besarion CixraZe

Tanamedrove satransporto saSualebebSi
eleqtromagnituri Tavsebadobis diagnostikisa da
analizis eqspertuli sistema

wardgenilia doqtoris akademiuri xarisxis
mosapoveblad

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informatikisa da marTvis sistemebis fakulteti

Cven, qvemore xelis momwerni vadasturebT, rom gavecaniT CixraZe besarionis mier Sesrulebul sadisertacio naSroms dasaxelebiT: "Tanamedrove satransporto saSualebebSi eleqtro-magnituri Tavsebadobis diagnostikisa da analizis eqspertuli sistema" da vaZlevT rekomendacias saqarTvelos teqnikuri universitetis informatikisa da marTvis sistemebis fakultetis sadisertacio sabWoSi mis ganxilvas doqtoris akademiuri xarisxis mosapoveblad.

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dasaxeleba: Tanamedrove satransporto saSual e-
                               bebSi   eleqtromagnituri   Tavseba-
                               dobis diagnostikisa da kvlevis
                               eqspertuli sistema

fakultetis dasaxeleba: informatikisa da marTvis sistemebis

individualuri   pirovnebebis   an   institutebis   mier
zemomoyvanili   dasaxelebis   disertaciis   gacnobis   misniT
moTxovnis SemTxvevaSi misi arakomerciuli miznebiT kopirebisa
da gavrcelebis ufleba miniWebuli aqvs saqarTvelos teqnikur
universitets.

avtori inarCunebs danarCen sagamomcemlo uflebebs da arc
mTliani   naSromis   da   arc   misi   calkeuli   komponentebis
gadabeWdva   an   sxva   raime   meTodiT   reproduqcia   dauSvebelia
avtoris werilobiTi nebarTvis gareSe.
    avtori irwmuneba, rom naSromSi gamoyenebul   saavtoro
uflebiT dacul masalebze miRebulia Sesabamisi nebarTva (garda
im   mcire   zomis   citatebisa,   romlebic   moTixoven   mxolod
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maTganze iRebs pasuxismgeblobas.

reziume

Tanamedrove satransporto saSual ebebs gaaCniaT rTuli eleqtruli sistemebi. sistemis komponentebs Soris eleqtromagniturma urTierTqmedebam, agreTve garemos eleqtromagniturma zemoqmedebam SeiZl eba Seuqmnas probl emebi mis gamarTul ad funqcionirebas.

satransporto saSual ebis daproeqtebisas rac ufro adreul etapze moxdeba el eqtruli sistemebis el eqtromagni turi Tavsebadobis diagnostika da anal izi, miT ufro nakl ebi iqneba konstruqciaSi cvl il ebis aucil ebl obiT gamowveul i droiTi da material uri danaxarj ebi.

naSromSi warmodgenil ia satransporto saSual ebebSi eleqtromagni turi Tavsebadobis diagnostikisa da anal izis eqsper tul i sistemis **EMC Expert** damuSaveba da real izacia. eqspertul i sistemis daniSnul ebaa satransporto saSual ebebis daproeqtebis adreul etapze aRmoaCinos mosal odnel i el eqtromagni turi Tav-sebadobis probl emebi da daexmaros inJinrebs maT aRmofxvraSi.

sistemis Seqmnis mizniT SemuSavebul i iqna satransporto saSual ebebis el eqtrogayvanil obis kompiuterul i model irebis meTodebi, eqspertul i codnis warmodgenis meTodebi, l ogikuri gadawyvetil ebebis birTvis muSaobis meTodebi, el eqtrogayvani-l obis komponentebs Soris el eqtromagni turi urTierTqmedebis model irebis meTodebi.

SemuSavda eqspertul i sistemis mTl iani struqtura dapro-eqtebis obieqtze orientirebul i da rel aciuri meTodebis gamoyenebiT. SemuSavda momxmarebl is interfeisebi da sistemis muSaobis Sedegebis warmodgenis saSual ebebi.

satransporto saSual ebebSi el eqtromagni turi Tavseba-dobis kvl evis eqspertul i sistemis programul i uzrunvel yofa damuSavebul ia **Microsoft Visual C++** garemoSi, **OpenGL, CLIPS, LibXML, VBScript** bibl ioTekebis gamoyenebiT.

el eqtromagni turi Tavsebadobis kvl evisaTvis ukve arse-bul i saSual ebebi iyeneben ricxviT meTodebs, roml ebic did gamoTvl iT da droiT resursebs moiTxoven. amitom maTi saSu-al ebiT SesaZl ebal ia mxol od sistemis cal keul i komponentebis gamokvl eva. eqspertul i sistema iyenebs eqspertul codnas, roml ic mis codnis bazaSia ganTavsebul i. mas ar sWirdeba rTul i gamoTvl ebis ganxorciel eba da Sesabamisad ar moiTxovs didi raodenobiT droisa da gamoTvl iT resursebs, amitom eqspertul i sistemis saSual ebiT SesaZl ebel ia satransporto saSual ebis mTl iani model is gaanal izeba da gamokvl eva el eqtromagni turi Tavsebadobis probl emebze. garda amisa, eqspertul i sistemis gamoyeneba ar moiTxovs inJinris maRal kval ifikacias el eqtrodinamikis sferoSi. eqspertul sistemas gaaCnia gafarToebis didi SesaZl ebl oba, imdenad, ramdenadac masSi SesaZl ebel ia codnis Cadeba wesebis damatebis saxiT.

naSromi Sedgeba Sesavali sa da oTxi Tavisagan.

Sesavalsi ganxilulia Tanamedrove satransporto saSual ebebSi el eqtromagnituri Tavsebadobis kvl evis aqtual uroba da mniSvnel oba, am miznisaTvis eqspertul i sistemis Seqmnis mizanSewonil oba. dasaxul ia naSromis ZiriTadi miznebi, amocanebi, maTi gadawyvetis gzebi da Sedegebi.

pirvel TavSi ganixil eba el eqtromagnituri Tavsebadobis arsi da is mizezebi, roml embac gamoiwvia satransporto saSual ebebis daproeqtebis adreul etapze misi gaTval iswineba. Camoyal ibebul ia satransporto saSual ebebis el eqtrul i sistemebis el eqtromagnituri Tavsebadobis kvl evis aqtual u-robis sakiTxebi. ganxil ul ia el eqtromagnituri Tavsebadobis kvl evis tradiciul i meTodebi Tavisi dadebiTi da uaryofiTi mxareebiT. dasabuTebul ia eqspertul i sistemis Seqmnis auci-l ebl oba. ganxil ul ia ukve arsebul i sistemebi, roml ebic gamo-iyeneba el eqtromagnituri Tavsebadobis kvl evisaTvis.

meore TavSi ganixil eba yvel a SemuSavebul i meTodi. esenia: satransporto saSual ebis el eqtrogayvanil obis aRweris da kompiuteris mexsierebaSi warmodgenis meTodebi, eqspertis codnis warmodgenis meTodebi produqciebis saxiT, saprobl emo aris Sesaxeb codnis warmodgenis meTodebi freimebis saxiT. SemuSavebul ia l ogikuri gadawyvetil ebebis birTvis muSaobis principebi. damuSavebul ia mavTul ebis sam ganzomil ebaSi model irebis da sivrceSi gadanawil ebis meTodebi, el eqtro-magnituri urTierTqmedebis model irebis meTodebi.

mesame TavSi warmodgenil ia sistemis real izaciis meTo-debi. Seqmnil ia mTl iani sistemis struqtura da komponentebs Soris urTierTkavSirebis sqema. dadgenil ia kl asebis ierarqia da obieqtebs Soris damokidebul ebebi. Seqmnil ia momxmarebl is grafikul i interfeisebi da Sedegebis gadamuSavebis saSual ebebi.

meoTxe TavSi warmodgenil ia sistemis muSaobis Sedegebis eqsperimentul i Semowmeba. eqsperimenti Catarda ideal ur model ze roca mavTul ebi ganTavsebul ia erTmaneTis paral e-l urad da real uri avtomobil idan aRebul i gayvanil obis model ze. model ebi gamokvl eul i iqna eqspertul i sistemisa da **EMC Studios**-s saSual ebiT da Sedegebi Sedarda erTmaneTs. agreTve gamokvl eul i iqna gamoTvl ebisaTvis saWiro droc.

Catarebul ma eqsperimentebma gviCvena, rom **EMC Experts**-s SeuZl ia swrafad da didi sizustiT aRmoaCinos el eqtro-magnituri Tavsebadobis potenciuri probl emebis mqone areebi satransporto saSual ebis rTul el eqtrogayvanil obaSi. aseTi areebi SemdgomSi SesaZl ebel ia amoRebul iqnas gayvanil obis mTl iani model idan da gamokvel ul iqnas zusti meTodebis gamoyenebiT.

gaweul i Sromis Sedegad real izebul iqna satransporto saSual ebebis daproeqtebis adreul etapze maTSi potenciuri el eqtromagnituri Tavsebadobis probl emebis diagnostikisa da anal izis eqspertul i sistema, romel ic warmatebiT iqna danergil i evropul i avtomwarmoebl ebis sawarmoo procesSi.

Summary

Contemporary transport vehicles have complex electrical systems. Electromagnetic interaction between system components, also electromagnetic influence of the environment can cause problems for correct functionality of electronic system components.

Electromagnetic compatibility diagnostics and analysis of the electronic systems on the early stage its design will reduce the time and material costs caused by the necessity of changes in the design if problems exist.

In this work is presented development and implementation of the EMC Expert, the expert system for electromagnetic compatibility diagnostics and analysis in transport vehicles. The destination of the system is to help engineers in discovering and fixing electromagnetic compatibility problems of electronic system at early stage of its development.

During development of the expert system following methods were elaborated: methods for modeling electrical systems of the vehicle, methods for representation of the expert knowledge, methods of functionality of the logical decisions core, methods for simulation of the electromagnetic interaction between components of the electronic system.

Whole system structure was defined. System was developed using object-oriented and relational methods of design. GUI and post-processing features were developed too.

Expert system is implemented in Microsoft Visual C++ environment using libraries such as OpenGL, CLIPS, LibXML and VBScript.

Existing tools for electromagnetic compatibility analysis are based on numerical computational methods that require large amount of time and computational resources. Because of this, only part of the whole electronic system can be analyzed using those tools. Expert System uses knowledge of the experts that is placed into its knowledge base. It does not require complex computations, so it does not require large amount of time and computational resources as well. Because of this fact the whole model of the vehicle can be analyzed using expert system. Besides, usage of the expert system does not require deep knowledge in electrodynamics from engineer. Expert system has extension capabilities as soon as new rules can be added to its knowledge base.

The thesis consists of introduction and four chapters.

