pain* from *prolapsed intervertebral disc*).

• Specialisation (SPEC): generating a specific hypothesis from a more general one (e.g. *disc prolapsed* from *mechanical cause*).

• Confirmation (CONF): validating a hypothesis based on evidence and including it in the differential diagnosis (e.g. *confirming disc prolasped if there is tenderness*).

• Elimination (ELIM): ruling out an hypothesis based on evidence, and removing it from the differential diagnosis (e.g. *eliminating disc prolasped if there is no bony tenderness*).

• Problem refinement (PREF): refining the problem presented by the patient by gathering more details (e.g. *refine pain to acute pain, or, refine patient case by asking about social history*).

• Hypothesis generation (HGN): generating one hypothesis from a symptom, signs or test results (e.g. *disc prolapsed* from *pain in lower back*).

2.3.2. Re-use of reasoning strategies for the accidentology:

Each strategy re-used for the accidentology is defined in a similar way as the ones found in medical problem solving (see section 2.3.1.). We have grouped them as follows:

1) Hypothesis-oriented reasoning strategies which include sub-categories:

1.1) Reasoning strategies for searching for hypothesis:

• Hypothesis generation (HGN): (clue, hypothesis)

Generating one hypothesis from a clue e.g. the hypothesis “problem of hidden visibility” *(problème de masque à la visibilité)* from the clue “presence of a bush” (*présence de buissons).*

1.2) Reasoning strategies for filtering hypothesis:

• Generalisation (GEN): (hypothesis-specific, hypothesis-general)

Generating a general hypothesis from a more specific one e.g. “problem of visibility” *(problème de visibilité)* from “problem of hidden visibility” *(problème de masque à la visibilité).*

• Specialisation (SPEC): (hypothesis-general, hypothesis-specific) perts' activity of searching for clues (see section 2.2.1.)

3. The models of reasoning strategies which were constructed were validated by the experts.

These three steps are detailed in the subsequent sections.

2.3 Reasoning strategies

Reasoning strategies can be classified as domain dependent and domain independent strategies. The former category includes strategies directly related to the domain (e.g. anatomical, pathological and physiological strategies in the medical domain), while the latter category contains strategies that can be used to solve other kinds of problem solving (e.g. diagnosis of a faulty circuit) as well as a medical problem.

For our study of the reasoning strategies applied in accidentology, we used the domain independent ones of the medical problem solving. In the following sections, we first present the reasoning strategies used in medical problem-solving and then how we re-used them in accidentology.

2.3.1. Reasoning strategies in medical problem-solving:

In the context of medical diagnosis, a reasoning strategy is used to refine the details of the patient's case and to generate one or more hypotheses which correspond to a diagnosis. A medical reasoning strategy is related to how one makes inferences between findings (e.g. signs, test results) and diseases. In using a medical reasoning strategy, the physician makes a decision about what move to make in the current state. This decision describes a choice between two or more actions and the move is based on the physician's knowledge.

We make a distinction between reasoning processes such as forward or backward reasoning and reasoning strategies such as generalisation or hypothesis generation. Forward and backward reasoning are concerned with the direction in which to conduct the search through the space (e.g. the domain of back problems), either top down or bottom up. In contrast to forward and backward reasoning, reasoning strategies result in a search space (e.g. possible hypotheses for a back pain problem) and reflect the degree of specificity of the solution i.e. choice of a hypothesis for medical diagnosis.

In the medical problem solving literature, we identified a set of reasoning strategies, and we refined them. These strategies* are domain generic and based on generalisation, specialisation, confirmation, elimination, problem refinement and hy-

* The refinement of some of the domain generic strategies such as the strategy over-generalisation have not been exploited in the current study.

the generation of hypotheses to explain the accident. The reasons for this choice are as follows:

1) The phase of knowledge elicitation of expertise from these experts in accidentology had begun a few months ago and was carried out by members of ACACIA-INRIA and of University Paris V. Modelling models of expertise in accidentology was already in progress at the time of starting the research project reported here. Thus, we have based our modelling task on already existing analyses of verbal protocols, in particular related to this specific activity.

2) This activity of searching for clues is an important aspect in the analysis of the accident, and is shared by the various kinds of experts.

3) The activity of searching for clues is related to the generation and testing of hypotheses, and as such is closely linked to the diagnostic task in which we are interested.

2.2.2. The experts involved

Members of the ACACIA team have worked with a group of seven experts from INRETS: two psychologists, two vehicle engineers and three infrastructure engineers. Experts were interviewed alone or in group. The protocols which were collected were of three types: free-conversation session (non directive), think-aloud case study by one expert only (individual problem solving), think-aloud case study by a group of experts (collective problem solving).