In the introduction the necessity and urgency of the electromagnetic compatibility analysis in contemporary transport vehicles is considered. The reasonability of development of expert system for these purposes is discussed. The goals of the work are specified and the ways of achieving these goals and results are defined.

In the first chapter the electromagnetic compatibility and the reasons of its consideration at early stage of the vehicle's design are discussed. The terms of necessity of electromagnetic compatibility analysis in vehicles are defined. Pros and cons of traditional methods of electromagnetic compatibility analysis are considered and the necessity of expert system development is proved. Existing systems of electromagnetic compatibility analysis are described.

In the second chapter all elaborated methods are described. These methods are: methods for description and representation in the computer memory of the vehicle

harness, methods of representation of the expert knowledge using productions, methods of representation of knowledge about research area using frames, principles of working of logical solver, methods of 3D wire routing, methods of electromagnetic interaction simulation.

In the third chapter expert system implementation methods are presented. The structure of the whole system is defined and scheme of interaction between its components is specified. The hierarchy of classes and relationship between objects are defined. GUI and results post-processing features are created.

In the fourth chapter the experimental testing of the system is presented. The experiment was carried on ideal model when two parallel wires are located plane and on real model taken from the automobile harness. Both models were investigated using expert system and EMC Studio. The results of working of two tools were compared. Also calculation time was investigated.

The results of the experiments showed that EMC Expert can quickly and accurately discover areas of potential electromagnetic compatibility problems in the complex harness. Such areas lately can be extracted from the whole harness and investigated using more accurate methods.

As the result of the work expert system for electromagnetic compatibility diagnostics and analysis of vehicle harness at the early stage of its design was developed. The expert system was successfully installed in the manufacturing process of the leading European car manufacturers.

Sinaarsi

naxazebis nusxa

disertaciaSi gamoyenebuli abreviaturebi

EMC – ElectroMagnetic Compatibility

FEM – Final Elements Method

MoM – Method of Moments

XML – Extensible Markup Language

EFIE – Electric Field Integral Equations

MAS – Method of Auxilary Sources

CLIPS – C Language Integrated Production System

BOM – Bill of Materials

GUI – Graphical User Interface

madl iereba

avtori madl obas ucxadebs fiz. maT. mec. kand. b-n roman jobavas da S.p.s "EM konsul taciebi da programuli uzrunvel - yofa"-s TanamSromlebs sadisertcio Temaze samuSaod saukeTeso pirobebis Seqmnisa da TandgomisaTvis.

Sesaval i

Tanamedrove satransporto saSual ebebis erT-erTi mTavari komponenti urTul esi el eqtrul i sistemebia. satransporto saSual ebebis ganviTarebis mTel i istoriis manZil ze el eqtrul i sistemebis rol i ganuxrel ad izrdeba, Sesabamisad izrdeba is moTxovnebi, roml ebsac isini unda akmayofil ebdnen.

el eqtrul i mowyobil obebis raodenobis da sirTul is zrdis gamo metad aqtual urad dgas maTi saimedo muSaobis saki Txi.

imisaTvis, rom uzrunvel yofil iqnas satransporto saSual ebebis saimedooba, el eqtrul i mowyobil obebisa da mTl ianad el eqtrul i gayvanil obis daproeqtebisas saWiro xdeba sxvadasxva faqtorebis gaTval iswineba. maT Soris erT-erTi umniSvnel ovanesi aris sistemis el eqtromagni turi Tavsebadoba.

sistemis el eqtromagni turi Tavsebadoba aris misi unari imuSaos Seferxebebis gareSe gansazRvrul el eqtromagni tur garemoSi. el eqtromagni turi Tavsebadobis kvl evisas ganixil eba rogorc gare faqtorebi, aseve sistemis komponentebs Soris arsebul i el eqtromagni turi zegavl ena.

Tanamedrove saavtomobil o industriaSi metad aqtual urad dgas produqciis warmoeba el eqtromagni turi Tavsebadobis gaTval iswinebiT. erTis mxriv, amas moiTxovs warmoebul i satransporto saSual ebis usafrTxoeba, xol o meores mxriv saxel mwifo standartebi, roml ebic evropis bevr qveyanaSi muSaobs da SezRudvebs uwesebs el eqtrul mowyobil obebs garemos dabinZurebis Tval sazrisiT. aseve mniSvnel ovania marke-tingis moTxovnebic, radgan produqcia, romel ic ar muSaobs gamarTul ad, ver daikavebs adgil s bazarze.

satransporto saSual ebis daproeqtebisas rac ufro adreul etapze moxdeba el eqtrul i sistemebis el eqtromag-ni turi Tavsebadobis diagnostika da anal izi, miT ufro nakl ebi iqneba konstruqciaSi cvl il ebis aucil ebl obiT gamowveul i

droiTi da materialuri danaxarjebi. amitom, metad did mniSvnelobas iZens programuli saSualebebi, romlebic inJinrebs saSualebas miscems daproeqtebis adreul etapze moaxdinon sistemis kompiuteruli modelireba da winaswar gansazRvron SesaZlo eleqtromagnituri Tavsebadobis problemebi.

mecnierebi da inJinrebi satransporto saSualebebis eleqtromagnituri Tavsebadobis kvlevisas iyeneben saSualebebs, romlebic zust gaTvlebzea dafuZnebuli (momentebis meTodi, damxmare wyaroebis meTodi da a.S.). aseTi sistemebi moiTxoven did gamoTvliT da droiT resursebs, ris gamoc maTi saSualebiT SeuZlebelia satransporto saSualebis mTliani eleqtruli sistemis kompleqsuri gamokvleva.

disertaciis mizans warmoadgens satransporto saSualebis eleqtromagnituri Tavsebadobis diagnostikis da kvlevis eqspertuli sistemis damuSaveba, romelic daproeqtebis adreul etapze aRmoaCens konstruqciis SesaZlo problemebs da momxmarebels SesTavazebs misi gadaWris gzebs.

eqspertuli sistema ar moiTxovs did gamoTvliT resursebs, ris gamoc misi saSualebiT SesaZlebelia satransporto saSualebis eleqtruli sitemis mTlianad da erTdroulad gamokvleva. igi ar moiTxovs momxmareblis maRal kvalifikacias, ris gamoc masTan muSaoba im inJinerasac SeuZlia, romelsac ara aqvs gamocdileba elqtrostatikisa da eleqtro-dinamikis sferoebSi. sistemas gaaCnia gafarToebis da masSi axli saSualebebis damatebis didi SesaZlebloba.

disertaciaSi ZiriTadi yuradReba eqceva Semdegi amocanebis gadaWras:

- satransporto saSualebis eleqtruli sistemebis mode-lirebis meTodebis SemuSaveba

- codnis warmodgenis meTodebis SemuSaveba

- logikuri gadawyvetilebebis birTvi da Sedegebis damu-Savebis meTodebis SemuSaveba

- el eqtromagnituri urTierTqmedebis model irebisaTvis meTodbis SemuSaveba

- sistemis mTliani model is da komponentebs Soris urTierTqmedebis sqemis SemuSaveba

- sistemis real izacia

Catarebul i muSaobis Sedegad Seiqmna satransporto saSual ebebis el eqtrogayvanil obis model irebisa da kompiute-rul i warmodgenis meTodebi; SemuSavda codnis baza, codnis warmodgenis meTodebi, l ogikuri gadawyvetil ebebis birTvis muSaobis principebi; SemuSavda el eqtromagnituri urTierTqme-debis model irebis saSual ebebi, monacemTa cxril uri, samgan-zomil ebiani da sqematuri warmodgenis saSual ebebi. ganisazRvra sistemis mTl iani arqiteqtura. damuSavda momxmarebl is grafi-kul i interfeisi. moxda mTl iani sistemis real izacia. Catarda sistemis muSaobis sizustisa da saimedobis kvl eva.

sadisertacio naSromi Sedgeba oTxi Tavisagan. pirvel TavSi dasabuTebul ia satransporto saSual ebebSi el eqtromagni-turi Tavsebadobis kvl evis aqtual uroba. ganxil ul ia ukve arsebul i saSual ebebis dadebiTi da uaryofiTi mxareebi. dasabuTebul ia eqspertul i sistemis Seqmnis aucil ebl oba da misi dadebiTi mxareebi. meore TavSi damuSavebul ia el eqtro-gayvanil obis model irebis meTodebi, codnis warmodgenisa da gadawyvetil ebebis miRebis meTodebi, el eqtromagnituri urTi-erTobis model irebis meTodebi. mesame TavSi SemuSavebul ia sistemis mTl iani arqiteqtura, monacemTa da codnis bazebi, momxmarebl is grafikul i interfeisi, l ogikuri gadawyvetil ebis birTvis real izaciis meTodebi. meoTxe TavSi moyvanil ia sistemis eqsperimentul i Semowmebis Sedegebi.

1 amocanis analizi da misi gadawyvetis gzebi

1.1 amocanis dasma da misi aqtualuroba

satransporto saSualebebSi, kerZod ki avtomobilebSi, eleqtruli mowyobilobebis roli ganuxrel ad izrdeboda mTeli misi ganviTarebis istoriis manZlze. es zrda gansakuTrebiT sagrZnobia bolo 30 wlis ganmavlobaSi, rac Tavis mxriv iwvevs avtomobilSi rogorc eleqtronuli mowyobilobebis raodenobis, aseve maTi sirTulis zrdas. es tendencia momavalSic gagrZeldeba. Tu dReisaTvis avtomobilis eleqtruli mowyobiloba misi Rirebulebis 25%-s gansazRvravs, 2010 wlisTvis es cifri 40%-s miaRwevs [1].

Tu Tvals gadavavlebT avtomobilebis eleqtronuli mowyobilobebis ganviTarebis istorias, masSi SeiZleba gamoiyos Semdegi ZiriTadi etapebi:

- 1970-iani wlebi – gamoCnda Zravis marTvis eleqtronuli sistemebi.
- 1980-iani wlebi – gamoCnda muxruWebis antiblokirebis sistemebi.
- 1990-iani wlebi – sahaero baliSebi gaxda standarti.
- 2000-iani wlebi – mikroprocesoruli sistemebi, globaluri pozicionirebis sistemebi, Zravis, transmisiis da sxva komponentebis muSaobis kontrolirebis da marTvis sistemebi, satelituri radio da a.S. gaxda umetesi avtomobilebis standartuli nawili.

magaliTisaTvis, 1998 wlis modelis mersedess aqvs 40 kompiuteri da 100-ze meti eleqtroZravi [2].

eleqtruli mowyobilobebis raodenobis da sirTulis aseTi zrdis gamo metad aqtualurad dgas maTi saimedo muSaobis sakiTxi, ris gamoc avtomobilebis eleqtruli mowyobilobebisa da mTlianad eleqtrogayvanilobis daproeqtebisas saWiro xdeba

sxvadasxva faqtorebis gaTvaliswineba. maT Soris erT-erTi umniSvnelovanesi aris sistemis eleqtromagnituri Tavsebadoba.

sistemis eleqtromagnituri Tavsebadoba SeiZleba ganisazRvros Semdegnairad: eleqtronuli sistemis eleqtromagnituri Tavsebadoba aris misi unari imuSaos Seferxebebisa da Secdomebis gareSe misTvis gansazRvrul eleqtromagnitur garemoSi da ar ganaxorcielos urTierTqmedeba sxva sistemebTan da garemoebTan [3].

arsebobs ori mizezi, ramac SeiZleba gamoiwvios eleqtronuli sistemis mdgradi muSaobis darRveva:

1. eleqtromagnituri urTierTqmedeba sistemis elementebs Soris.