For our study, we based our work on:

1) the protocol analysis of two psychologists (we will refer to those experts as PSY1 and PSY2). For PSY1, the protocol analysis was based on the free-conversation interview, while for PSY2 it was based both on the free-conversation session as well as on the specific case studies.

2) the protocol analysis of one road infrastructure engineer (we will refer to that expert as INFRA1). For INFRA1, the protocol analysis was based on the free-conversation session.

2.2.3. Methodology

Our approach for modelling reasoning processes in the domain of accidentology includes the following steps:

1. Our starting point is the work we have carried out on modelling medical diagnostic processes [2]. We have re-used selected reasoning strategies applied in the medical problem solving, and tailored those strategies to another domain of diagnostic i.e. the diagnostic of the CVI system in accidentology.

2. Based on the protocol analysis of experts done in the ACACIA project and with those reasoning strategies in hand, we have constructed models of reasoning strategies. The examples of application of those reasoning strategies focus on the ex-

1.1) Data gathering which takes place on the site where the accident happened. The information which is collected includes, for example, the interviews with the drivers involved in the accident, and technical data related to the cars and to the roads. Data gathering is carried out by investigators, who have their own domains of specialities.

1.2) Kinematics analysis. This phase aims at identifying the movements of the vehicles involved in the accident e.g. their positions, speed and acceleration.

The brief includes the synthesis of the accident, which constitutes the result of the pre-analysis.

2) Treatment of the brief. This phase contains the analysis of the accident *per se* by the three types of experts from INRETS. The experts use the brief for carrying out a detailed analysis of the accident (including thematic studies).

It is important to stress that both phases of preparation and treatment of the brief form one process. In other words, both steps cannot be dissociated from one another. Thus, this means that the persons responsible for the preparation of the brief (i.e. investigators) not only need to follow a check-list of the investigation, but also to deepen the reconstitution of the accidents; each accident has its own specificity.

With regards to the models exploited by the experts for analysing accidents, we can mention among others, two of them:

1) The "functional model" which favoured functional sequencing (e.g. information gathering, treatment, decision and action) from the driver's point of view. This model is centred on the description of mechanisms involved during the accident and on the explanation of the malfunctioning [25].

2) The phase model which is based upon the decomposition of the accident into phases (driving, accident, rupture, urgence, shock) [10].

Both types of models are in fact complementary. It is useful to use a phase model in order to go back as far as possible to the sequencing of the accident. The analysis of each event is then possible using a functional model in order to identify the mechanisms of the accident involved, the malfunctioning and consequently the related factors which explain the accident.

2.2 Framework of our study

2.2.1. Selected context within the accidentology

Understanding a given accident whatever the methods used (see section 2.1.3.) involves a wide range of activities to perform. Given the scope of our study and our limited time scale, we have focused our work on a specific aspect of the accident analysis, namely, the search for clues/signs which are intertwined with

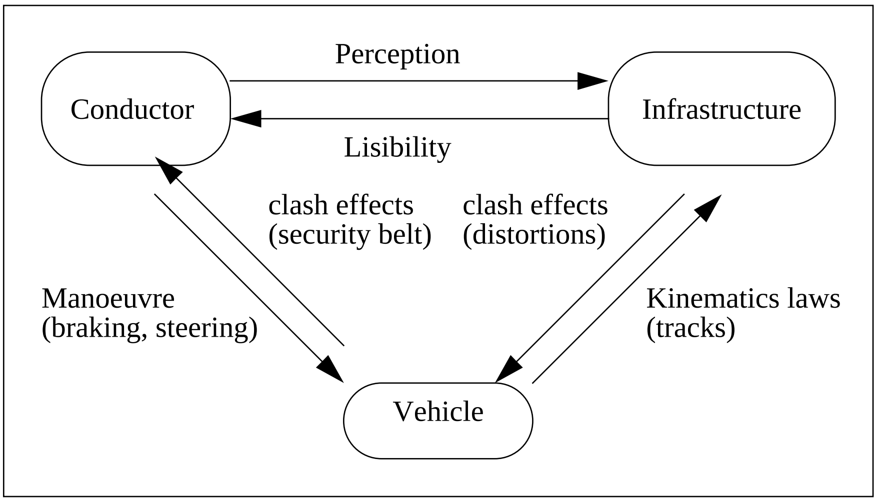


Figure 2. The CVI system

2.1.2. Multi-expertise

The analysis of the accident requires a diversity of knowledge coming from various disciplines such as psychology, engineering of the vehicle and of the infrastructure, mathematics (kinematics), and so on. Experts from INRETS are of three types:

1) Psychologists (specialists in driver behaviour),

2) Vehicle engineers,

3) Road infrastructure engineers.

During the analysis of the accident, all the experts share a common focus: 1) understand how the accident happened, and 2) identify the accident factors. However, each specialist has specific sub-tasks (corresponding to his specialty) in order to bring his contribution to the common goal. Thus, for example, the psychologist will be interested in understanding the behaviour of the driver, the vehicle engineer will be concerned with a possible malfunctioning of the car while the road infrastructure engineer will be interested in diagnosing the dangers due to the road infrastructure.

2.1.3. Analysis and modelling of accidents

The analysis of an accident is a complex task. There are a number of phases within that process which are:

1) Preparation of the brief for the given accident. This step in turn includes:

in ACACIA [31] which supports the construction of conceptual graphs and the associated typologies of concepts and relations.

The question addressed for this objective is a) on the feasibility of representing cognitive processes such as reasoning strategies (with CGs), and b) on the usability of a CG-oriented tool such as CGKAT.

2 Modelling reasoning strategies in accidentology

This chapter describes the approach taken for modelling reasoning strategies in the domain of accidentology. The analysis and diagnosis of the accident form a complex task. Section 2.2 specifies the context which has been chosen within the domain of accidentology. Sections 2.3 and 2.4 report on our previous work carried out in the area of medical problem solving, and detail the reasoning strategies which are the starting point for our study here. Section 2.5 describes the models of reasoning strategies which have been built for experts from different specialities in accidentology. The validation of these models by the human experts are reported in section 2.5.1. Discussion on modelling reasoning strategies in accidentology is found in section 2.5.5.

2.1 Domain of accidentology

2.1.1. The CVI system

The accidentology is defined as the analysis of the malfunctioning and needs of the system conductor/vehicle/infrastructure (CVI). The aims of this analysis are 1) to understand the sequencing of the accident, 2) to explain the origins of the malfunctioning of the CVI system, and 3) to foresee actions to be taken in order to prevent similar accidents in the future. Analysing the malfunctioning of the CVI system involves a diagnostic task i.e. diagnosis of the problems concerning the three components (CVI) or their interactions [8], [6].

The CVI system (see Figure 2.) which is analysed has three components: 1) the driver, 2) his/her vehicle and 3) the infrastructure (such as the road). More than one driver and vehicle may be involved in the accident, and thus included in the CVI system. The interrelations between these components include a) the information taken from the dynamic environment, b) the actions on the vehicle and its reactions, and c) the links vehicle/road.

In a normal situation, the three components of the CVI system interact in accordance. However, an accident which occurs is the result of the malfunctioning between these elements of the CVI system. Aspects such as the driver’s behaviour, the state of the car as well as the setting of infrastructure have to be taken into account. It is possible to interpret dual relations within the CVI system (as done in [9]) e.g. relation C/I to indicate the information that the conductor has treated.

In ACACIA, knowledge modelling has been carried out from the experts' protocols [8]. This has led to describe informal rules of expertise and partial typologies (for some of the experts). Then, with these results and using the CG representation, conceptual graphs and typologies have been constructed. We have actively participated in both activities.

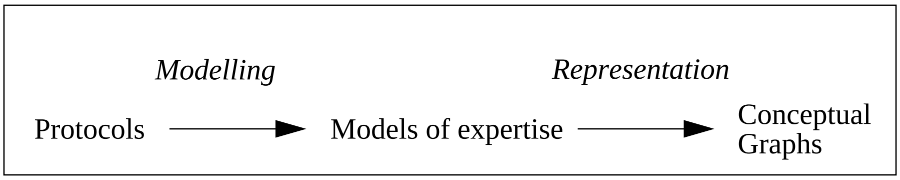


Figure 1. From experts' protocols to CG representation

Cognitive modelling of reasoning strategies in accidentology:

The research actions for this first objective are concerned with the analysis and modelling of reasoning strategies used by the experts from different specialities.

The ground to perform this task is based on our previous work carried out in modelling medical reasoning strategies [2]. In a diagnostic task, problem solving methods, including the reasoning strategies involved, represent an important aspect of the cognitive resources used by human experts. Both the expertise in accidentology and the medical expertise involve a diagnostic problem solving process. The diagnostic task in accidentology consists of diagnosing the malfunctioning of the system driver/vehicle/infrastructure, whereas medical diagnostic task involves finding out what the patient's problem is in terms of diseases or pathologies. By adopting this approach of re-using reasoning strategies for one domain to another one, we are also interested in capturing generic elements of comparison between these two diagnostic tasks.

The questions addressed for this objective are a) on the generic features of modelling reasoning strategies for diagnostic problem solving tasks, and b) on whether experts from a same domain with different specialities, share similar reasoning strategies in problem solving.