2. garemos eleqtromagnituri zemoqmedeba sistemaze.

warmovidginoT, rom gvaqvs ori mowyobil oba **A** da **B** (nax. 1.). sistema iqneba eleqtromagniturad Tavsebadi, Tu orive mowyobilobis erTdrouli ad muSaobisas isini gavlenas ar moaxdenen erTmaneTze da agreTve verc garemoSi arsebuli eleqtromagnituri veli Seaferxebs maT muSaobas.

eleqtromagnituri Tavsebadobis problemebis tipiur magaliTebs warmoadgens radioSi warmoqmnili xmauri Zravis CarTvis dros, xazebi televizoris ekranze, roca rekavs mobiluri telefoni da a.S.

ismis kiTxva: ratom gaxda aqtualuri satransporto saSualebebis eleqtrul sistemebSi eleqtromagnituri Tavsebadobis gaTvaliswineba? amis sami ZiriTadi mizezi arsebobs:

1. vinaidan eleqtronuli mowyobilobebis gamarTul ad muSaobaze damokidebulia avtomobilis usafrTxoeba, avtomwarmoeblebi iZulebulebi arian uzrunvelyon maTi gamarTuli muSaoba nebismier pirobebSi.

2. arsebobs saxelmwifo standartebi, romlebic aiZuleben mwarmoeblebs maTi produqcia akmayofilebdes garemoze radiaciuli zegavlenis SezRudvebs.

nax. 1. eleqtromagniTuri urTierTqmedeba

3. marketingis moTxovnebi. produqcia, romelic ar muSaobs gamarTulad, ver daikavebs adgils bazarze.

amrigad, Tanamedrove satransporto saSualebebis industriaSi metad aqtualurad dgas produqciis warmoeba eleqtronuli mowyobilobebis eleqtromagnituri Tavsebadobis gaTvaliswinebiT.

mwarmoebl ebis winaSe dgas amocana Semowmebuli iqnas maTi produqti eleqtromagnitur Tavsebadobaze jer kidev daproeqtebis etapze, raTa Tavidan iqnas acilebuli dasrulebuli produqtis xelaxla daproeqteba masSi cvlilebebis Setanis mizniT. daproeqtebis rac ufro adreul etapze moxdeba eleqtromagnituri Tavsebadobis Seswavla, miT ufro naklebi iqneba danaxarjebi problemebis gamosasworeblad.

amgvarad, iseTi programuli uzrunvelyofis Seqmna, romelic moaxdens avtomobilis eleqtrogayvanilobaSi eleqtromagnituri movlenebis modelirebas da Seswavlas daproeqtebis adreul etapze, metad aqtualuria.

naSromis mizans warmoadgens eqspertuli sistemis Seqmna, romelic ganaxorcielebs satransporto saSualebebis eleqtromagnituri Tavsebadobis problemebis diagnostikas, analizs da aRmofxvras daproeqtebis etapze.

3

1.2 arsebuli sistemebis mimoxilva

eleqtromagnituri Tavsebadobis kvlevisaTvis dResdReobiT bazarze arsebuli programuli uzrunvelyofa gamoyenebuli meTodebis mixedviT SeiZleba daiyos oTx nawilad:

1. programebi, romlebic iyeneben analitikur meTodebs.
2. programebi, romlebic iyeneben ricxviT meTodebs.
3. programebi, romlebic iyeneben hibridul meTodebs.
4. eqspertuli sistemebi.

ganvixiloT TiToeuli maTgani cal-calke:

analitikuri modelirebis saSualebebi iyeneben martiv gamosaxulebebs da/an winaswar gaTvlil amocanebs nacnobi geometriisaTvis. aseTi programebi cdiloben Seusabamon arsebuli problema im problemas, romlis amonaxsnic ukve cnobilia [4].

aseTi sistemebis dadebiTi mxareebia:

- gaTvlebisaTvis saWiro mcire dro.

uaryofiTi mxareebia:

- amocanebis klasi, romlis gadawyvetac SeiZleba, Zalze SezRudulia.
- Sedegebis naklebi sizuste.

ricxviT meTodebze damyarebuli modelirebis saSualebebi xsnian maqsvelis gantolebebs ricxviTi meTodebiT. ZiriTadi meTodebi, romlebsac isini gamoiyeneben aris momentebis meTodi (**MoM**) da sasruli elementebis meTodi (**FEM**) [5]. aseTi tipis programuli uzrunvelyofis dadebiTi mxareebia:

- Sedegebis didi sizuste.

uaryofiTi mxareebia:

- gaTvlebisaTvis saWiro didi droiTi da kompiuteruli resursebi.
- sawyisi monacemebis momzadeba warmoadgens sirTules.
- Sedegebis sizuste damokidebulia sawyisi monacemebis momzadebis sizusteze.

satransporto saSual ebebis mTliani eleqtrogayvanilobis eleqtromagnituri Tavsebadobis kvlevisaTvis maTi gamoyeneba SeuZlebelia, radgan:

- rTulia sawyisi monacemebis momzadeba, raTa gaTvlebi ganxorcieldes mTlian avtomobilze mTeli misi eleqtrogayvanilobis gaTvaliswinebiT.

- romc moxerxdes monacemebis momzadeba gaTvlebisaTvis saWiro resursebi imdenad didia, rom gamoTvliTi teqnikis ganviTarebis Tanamedrove donis gaTval is-winebiT maTi ganxorcieleba SeuZlebeli xdeba (avtomo-bilis Zaris model irebisaTvis saWiroa 20000 elementi, mavTulebis saerTo sigrZe aRemateba 20 km-s, 1 m mavTul-ze modis 100 segmenti. yovelive amis gaTvaliswinebiT gaTvlebisaTvis saWiro cvladebis raodenoba aRwevs 230000-s, gaTvlebisaTvis saWiro operatiuli mexsiereba 788 gigabaits, xolo 1.4 gigahercis sixSiris mqone procesorze gaTvlebs dasWirdeba 2 welze meti).

Tumca, unda aRiniSnos, rom lokaluri amocanebis gadawyveta (magaliTad, gaTvlebi mxolod ramdenime mavTulze) warmatebiT xorcieldeba ricxviTi meTodebis gamoyenebiT.

programuli produqtebi, romlebic dafuZnebulia ricxviT meTodebze aris: **EMC Studio, FEKO, Microwave Studio, PAM-CEM** da a.S.

hibridul meTodebze dafuZnebuli programuli saSualebebi iyeneben sxvadasxva ricxviTi meTodebis Serwymas [37]. gaTvlebis nawili xdeba erTi meTodiT, xolo nawili ki sxva meTodebiT

hibriduli programuli saSualebebis upiratesobebi ricxviT meTodebze dafuZnebul saSualebebTan SedarebiT aris:

- upiratesobebi zogierTi specifikuri amocanis gadawyve-tisas.

- sawyisi monacemebis momzadebis simartive zogierTi hibriduli sistemebisaTvis.

hibriduli programuli saSualebebis uaryofiTi mxareebia:

- Sedegebis sizuste Zalze damokidebulia amocanis specifikaze.

- rTul amocanebze saWiroa didi raodenobiT droiTi da kompiuteruli resursebi.

avtomobilebis eleqtromagnituri Tavsebadobis Sesaswav- lad hibriduli meTodebis gamoyeneba SeuZlebelia igive mizezTa gamo, romeli mizezebic analitikuri da ricxviTi meTodebis SemTxvevaSi iyo aRniSnuli.

hibridul meTodebze dafuZnebulia Semdegi programuli saSualebebi: **XTalk, RHybrid, SHybrid** [34].

eqspertuli sistema es aris kompiuteruli programa, romelic operirebs codniT garkveul sagnobriv areSi rekomen- daciis gamomuSavebis an porblemis gadawyvetis mizniT [6].

Tuki zemoT aRniSnuli programuli saSualebebi garkveul- wilad universaluria da maTi meSveobiT SesaZlebelia eleqtro- magnituri Tavsebadobis amocanis gadawyveta sxvadasxva sferoSi, eqspertul sistemebs gaaCnia viwro specializacia. es gamowve- ulia TviT eqspertuli sistemebis specifikiT. programa SeiZleba CaiTvalos eqspertul sistemad, Tu mas gaaCnia codna. es codna koncentrirebuli unda iyos garkveul sagnobriv areze. codnidan unda gamomdinareobdes problemis gadawyveta [7].

zemoT aRwerili saSualebebi dafuZnebulia maTematikur meTodebze, amitom maTTvis mTavaria Sesabamisi sawyisi monace- mebis momzadeba (modelis ageba), gaTvlebisTvis sxva rames mniSvneloba ar gaaCnia. maTi saSualebiT SeiZleba gadawydes problemebi manqanTmSeneblobis, eleqtronikis da a.S. sferodan.

eqspertuli sistemebi dafuZnebulia eqspertul codnaze, romelic sxvadasxva sferoSi sxvadasxvaa. eqspertuli sistemebis codnis baza moicavs wesebis erTobliobas, romel Ta amoqmedebac xdeba saproblemo aris modelze. wesebi, romlebic gamoiyeneba eleqtronikaSi, SeuZlebelia gamoyenebul iqnas manqanaTmSeneb- lobaSi da a.S. garda amisa sawyisi monacemebic (modeli, romel-

6

zec xdeba wesebis amoqmedeba) momzadebul i unda iyos konkre-
tul i sferos specifikis gaTval iswinebiT.

eqspertul i sistemebis dadebiTi mxareebia:

- ar sWirdeba didi raodenobiT kompiuterul i da droiTi
resursebi.
- ar moiTxovs momxmarebl is maRal kval ifikacias.
- aqvs gafarToebis didi SesaZl ebl obebi.

uaryofiTi mxareebia:

- viwro special izacia.
- eqspertul i codnis Segrovebis sirTul e.

dReisaTvis Seqmnil ia eqspertul i sistemebi, roml ebic
gamoiyeneba el eqtromagnituri Tavsebadobis kvl evisaTvis el eq-
tronul pl atebSi (**Quiet Expert** da a.S), magram maTi gamoyeneba
SeuZl ebel ia satransporto saSual ebebis el eqtrogayvanil obis
Sesaswavl ad.

ganvsazRvroT mizanSewonil ia Tu ara eqspertul i sistemis
Seqmna da gamoyeneba satransporto saSual ebebis el eqtromagni-
turi Tavsebadobis probl emis gadawyvetis sferoSi.

im saprobl emo areebis dasadgenad, sadac SeiZl eba
eqspertul i sistemis gamoyeneba, mraval i faqtoris gaTval is-
wineba aris saWiro. magal iTad, Tu saprobl emo aris codnis
sfero Zal ze didia, misTvis SeiZl eba SeuZl ebel ic iyos eqsper-
tul i sistemis Seqmna. Tu probl emis gadawyveta SeiZl eba moxdes
maTematikuri meTodebis gamoyenebiT, am SemTxvevaSic ar aris
saWiro da mizanSewonil i eqspertul i sistemebis midgomis gamoye-
neba. sagnobrivi sferos Sesabamisoba eqspertul i sistemebis
midgomisaTvis ganisazRvreba ori ZiriTadi kriteriumiT: saprobl-
l emo aris xasiaTi da sazRvrebi, sistemis praqtikul oba [7].

codna, romel ic SeiZl eba gadaeces eqspertul sistemas,
SemosazRvrul ia. amitom misi gamoyeneba, rogorc zemoT iyo
aRniSnul i, SesaZl ebel ia mxol od viwro special izaciiT. aqedan
gamomdinare, saprobl emo are aucil ebl ad unda iyos Semo-

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sazRvruli. Cvens SemTxvevaSi saproblemo are SemozRudulia da igi moicavs mxolod satransporto saSualebis eleqtrogayvanilobas da gareSe gamosxivebis wyaroebs.

eqspertuli sistemebis moqmedebis principi dafuZnebulia simbolur gansjaze da ara pirdapir ricxviT gamoTvlebze, amitom problemis arCevis erT_erTi kriteriumi unda iyos misi warmodgenis SesaZlebloba simboluri saxiT [8]. es niSnavs, rom monacemebis warmodgena unda iyos SesaZlebeli simboluri saxiT, romlebic gamoiyeneba informaciis misaRebad da ara ricxvebis saxiT, romlebic gamoiyeneba gaTvlebis dros. satransporto saSualebis eleqtrogayvaniloba Sedgeba uamravi mavTulisgan, koneqtorisgan, terminalisgan, kontaqtisgan da a.S. TiToeuli maTgani Tavis mxriv warmoadgens rTul obieqts, amis gamo satransporto saSualebis mTliani modelis warmodgena iseTi saxiT, rom ganxorcieldes ricxviTi meTodebiT gaTvala, SeuZlebelia. misi warmodgena SeiZleba moxdes relaciuri modelis saxiT, romelic kargad miesadageba eqspertuli sistemis ideologias.

Tuki problemas gaaCnia potenciali gadawydes ricxviTi meTodebiT, maSin misTvis eqspertuli sistemis Seqmna ar iqneba gamarTlebuli. marTalia, Teoriulad SesaZlebelia Cveni amocanis ricxviTi meTodebiT gadawyveta, magram gamoTvliTi teqnikis dRevandeli ganviTarebis donisa da iseTi faqtorebis gamo, rogoricaa sawyisi moncemebis momzadebis sirTule, es idea ar aris ganxorcielebadi.

sxva faqtori, romelic mxedvelobaSi unda miviRoT, aris problemis warmoSobis sixSire. problema unda warmoiSvebodes sakmaod xSirad, raTa gamarTlebuli iyos misTvis eqspertuli sistemis Seqmna. Tu problema warmoiSveba iSviaTad, maSin ekonomikurad ufro gamarTlebuli iqneba (rogorc drois, aseve xarjebis mxrivac) eqspertis mowveva mis gadasaWrelad. rogorc zemoT iyo aRniSnuli, eleqtromagnituri Tavsebadobis kvlevis

probl ema aqtual uria nebismieri axali satransporto saSu-
al ebis daproeqtebis dros.

eqspertul sistemas yovel Tvis ar SeuZl ia optimaluri
gadawyvetis povna. Tu probl ema mudmivad moiTxovs optimal ur
amonaxsns, eqspertul i sistema ar gamogvadgeba. xol o Tuki
probl emis miaxl oebiTi amonaxsni misaRebia da zemoT aRniSnul i
yvel a sxva kriteriumi dakmayofil ebul ia, sagnobrivi sfero-
saTvis SeiZl eba Seiqmnas eqspertul i sistema. Cvens SemTxvevaSi,
umetesi probl emis dafiqsireba SesaZl ebel ia eqspertul i
sistemis saSual ebiT. Tu mainc gaCnda moTxovnil eba uzustesi
ricxviTi gamoTvl ebisa, maSin eqspertul i sistemis saSual ebiT
dadgindeba probl emuri komponentebi da avtomobil is mTl iani
model idan gamoiyofa mxol od isini. amrigad mTl iani model idan
miviRebT mxol od mis mcire nawils, romel zedac ukve
SesaZl ebel i iqneba gamoTvl ebis ganxorciel eba ricxviTi
meTodebis gamoyenebiT.

amrigad, Cveni saprobl emo are, kerZod ki el eqtro-
magnituri Tavsebadobis anal izi da diagnostika satransporto
saSual ebebSi, akmayofil ebs yvel a kriteriums, raTa mizanSe-
wonil i iyos masze eqspertul i sistemis Seqmna.

ganvixil oT sistemis praqtikul oba.

pirvel i nabiji, romel ic unda gadaidgas, mdgomareobs imis
gansazRvraSi, sistema unda Seiqmnas eqspertis Sesacvl el ad Tu
mis damxmare iaraRad [7]. Seqmnil i eqspertul i sistema daxmarebas
gauwevs rogorc kval ificiur eqsperts, aseve nakl ebi
gamocdil ebis mqone inJinersac. aseve mas saSual eba eqneba
Secval os eqsperti garkveul SemTxvevebSi.

codnis bazis ganviTareba ar unda warmoadgendes
sirTul es. advil ad unda iyos SesaZl ebel i axal i codnis
gadacema sistemisTvis da misiT manipul ireba. Seqmnil sistemas
eqneba moxerxebul i da intuiciuri interfeisi axal i codnis
damatebisa da codnis bazasTan muSaobisaTvis.

SesaZlebeli unda iyos sistemis Semowmeba testebis saSualebiT. damuSavebuli sistema SeiZleba Semowmdes adre ukve Catarebuli realuri eqsperimentebis saSualebiT.

sistema megobruli da advilad gamosayenebeli unda iyos momxmareblisTvis. damuSavebuli sistema mTlanad daakmayofilebs am kriteriums, radgan mas eqneba konfigurirebadi momxmareblis interfeisi, monacemebis sxvadasxva saxiT warmodgenis farTo SesaZlebloba (cxrilebi, samganzomilebiani vizualizacia, sqematuri warmodgena), angariSebis, codnis bazis redaqtirebis, Sedegebis damuSavebis mZlavri meqanizmebi da a.S.

rogorc yovelive zemoT Tqmulidan Cans, satransporto saSualebebis eleqtrogayvanilobis eleqtromagnituri Tavsebadobis kvlevisaTvis eqspertuli sistemis Seqmna gamarTlebulia da eqneba didi praqtikuli mniSvneloba. eqspertuli sistema, romelic orientirebuli iqneba satransporto saSualebebis eleqtrogayvanilobis eleqtromagnituri Tavsebadobis problemebis diagnostikasa da gamosworebaze jerjerobiT ar arsebobs. misi Seqmna warmoadgens naSromis mizans.

sistemis saSualebiT:

- SesaZlebeli iqneba eleqtromagnituri Tavsebadobis problemebis gamovlena satransporto saSualebis daproeqtebis etapze.

- SesaZlebeli iqneba analizi gaukeTdes satransporto saSualebis mTel eleqtrul sistemas, radgan mas ar esaWiroeba didi raodenobiT gamoTvliTi resursebi.

- SesaZlebeli iqneba eqspertuli sistemis gafarToeba codnis bazaSi axali wesebis damatebiT.

- SesaZlebeli iqneba eleqtrogayvanilobis rogorc eleqtromagnituri, aseve topologiuri problemebis aRmoCena da aRmofxvra.

sistema

- mosaxerxebeli iqneba momxmareblisaTvis da ar moiTxovs mis maRal kvalifikacias.

- saSualebas miscems momxmarebels Tavidan aicilos rTuli gaTvlebi.

- masSi integrirebuli iqneba analitikuri da ricxviTi meTodebi zusti gaTvlebis saWiroebis SemTxvevaSi.

- eqneba monacemTa vizualizaciis, Zebnis da angariSebis generaciis mZlavri saSualebebi.

amrigad, dResdReobiT satransporto saSualebebis warmo-ebaSi mkveTrad dgas produqciis eleqtromagnituri Tavsebadobis Seswavlis amocana, ukve arsebuli saSualebebi ki ar aris sakmarisi am amocanis gadasawyvetad. damuSavebuli eqspertuli sistema saSualebas miscems avtomobilebis konstruqtorebs da inJinrebs daproeqtebis adreul etapze gamoavlinon gayvani-lobaSi arsebuli eleqtromagnituri Tavsebadobis problemebi da droul ad moaxdinon maTi aRmofxvra.

1.3 sistemis arqiteqtura

tipiuri eqspertuli sistema Sedgeba Semdegi ZiriTadi komponentebisagan: amomxsnelisagan (interpretatori), monacemTa bazisagan, codnis bazisagan, codnis miRebisaTvis saWiro komponentebisagan [9].

satransporto saSualebebSi eleqtromagnituri Tavsebado-bis diagnogistikisa da anlizis eqspertuli sistema **EMC Expert** aris rTuli programuli kompleqsi [35][36]. masSi erTmaneTTan dakavSirebulia codnis baza, eleqtrogayvanilobis modelirebis birTvi, logikuri gadawyvetilebebis birTvi, eleqtromagnituri gaTvlebis moduli, samganzomilebiani vizualizaciis saSu-alebebi, Sedegebis damuSavebis saSualebebi, mZlavri angariSebis generaciis birTvi, gayvanilobis sqematuri warmodgenis moduli, sistemisTvis codnis gadacemis saSualebebi, konfigurebadi

momxmareblis interfeisi, monacemTa Zebnisa da filtraciis saSualebebi da a.S.

eqspertul sistemas SeuZlia mTlianad aiRos sakuTar Tavze funqciebi, romelTa Sesrulebac moiTxovs gamocdili specialistis codnas, an Seasrulos gadawyvetilebis mimRebi adamianis asistentis roli. sxva sityvebiT rom vTqvaT, amocanis gadawyveta SeiZleba miRebul iqnas TviT programis mier, an adamianis mier programisagan SeTavazebuli rekomendaciis safuZvelze. **EMC Expert**–Si realizebulia orive saxis funqcionaluroba.

zogadad, eqspertuli sistemis Sesaqmnelad SemuSavebul unda iqnas meTodebi da saSualebebi sistemisTvis codnis gadasacemad, codnis warmosadgenad, gadawyvetilebis miRebis procesis samarTavad, Sedegebis momxmareblisaTvis mosaxerxebeli formiT warsadgenad.