Representing reasoning strategies using conceptual graphs:

In ACACIA, the formalism of conceptual graphs has been used to model elements of the domain level of KADS expertise models, and an algorithm of comparison of conceptual graphs has been developed [7], [18]. Our action for the current objective has been to use conceptual graphs to represent our set of reasoning strategies. The approach for this task has been to test a computer-based tool CGKAT developed

1 Introduction

1.1 Context of the research work

The research work reported in this document has been carried out in the context of a post-doctoral visit* [5] in the ACACIA project [1] conducted at the INRIA research centre in Sophia-Antipolis (France). ACACIA (Acquisition des Connaissances pour l'Assistance à la Conception par Interaction entre Agents) focuses on knowledge acquisition from multiple expert sources for the development of knowledge based systems or for capitalizing expertise. One key issue is on how to solve the problems raised by the acquisition of knowledge from multiple experts/specialists [19].

Domain of application: One domain of application in ACACIA is accidentology, in particular the analysis of road accidents. In this domain, the experts of INRETS (Institut National de REcherche sur les Transports et leur Sécurité) come from various disciplines. They are psychologists (specialists in driver behaviour), vehicle engineers, road infrastructure engineers. This application domain is interesting as the study of multi-expertise involves several experts of the same domain of expertise but who use different problem solving methods as well as several specialists coming from different domains of expertise. The longer term aim of the knowledge modelling of such experts is to develop a computer-aided system for road accident analysis which will be able to play the role of several specialists [7], [8], [6].

Methods: The phase of knowledge acquisition of expertise from these experts in accidentology has been carried out by members of ACACIA-INRIA and of University Paris V. These knowledge elicitation sessions involved 2 psychologists, 2 vehicle engineers and 3 infrastructure engineers [7]. In ACACIA, the method KADS [46] has been chosen for the modelling of expertise.

1.2 Objectives

In the context of the post-doctoral research work reported here, the objectives have been of two fold: 1) Modelling reasoning strategies in accidentology, based on our previous work carried out in modelling medical problem solving; 2) Representing these reasoning strategies with the formalism of conceptual graphs [43] and using a computer-based tool for knowledge acquisition using conceptual graphs (CG) developed in the ACACIA project [31]. The two activities are intertwined, and can be done in parallel or in progression in order to build the Knowledge Base System (KBS) in accidentology (see Figure 1.).

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Modélisation de stratégies de raisonnement, et représentation en graphes conceptuels: application à l'accidentologie

Résumé : Ce rapport présente des travaux effectués dans les domaines de la modélisation cognitive et de la représentation des connaissances. Nous avons travaillé sur deux actions (complémentaires) de recherche. Le premier point de recherche a porté sur la modélisation de stratégies de raisonnement d'experts de spécialités différentes dans le domaine de l'accidentologie. Cette tâche de modélisation trouve ses bases dans notre travail antérieur sur la résolution de problème médical. La seconde action de recherche a été centrée sur la représentation de ces stratégies de raisonnement à l'aide du formalisme des graphes conceptuels. Notre approche pour construire les typologies de concepts et de relations, ainsi que les graphes a été expérimentale. En effet, nous avons utilisé un outil récemment développé par le projet ACACIA, et spécialement dédié à la construction de graphes conceptuels.

Mots-clé : stratégies de raisonnement, modélisation d'expertise, représentation des connaissances, graphes conceptuels, accidentologie

Modelling of reasoning strategies, and representation through conceptual graphs: application to accidentology

Laurence Alpay*

Programme 3 : Intelligence artificielle,
systèmes cognitifs et interaction homme-machine

Projet ACACIA

Rapport de recherche n°2810 - Février 1996

80 pages

Abstract: This document reports on a work carried out in the areas of cognitive modelling and knowledge representation. Two specific and complementary issues are addressed. The first one is concerned with modelling reasoning strategies used by experts from different specialities in the domain of accidentology. This modelling task is grounded on our previous work carried out in medical problem solving. The second issue is centred on representing those reasoning strategies with the conceptual graph formalism. The approach to build the typologies of concept types and relation types as well as the conceptual graphs in the domain of accidentology is experimental as we use a computer-based tool dedicated to conceptual graphs, developed in the ACACIA project.

Key-words: reasoning strategies, expertise modelling, knowledge representation, conceptual graphs, accidentology

(Résumé : tsvp)

* Email:lalpay@sophia.inria.fr | L.L.Alpay@open.ac.uk

INSTITUT NATIONAL DE RECHERCHE EN INFORMATIQUE ET EN AUTOMATIQUE

Unité de recherche INRIA Sophia Antipolis : 2004, route de Lucioles - B.P. 93 - 06902 Sophia Antipolis cedex **(France)**

Téléphone : +33 93 65 77 77 - Télécopie : (33) 93 65 77 65 - Télex : 970 050 F

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