EMC Expert sistemis zogadi sqema mocemulia nax. 2.-ze.

momxmareblis grafikuli interfeisis saSualebiT xorcieldeba dialogi momxmarebelsa da eqspertul sistemas Soris. pirobiTadigi SesaZlebelia gavyoT ornawilad: pre-procesorad da post-procesorad.

pre-procesori Sedgeba saSualebebisagan, romelTa daxmarebiTac momxarebeli axorcielebs sawyisi monacemebis momzadebas: stransporto saSualebis eleqtrogayvanilobis sistemaSi CatvirTvas da masTan muSaobas, codnis bazasTan muSaobas (wesebis Seqmna, redaqtireba, waSla, dajgufeba da a.S.), eqspertuli sistemis birTvis amuSavebas da a.S.

pre-procesori Sedgeba eleqtrogayvanilobis tabularuli saxiT warmodgenis, samganzomilebiani saxiT warmodgenis, sqematuri saxiT warmodgenis, redaqtirebis, informaciis Zebnisa da filtraciis, codnis bazis redaqtirebis modulebisagan.

post-procesori axorcielebs logikuri daskvnebis birTvis muSaobis Sedegebis damuSavebas da mis wardgenas momxmareblisaTvis. eqspertuli sistemis daskvnebi da

rekomendaciebi momxmarebels waredgineba ramdenime saxiT: cxrilebis saxiT, sadac mas SeuZlia sakuTari komentarebis damateba, riskebis gansazRvra da a.S., grafikebis saxiT sadac mocemulia eleqtro dinamikuri gaTvlebis Sedegebi da angariSebis saxiT.

nax. 2. sistemis zogadi sqema

codnis baza warmoadgens eqspertuli codnis sacavs. eqspertis codna sistemaSi warmodgenilia wesebis saxiT.

eleqtrogayvanilobis baza inaxavs informacias satransporto saSualebis eleqtrogayvanilobis Sesaxeb. mas gaaCnia relaciuri struqtura.
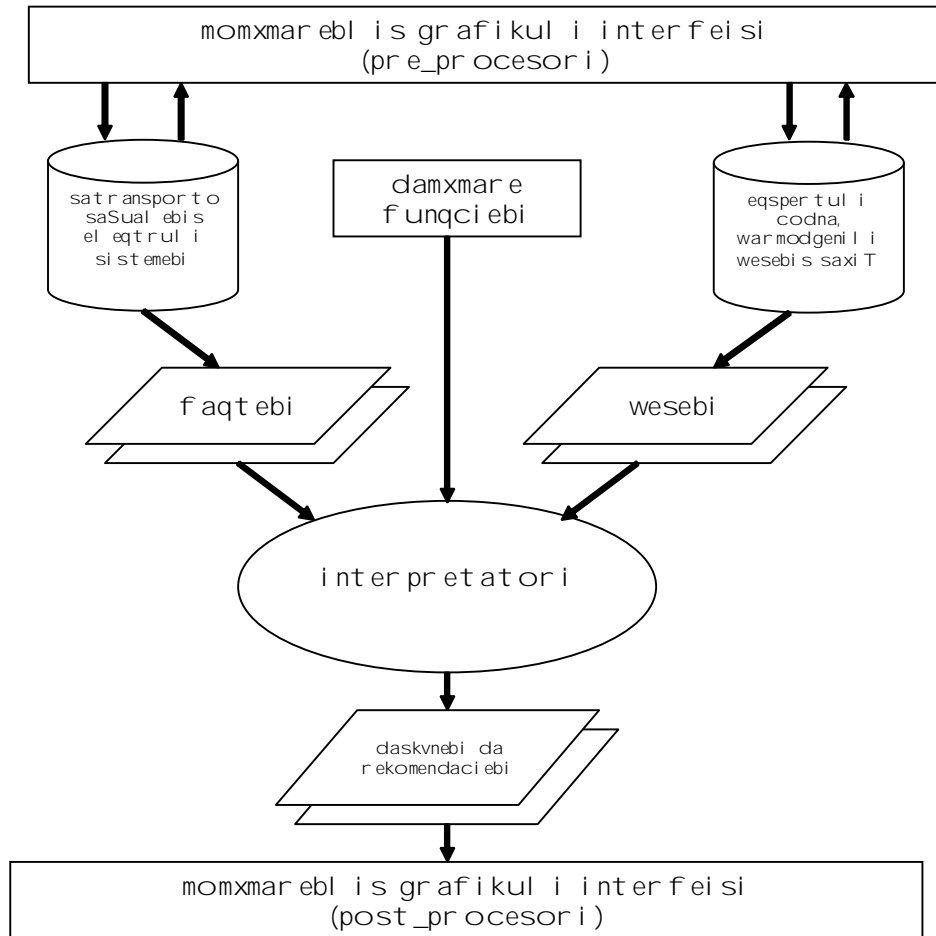
interpretatori axorciel ebs wesebis amuSavebas el eqtro-gayvanil obaze. igi aris sistemis intel eqtual uri nawili. mas Sesasvl el ze gadaecema faqtebi el eqtrogayvanil obis bazidan da wesebi codnis bazidan. am wesebisa da faqtebis saSual ebiT xdeba l ogikuri gadawyvetil ebebis miReba da Sesabamisi moqmedebebis ganxorciel eba. mas agreTve saSual eba aqvs gamoiyenos damxmare funqciebi, rogoricaa: el eqtrodinamikuri gaTvl ebi, el eqtro-statikuri gaTvl ebi, geometriul i gaTvl ebi, informaciis Zebnis funqciebi da a.S. interpretatoris muSaobis Sedegad gamomuSav-deba daskvnebi, romel ic gadaecema post-procesors momxmareb-l isaTvis warsadgenad.

momxmarebl is eqspertul sistemasTan muSaobis scenari Semdegia:

sistemas gaaCnia codnis baza, romel Sic inaxeba eqspertebis mier Seqmnil i wesebi. codnis bazis redaqtirebis modul is saSual ebiT SesaZl ebel ia masSi axal i wesebis damateba, ukve arsebul is redaqtireba, waSl a da daj gufeba. codnis bazaSi informacia inaxeba mudmivad.

momxmarebel i sistemasTan muSaobis seansis dasawyisSi qmnis axal proeqts da tvirTavs monacemebs avtomobil is el eqtrogayvanil obis Sesaxeb. es informacia moTavsdeba el eqtrogayvanil obis bazaSi. erTi proeqtis fargl ebSi SesaZl ebel ia ramdenime el eqtrogayvanil obis CatvirTva. el eqtrogayvanil obis redaqtirebis modul is saSual ebiT momxmarebel i SeZl ebs sxvadasxva gayvanil obebis gaerTianebas, misgan nawil is gamoyofas, erTmaneTTan Sedarebas, komponentebis modificirebas da a.S.

CatvirTul i el eqtrogayvanil obis vizual izaciis ramdenime SesaZl ebl oba arsebobs: tabul arul i, roca gayvanil obis komponenetebi warmodgenil ia cxril ebis saxiT, sqematuri, roca gayvanil oba warmodgenil ia el eqtrul i sqemis saxiT da samganzomil ebiani, roca gayvanil oba warmodgenil ia samganzomi-l ebiani model is saxiT.

gayvanilobis Semadgenel TiToeuli tipis komponents (mavTuli, koneqtori da a.S.) gaaCnia redaqtirebis calke fanjara.

garda amisa, momxmarebels SeuZlia CatvirTos avtomobilis an sxva satransporto saSualebis Zaris modeli da antenebi.

momxmarebels SeuZlia Seqmnas wesebi TviT proeqtSi an gadmoitanos isini codnis bazidan.

momxmarebeli gaaaqtiurebs erT-erT gayvanilobas, moniSnavs wesebs, romlis amoqmedebac surs da gauSvebs Sesrulebaze. am dros programa qmnis faqtebs gayvanilobis bazis monacemebze dayrdnobiT, iRebs moniSnul wesebs da gadascems logkiuri daskvnebis birTvs. birTvis muSaobis Sedegebi Sesrulebuli wesebis Sesabamisad SeiZleba iyos Semdegi saxis:

- gamomuSavdes rekomendaciebi da waredginos momxmarebels.

- ganxorcieldes gayvanilobis modificireba da amis Sesaxeb Setyobineba gadaeces momxmarebels.

- Catardes eleqtrodinamikuri da eleqtrostatikuri gaTvlebi da Sedegebi gadaeces momxmarebels.

- moxdes angariSebis generacia (teqsturi, grafikuli).

Sedegebis vizualizaciis modulis saSualebiT eqspertuli sistemis muSaobis Sedegebi waredgineba momxmarebels. am informaciis safuZvelze mas SeuZlia gaakeTos Sesabamisi daskvnebi da moaxdinos gayvanilobis modificireba. agreTve SesaZlebloba aqvs gaakeTos angariSebi sistemis Sedegebis muSaobis Sesaxeb.

SesaZlebelia proeqtis damaxsovreba da momaval Si muSaobis gagrZeleba.

imisaTvis, rom realizebuli iyos zemoT aRweril i sistema, saWiroa gadawydes Semdegi amocanebi:

- SemuSavdes satransporto saSualebis eleqtruli sistemebis modelirebis meTodebi

- SemuSavdes codnis warmodgenis meTodebi

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- damuSavdes logikuri gadawyvetilebebis birTvi da Sedegebis damuSavebis meTodebi

- damuSavdes meTodebi eleqtromagnituri urTierTqmedebis modelirebisaTvis.

- damuSavdes sistemis mTliani modeli da komponentebs Soris urTierTqmedebis sqema.

- moxdes sistemis programuli realizacia.

1.4   daskvna pirveli Tavis Sesaxeb

1. Camoyalibebulia satransporto saSualebebSi eleqtromagnituri Tavsebadobis kvlevis aqtualuroba. ganxilulia mizezebi ris gamoc aucilebelia aseTi kvlevis Catareba dapreoqtebis adreul etapze.

2. ganxilulia kvlevis arsebuli meTodebi Tavisi dadebiTi da uaryofiTi mxareebiT. dasabuTebulia eqspertuli sistemis Seqmnis mizanSewoniloba da moyvanilia misi upiratesobebi.

3. warmodgenilia eleqtromagnituri Tavsebadobis diagnostikisa da analizis eqspertuli sistemis arqiteqtura. Camoyalibebulia misdami ZiriTadi moTxovnebi da dasaxulia amocanebi, romelTa gadawyvetac aucilebelia eqspertuli sistemis realizaciisaTvis.

2 eqspertuli sistemis realizaciis meTodebis damuSaveba

2.1 satransporto saSualebis eleqtrogayvanilobis modelireba

eqspertul sistemaSi umniSvnelovanesi adgili ukavia monacemTa bazas, romelic Seicavs informacias saproblemo aris Sesaxeb. Cvens SemTxvevaSi saproblemo ares warmoadgens satransporto saSualebis eleqtrogayvaniloba yvela misi Semadgeneli komponentiT. udidesi mniSvneloba eniWeba saproblemo aris modelis sworad SemuSavebas, radgan masze mniSvnelovnad aris damokidebuli eqspertuli sistemis warmadoba, Sedegebis sizuste, saimedoba da momxmareblis mier misi gamoyenebis sirTulis xarisxi.

satransporto saSualebis eleqtruli sistemis modeli, erTis mxriv, zustad da amomwuravad unda asaxavdes real ur obieqts, xol o meores mxriv, unda iyos kompaqturi da kargad organizebuli, raTa ar moiTxovdes did resursebs da swrafad xdebodes saWiro informaciis moZieba.

satransporto saSualebis eleqtrogayvaniloba warmoad-gens rTul sistemas, romelic Sedgeba erTmaneTTan dakavSirebu-li mravali komponentisagan. amas Tan erTvis TviT komponentebs Soris kavSirebis sirTul ec.

satransporto saSualebis eleqtrogayvanilobis maTemati-kuri modelis Sesaqmnelad saWiroa igi logikurad davyoT sxvadasxva tipis nawilebad da davadginoT maT Soris kavSirebi. satransporto saSualebis eleqtrogayvanilobaSi SeiZleba gamovyoT fizikuri komponentebi (mavTulebi, koneqtorebi, terminalebi da a.S.), eleqtruli kavSirebi (romeli mavTuli romel koneqtorTan aris dakavSirebuli da a.S.), komponentebis

ganl ageba sivrceSi (koneqtorebis mdebareobebi, mavTul ebis gayvanis traeqtoriebi da a.S.). maSasadame miviRebT:

$$H = \{P, C, L, G\} \qquad (2.1.1)$$

sadac **H** aris satransporto saSual ebis el eqtrul i sistema, **P** aris satransporto saSual ebis el eqtrogayvanil obis Semadgenel i komponentebi, **C** aris el eqtrul i kavSirebi, **L** aris komponentebis sivrceSi ganl agebis aRwera, **G** aris komponetebis daj gufeba maTi funqcional uri daniSnul ebis mixedviT.

el eqtrogayvanil obis Semadgenel i komponentebi **P** warmo-adgens sxvadasxva saxis komponentebis erTobl iobas:

$$P = (p_1, p_2, ..., p_{i,} ... p_n) \qquad (2.1.2)$$

sadac, p_i aris gayvanil obis Semadgenel i konkretul i komponenti.

koponentebi SeiZl eba davaj gufoT maTi tipis mixedviT. satransporto saSual ebis el qtrul sistemaSi gamoiyeneba Semdegi tipis komponentebi: mavTul i, mraval gul iani mavTul i, koneqtori, terminal i, kontaqtis SemamWidrovebel i, kontaqtis sarqvel i, kontaqtis terminal i, fiqsatori, damxmare komponenti [10]. Tu ganvixil avT komponentebs tipebis mixedviT maSin miviRebT, rom

$$P = T_1 \cup T_2 \cup ... \cup T_n \qquad (2.1.3)$$

sadac, T_i aris konkretul i tipis komponentebis erTob-l ioba.

TiToeul komponents gaaCnia parametrebi, roml ebic mas aRwers. es parametrebi SeiZl eba gavyoT or nawil ad, komponentis fizikur parametrebad (misi forma, zoma, masal a da a.S., e.i. TviTon fizikuri obieqti) da misi konkretul i gamoyenebis parametrebad (mavTul is sigrZe, romel ic gamoiyeneba SuSis el eqtroamwevis kvebisaTvis, romel ime koneqtorSi Casmul i kontaqtebis raodenoba da a.S.). maSasadame:

$$p_i = (v, o) \qquad p_i \in P \quad i = \overline{1, n} \qquad (2.1.4)$$

sadac p_i aris gayvanilobis Semadgeneli komponenti, v aris komponentis fizikuri Tvisebebis aRmweri parameterebi, o aris misi gamoyenebis aRmweri parametrebi, xolo n aris gayvanilobaSi komponentebis raodenoba. maSasadame, satransporto saSualebis eleqtruli sistemis Semadgeneli TiToeuli komponentis aRsawerad saWiroa misi fizikuri (v) da gamoyenebis (o) parametrebis aRwera.

magaliTad, vTqvaT p_i aris mavTuli, romelic kvebis wyaros aerTebs minis eleqtroamwevTan. maSin, v = (kveTis farTobi, izolaciis sisqe, feri, nivTiereba, ...), xolo o=(sigrZe, identifikatori, mavTulis nomeri, ...).

unda aRiniSnos, rom komponentis Semadgeneli v nawili SesaZlebelia erTnairi iyos ramdenime komponentisTvis, xolo o gamoyenebis nawili ki unikaluri iqneba TiToeuli maTganisaTvis. magaliTad, erTi da imave tipis mavTuli, romlis feric aris mwvane, gulis diametri 1 mm, xolo izolaciis sisqe 0.5, gayvanilobaSi SeiZleba gamoyenebul iqnes mraval jer (magaliTad, rogorc avtomobilis marcxena karis minis eleqtroamwevisTvis, aseve marjvena karis minis eleqtroamwe-visTvis).

Tuki TiToeul komponents aRvwerT cal-calke, miviRebT informaciul siWarbes, radgan v nawili ganmeordeba TiToeuli erTnairi komponentisTvis. amitom, umjobesi iqneba, Tu komponetebis v fizikur parametrebs aRvwerT calke da maT o gamoyenebebs gayvanilobaSi _ calke. es saSualebas mogvcems TiToeuli saxis fizikuri obieqti aRvweroT erjer, xolo komponentis aRwerisas ganvsazRvroT mxolod misi gamoyenebis nawili da mivuTiToT ukve aRweril im fizikur obieqtze, romelic gamoiyeneba. zemoT ganxiluli SemTxvevisTvis mavTuli aRiwereba erTjer, xolo im komponentisTvis, romelic gamoiyeneba marcxena karSi, aRvwerT mxolod gamoyenebis parametrebs (sigrZes, damontaJebis parametrebs da a.S.) da

mivuTiTebT, rom gamoiyeneba konkretuli tipis ukve aRwerili fizikuri mavTuli. aseve marjvena karisaTvis aRvwerT mxolod gamoyenebis parametrebs da mivuTiTebT igive fizikur obieqtze.

garda amisa, saWiroa aRiniSnos is faqtic, rom zogierTi komponenti SeiZleba Seicavdes sxva komponents. es Seexeba rogorc fizikur obieqtebs, aseve maT gamoyenebebsac. pirvel is magaliTia koneqtori, romelic Seicavs slotebs, xolo slotebi Seicavs kontaqtebs. meores magaliTia mavTulis gulebis gamoyeneba mraval gulian mavTulSi.

maSasadame miviRebT, rom satransporto saSualebis eleqtrul sistemaSi Semavali komponentebi **P** aRiwereba Semdeg-nairad:

$$P = \{V, O, R, CV, CO\} \qquad 2.1.5$$

sadac, $V = (v_1, v_2, ..., v_i, ... v_n)$ aris fizikuri obieqtebis aRweril obebis erToblioba, **n** aris mTlianad gayvanilobaSi gamoyenebuli sxvadasxva tipiis fizikuri obieqtebis raodenoba. $O = (o_1, o_2, ..., o_i, ..., o_m)$ aris komponentebis gamoyenebis aRweril obebi, **m** aris komponentebis raodenoba gayvanilobaSi, $R = (r_1, r_2, ..., r_i, ... r_m)$ aris simravlis mimarTeba **V** simravleze. misi Semadgeneli TiToeuli r_i elementi asaxavs kavSirs o_i obieqtis gamoyenebisa v_j fizikur obieqtTan. maSasadame,

$$r_i = f(o_i, v_j) \quad r_i \in R, \quad i = \overline{1, m}, j = \overline{1, n} \qquad (2.1.6)$$

sadac **m** aris komponentebis raodenoba gayvanilobaSi, **n** aris fizikuri obieqtebis raodenoba, xolo f aris kavSiri i komponetsa da mis Sesabamis j fizikur obieqts Soris. sqematurad es gamosaxulia nax. 3.-ze.

$CV = (cv_1, cv_2, ..., cv_i, ..., cv_m)$ aris mimarTeba **V** fizikuri obieqtebis simravlisa sakuTar Tavze da aRwers erTi fizikuri obieqtis meores SigniT gamoyenebas.

$$cv_k = g(v_i, v_j) \quad cv_k \in CV, i = \overline{1, n}, i \neq j, k = \overline{1, m} \qquad (2.1.7)$$
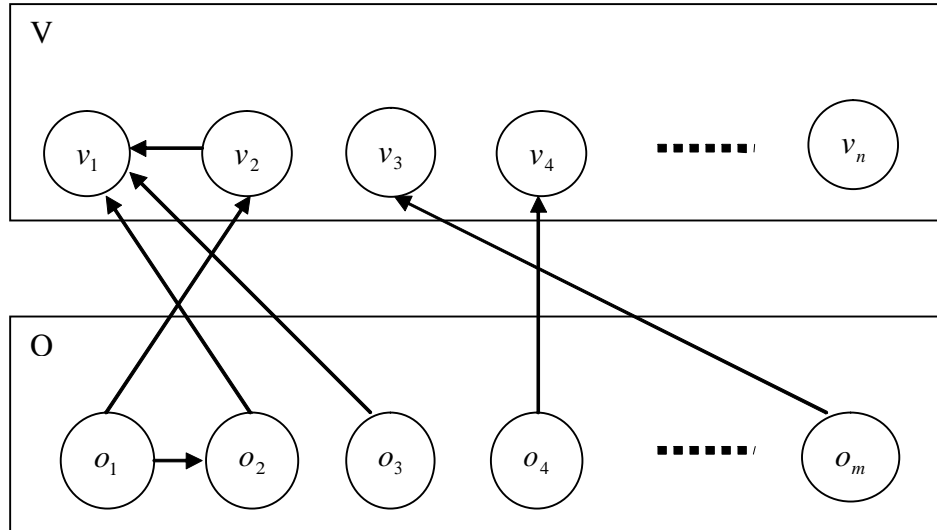
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nax. 3. kavSirebi komponentebis gamoyenebebsa da fizikur obieqtebs Soris

g aris kavSiri v_i obieqtisa mis Semadgenel v_j obieqtTan. n aris fizikuri obieqtebis raodenoba, xol o m aris obieqtebs Soris kavSirebis raodenoba.

$CO = (co_1, co_2, ..., co_i, ..., co_m)$ aris mimarTeba O komponentebis gamoyenebis simravlisa sakuTar Tavze da aRwers erTi komponentis meores SigniT gamoyenebas.

$$co_k = g(o_i, o_j) \quad co_k \in CO, i = \overline{1,n}, i \neq j, k = \overline{1,m} \tag{2.1.8}$$

g aris kavSiri o_i komponentis gamoyenebisa mis Semadgenel o_j komponentis gamoyenebasTan. n aris obieqtebis gamoyenebaTa raodenoba, xol o m aris gamoyenebaTa Soris kavSirebis raodenoba.

modelis aseTi saxiT organizeba damatebiT imiTac aris mosaxerxebeli, rom Tu Seicvleba obieqtis raime fizikuri parametri, misi Secvla saWiro iqneba mxolod erT adgilas V simravleSi, rac avtomaturad aisaxeba yvela komponentSi, romelic am tipis fizikur obieqts warmoadgens.

satransporto saSualebis Semadgenel komponentebs Soris arsebobs eleqtruli kavSirebi, romlebsac gaaCnia damatebiTi

parametrebi. eleqtruli kavSiri aris virtualuri cneba, igi fizikurad warmodgenilia mavTulisa da mis boloebTan mierTebuli ori koneqtoris saxiT. misi damaxasiaTebeli parametria signalis saxeli, romelic gansazRvravs Tu risTvis gamoiyeneba es kavSiri (magaliTad, Tu signalis saxeli iwyeba 31-iT es niSnavs rom mavTuli uerTdeba damiwebas). eleqtruli kavSirebi warmovidginoT Semdegi saxiT:

$$C = \{(c_s, p_s, c_e, p_e, w)_1, (c_s, p_s, c_e, p_e, w)_2, ..., (c_s, p_s, c_e, p_e, w)_n\} \quad (2.1.9)$$

sadac, c_s, c_e aris koneqtorebi Sesabamisad mavTulis dasawyisSi da dasasrulSi, p_s, p_e aris kontaqtebi roml ebTanac mavTuli aris mierTebuli sawyis da saboloo koneqtorTan, w aris TviT mavTuli.

satransporto saSualebis eleqtruli sistemebis Semadgeneli komponentebis sivrceSi ganlagebis aRsawerad saWiroa ori saxis meqanizmis damuSaveba. erTi aris iseTi komponentebis mdebareobis gansazRvra sivrceSi rogoricaa koneqtori, terminali da a.S. (maT gaaCniaT garkveuli koordinatebi sivrceSi). xolo meores mxriv sivrceSi gavlis traeqtoriebi mavTulebisaTvis. amisaTvis SemovitanoT kvanZisa da segmentis cnebebi. kvanZi aris virtualuri wertili sam ganzomilebian sivrceSi. kvanZze miebmeba konkretuli komponentebi. magaliTad, vTqvaT gansazRvrulia kvanZi koordinatebiT (100,30,50) da masze mibmulia koneqtori, maSin am koneqtoris koordinatebi iqneba (100,30,50). segmenti aris mrudi sivrceSi, igi Sedgeba bi-splainuri [11] mrudebisagan. segmentic, iseve rogorc kvanZi, virtualuri obieqtia, radgan fizikurad igi ar arsebobs satransporto saSualebis eleqtrogayvanil obaSi. sivrceSi ganlagebis aRwera warmovadginoT Semdegi saxiT:

$$L = \{N, S\} \quad (2.1.10)$$

L aris sivrceSi obieqtebis ganlagebis aRwera, N aris kvanZebis simravle, S _ segmentebis simravle.

segmentebis mimdevroba qmnis mavTulis traeqtorias sivrceSi. aRsaniSnavia, rom erT segmentSi ramdenime mavTuli SeiZleba gadiodes da piriqiT, erTi mavTulic SesaZlebelia ramdenime segmentSi gadiodes.

garda amisa, saWiroa SemovitanoT meqanizmi, romelic erTmaneTTan daakavSirebs mavTulebs da segmentebs. am meqanizms vuwodoT mavTulis trasireba.

$$T = (w, S')$$ (2.1.11)

sadac, $w \in P$ aris mavTuli, xolo $S' \subset S$ aris segmentebis mimdevroba.

satransporto saSualebis eleqtrul sistemaSi Semavali komponentebi daj gufebulia modulebad da anakreb komponentebad maT mier Sesasrulebeli funqciis mixedviT. magaliTad, yvela is eleqtruli komponenti, romelic emsaxureba Zravis muSaobas, gaerTianebulia erT moduleSi, eleqtrominebis momsaxure koponentebi sxva moduleSi da a.S. komponentebis aseTi daj gufeba mniSvnelovania maTi eleqtromagnituri Tavsebadobis analizisas funqcionalobis gaTvaliswinebiT.

2.2   logikuri daskvnebis meqanizmebis damuSaveba

eqspertuli sistemis Seqmnisas udidesi mniSvneloba eniWeba logikuri daskvnebis birTvis (interpretatoris) damuSavebas. satransporto saSualebebis eleqtromagnituri Tavsebadobis kvlevis eqspertuli sistemis logikuri daskvnebis birTvi unda gamoiyenebdes gadawyvetilebaTa pirdapir jaWvs [12], romlis drosac monacemebze (eleqtrogayvanilobis parametrebi da gare faqtorebi) dayrdnobiT sistema aformirebs hipoTezebs potenciuri eleqtromagnituri Tavsebadobis problemebis Sesaxeb. magaliTad, "Tu mavTulis zogadi klasi aris "antena" da manZili

antenidan mavTul amde nakl ebia dasaSvebze, maSin mavTul i arasworadaa gayvanil i".

interpretatori interpretacias ukeTebs codnis bazaSi arsebul wesebs da satransporto saSual ebis el eqtrul i sistemis model is mixedviT formirebul i faqtebis safuZvel ze akeTebs l ogikur daskvnebs. imisda mixedviT, Tu rogoria wesebSi aRweril i l ogika, SesaZl ebel ia daformirdes axal i faqtebi, roml ebic gamoiyeneba Semdgomi gadawyvetil ebebis misaRebad.

stransporto saSul ebebSi el eqtromagni turi Tavsebadobis diagnostikis eqspertul i sistemis interpretatori muSaobs Semdegi principiT:

1. codnis bazidan SeirCeva wesi, roml is interpretaciac unda moxdes.

2. xdeba faqtebis SesabamisobaSi moyvana wesSi aRweril l ogikasTan.

3. Tu wina punqtis Sedegi damakmayofil ebel ia, xdeba gadasvl a punqt 4-ze, winaaRmdeg SemTxvevaSi punqt 6-ze.

4. xdeba wesSi aRweril i l ogikuri moqmedebebis Sesrul eba.

5. wina punqtis muSaobis Sedegad formirdeba axal i faqtebi an xorciel deba daskvnebis gamomuSaveba.

6. Tu arsebobs kidev wesi, romel ic unda amoqmeddes, xdeba gadasvl a punqt 1-ze, winaaRmdeg SemTxvevaSi srul deba interpretatoris muSaoba.

ase rom, l ogikuri daskvnebis birTvis Sesaqmnel ad saWiroa SemuSavebul iqnas faqtebis formirebis meTodebi, wesebSi codnis aRweris da maTi interpretaciis meTodebi, gadawyvetil ebebis miRebis meTodebi.

faqtebi, erTis mxriv, formirdeba saproblemo aris model is safuZvel ze, xol o, meores mxriv, TviT l ogikuri daskvnebis birTvis muSaobis procesSi. amitom:

$$F = Fm \cup Fe \qquad (2.2.1)$$

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sadac, *F* aris faqtebis simravle, *Fm* aris faqtebi, formirebuli modelis safuZvelze, xolo *Fe* aris faqtebi, formirebuli wesebis amoqmedebis Sedegad. *Fm* simravle formirdeba interpretatoris amuSavebamde da igi ar icvleba misi muSaobis damTavrebamde. xolo *Fe* simravle interpretatoris muSaobis dawyebis momentisaTvis carielia, xolo muSaobis procesSi TandaTan emateba elementebi.

faqtebi formirdeba saproblemo aris modelis safuZvelze. satransporto saSualebis eleqtruli sistemebis eleqtromagnituri Tavsebadobis kvlevis eqspertuli sistemisaTvis SemuSavebuliqna faqtebis warmodgenis meTodebi freimebis saxiT [13]. eleqtrogayvanilobis Semadgeneli TiToeuli komponents (2.1.2) SevusabamebT sakuTar freims. freimebic SeiZleba davajgufoT gayvanilobis komponentebis tipebis mixedviT (2.1.3). TiToeuli tipis obieqtisaTvis miviRebT prototip freims, romlis TiToeuli slotiT iqneba aRwerili obieqtis TiTo parametri.

amrigad, freimi SeiZleba warmovidginoT Semdegi saxiT:

$$Fr = (T, S) \qquad (2.2.2)$$

sadac *T* aris freimis prototipis identifikatori. vinaidan TiTouli komponentis tips Seesabameba freimis sakuTari prototipi, swored *T* gansazRvravs am Sesabamisobas. *S* aris slotebis simravle.

$$S = \{s\} \qquad (2.2.3)$$

slots, Tavis mxriv, gaaCnia saxel wodeba, romelic unikalurad gansazRvravs mas, mniSvneloba da mniSvnelobis tipi.

$$s = (i, v, t) \qquad (2.2.4)$$

s aris sloti, sadac, *i* aris slotis dasaxeleba, *v* aris misi mniSvneloba, *t* aris mniSvnelobis tipi.

magaliTad, zemoT aRwerili meTodis mixedviT satransporto saSualebis eleqtrogayvanilobaSi Semavali iseTi komponentis tips, rgoricaa mavTuli, Seesabameba erTi freimis prototipi, igi saerTo iqneba yvela mavTulisaTvis, xolo roca

prototipSi slotebis mniSvnelobebs SevavsebT konkretuli mavTulebis Sesabamisi maxasiaTeblebis mniSvnelobebiT, miviRebT konkretul freimebs, roml ebic Seesabameba ukve konkretul obieqtebs. mavTul isTvis freimis prototips eqneba Semdegi saxe:

(mavTul i

(<saxel i> <> <simbol oTa masivi>)

(<gul is kveTis farTobi> <> <ricxvi mcuravi mZimiT>)

(<nomeri> <> <mTel i ricxvi>)

. . .

)

rogorc vxedavT, freimis prototipi saerToa yvel a mavTul isTvis. konkretul mavTul s ki Seesabameba Semdegi konkretul i freimi:

(mavTul i

(<saxel i> <**WR_1_37**> <simbol oTa masivi>)

(<gul is kveTis farTobi> <0.25> <ricxvi mcuravi mZimiT>)

(<nomeri> <5> <mTel i ricxvi>)

. . .

)

es freimi aRwers faqts, rom sakvl evi obieqtis el eqtrul sistemaSi arsebobs mavTul i, roml is saxel ia **WR_1_37**, gul is kveTis farTobia 0.25, nomeria 5 da a.S.

aqve unda aRiniSnos, rom mxol od statikuri monacemebi satransporto saSual ebis el eqtrul i sistemis Sesaxeb sakmarisi ar aris, interpretators esaWiroeba sxvadasxva tipis monacemebi, roml ebic gaTvl ebis Sedegad miiReba. ZiriTadad es aris geometriul i maCveneblebis (manZil ebi sxvadasxva obieqtebs Soris da a.S.) da el eqtromagnituri maxasiaTeblebis gaTvl a (magnituri vel ebi, urTierTqmedebis denebi da a.S.) am monacemebis miReba faqtebis safuZvel ze SeuZl ebel ia, amitom isini realizebul ia gare funqciebiT, roml ebsac gamoiZaxebs interpretatori.

amrigad, interpretatorisaTvis informaciis wyaros warmo-adgens faqtebi da gare funqciebi.

eqspertul i codna satransporto saSual ebebis el eqtrul i sistemebis el eqtromagnituri Tavsebadobis kvl evis eqspertul sistemaSi inaxeba da gamoiyeneba wesebis saxiT.

wesebSi codnis warmodgena damyarebul ia produqciebze [13]. produqcia SeiZl eba warmovidginoT Semdegnairad:

$$U : A \rightarrow B \qquad (2.2.5)$$

sadac, U aris piroba, romel ic unda Sesrul des produqciis asamoqmedebl ad, $A \rightarrow B$ aris produqciis birTvi _ A aris piroba, xol o B aris moqmedeba. pirobiT nawil s sxvanairad marcxena nawil sac uwodeben, xol o moqmdebis nawil s ki marj vena nawil s.

imis gansazRvra, amoqmeddeba Tu ara konkretul i wesi, damokidebul ia faqtebisa da produqciis pirobiT nawil Si aRweril cvl adebze. produqciis marcxena nawil i warmovadginoT Semdegi saxiT:

$$A = \{Cf, Ca\} \qquad (2.2.6)$$

sadac, Cf aris piroba, romel ic mowmdeba faqtebis safuZvel ze, xol o Ca aris damatebiTi piroba, romel ic SeiZl eba iyos nebismieri l ogikuri gamosaxul eba. produqcia amoqmeddeba mxol od im SemTxvevaSi Tu dakmayofil da orive piroba. e.i.

$$U = Cf \wedge Ca \Rightarrow TRUE \qquad (2.2.7)$$

unda aRiniSnos, rom SeiZl eba arsebobdes pirobebis Semdegi kombinaciebi: marcxena nawil Si arsebobs rogorc Cf aseve Ca, marcxena nawil Si arsebobs mxol od Cf, marcxena nawil Si arsebobs mxol od Ca, marcxena nawil Si ar arsebobs arc Cf da arc Ca. bol o SemTxvevaSi produqcia aris upirobo da igi amoqmeddeba yovel Tvis. vinaidan Ca aris nebismieri l ogikuri gamosaxul eba, igi ganxil vas ar saWiroebs. ganvixil oT rogor aris real izebul i Cf.

Cf warmoadgens freimebze mimarTvebis simravles.

$$Cf = (Rf_1, Rf_2, ..., Rf_n) \qquad (2.2.8)$$

sadac *Rf* aris freimze mimarTva.

freimze mimarTva SeiZleba iyos warmatebuli an warumatebeli. vTvliT, rom piroba *Cf* dakmayofilda, Tu warmatebulia aRmoCnda yvela freimze mimarTva.

$$\text{Re}s(Cf) = \text{Re}s(Rf_1) \wedge \text{Re}s(Rf_2) \wedge ... \wedge \text{Re}s(Rf_n) \qquad (2.2.9)$$

sadac $\text{Re}s(Cf)$ aris *Cf*-is dakmayofilebis Sedegi, $\text{Re}s(Rf)$ aris freimze mimarTvis warmatebuloba.

freimze mimarTvebis ganxorcieleba xdeba pirobebis SesabamisobaSi moyvaniT arsebul faqtebTan. Tu arsebul ma faqtebma daakmayofila yvela piroba, maSin freimze mimarTva CaiTvleba warmatebulad, winaaRmdeg SemTxvevaSi _ warumateblad.

TiTOeuli freimze mimarTva warmodgenilia freimis prototipis identifikatoriT, cvladebisa da cvladebis gansazRvrebebis saxiT.

$$Rf_i = \{Fid, V, D, f(V, D)\} \qquad (2.2.10)$$

sadac *Rf* aris freimze mimarTva, *Fid* aris freimis identifikatori, *V* aris cvladebis simravle, *D* aris cvladebis gansazRvrebebis simravle, xolo $f(V, D)$ akavSirebs TiTOeul cvlads Tavis gansazRvrebasTan. unda aRiniSnos rom TiTOeuli $v \in V$ cvladi *V* simravlidan Seesabameba freimis erT slots. TiTOeul cvlads Seesabameba TiTO $d \in D$ gansazRvreba *D* simravlidan. gansazRvreba Sedgeba slotis identifikatorisagan da SemzRudavi pirobebisagan.

$$d = \{Sid, Rst\} \qquad (2.2.11)$$

sadac *Sid* aris slotis identifikatori, xolo *Rst* SezRudva.

slotis identifikatori gansazRvravs Tu romeli slotidan unda iqnas amoRebuli cvladis mniSvneloba, xolo SezRudva gansazRvravs Tu ra pirobas unda akmayofilebdes es mniSvneloba. Tu mniSvnelobam SemzRudavi piroba ar daakma-

yofila, maSin cvl adSi ar xdeba slotis mniSvnelobis amoReba da freimze mimarTva iTvleba warumateblad. maSasadame, Tu freimze mimarTvaSi arsebuli yvela cvladis mniSvnelobis aReba moxda warmatebiT, freimze mimarTva warmatebulia, xolo winaaRmdeg SemTxvevaSi _ warumatebeli.

$$\text{Re}\,s(Rf) = g(Rst_1) \land g(Rst_2) \land ... \land g(Rst_n) \qquad (2.2.12)$$

sadac $g(Rst_i)$ aris Rst_i SezRudvis dakmayofilebis Sedegi.

freimze mimarTvis procesi unda warmovidginoT Semdegnairad:

1. freimis prototipis identifikatoris mixedviT aiReba konkretuli freimi.

2. TiToeuli $v_i \in V$ cvladisaTvis moiZebnaba $d_i \in D$ gansazRvrebis Sid nawilSi aRwerili sloti da aiReba masSi Caweril i mniSvneloba.

3. xdeba Semowmeba, aRebuli mniSvneloba akmayofilebs Tu ara Rst_Ti gansazRvrul SezRudvebs.

4. Tu piroba dakmayofilda, aRebuli mniSvneloba mieniWeba v_i cvlads. winaaRmdeg SemTxvevaSi xdeba momdevno konkretul freimze gadasvla.

im SemTxvevSi, Tu produqciis amoqmedebis piroba dakmayofilda, ganxorcieldeba produqciis B nawili. unda aRiniSnos, rom marcxena nawilSi aRebuli cvladebisa da maTi mniSvnelobebis gamoyeneba SesaZlebelia marjvena nawilic.

magaliTad, freimze mimarTva SeiZleba mocemuli iyos Semdegi saxiT:

(mavTuli (x <gulis kveTis farTobi> [<0.5]) (y <nomeri>[=5]))

es mimarTva eZebs mavTuls, romlis gulis kveTis farTobi naklebia 0,5-ze da nomeri aris 5. Tu aseTi mavTuli moiZebna, x-s mieniWeba misi gulis kveTis farTobi, xolo y-s nomeri.

TviT wesebi Tavisi Sinaarsis mixedviT, pirobiTad SeiZleba davajgufoT or nawilad: wesebi, romlebic qmnian axal faqtebs

da wesebi, romel Ta muSaobis Sedegad xdeba mxol od daskvnebis gamotana da hipoTezebis SeTavazeba eqspertul i sistemis momxmarebl isaTvis. pirvel rigSi interpretatori asrul ebs wesebs, roml ebic qmnian axal faqtebs, xol o Semdeg xdeba danarCeni wesebis amoqmedeba.

B nawil Si gansazRvrul i aris ukve konkretul i moqmedebebi, roml ebic unda ganxorciel des wesis amoqmedebisas. moqmedebebTan erTad am nawil Si SeiZl eba gamoyenebul iqnas pirobiTi gamosaxul ebebic, rac SesaZl ebl obas iZl eva Seqmnil iqnas ufro rTul i l ogikis wesebi, es ki, Tavis mxriv, afarToebs eqspertul i sistemis SesaZl ebl obebs. produqciis marj vena nawil i SesaZl ebel ia warmovidginoT Semdegi saxiT:

$$B = \{O, C, F, V\} \qquad (2.2.13)$$

sadac O operatorebia, C _ pirobiTi gamosaxul ebebi, F _ gare funqciebi, xol o V _ cvl adebi.

gamoviyenebT ori saxis operatorebs: maTematikurs da l ogikurs. pirobiT gamosaxul ebebs aqvT saxe: Tu (piroba), maSin (moqmedeba), winaaRmdeg SemTxvevaSi (moqmedeba), sanam (piroba) manamde (moqmedeba). gare funqciebi, rogorc zemoT iyo aRniSnul i, gamoiyeneba sxvadasxva saxis geometriul i da el eqtromagnituri gaTvl ebis ganxorciel ebisaTvis, aseve saprob-l emo aris model Si cvl il ebebis Sesatanad. cvl adebi arsebobs sami tipis: cvl adebi, roml ebic gadmodian marcxena (A) nawil idan da roml ebic zemoT iyo aRweril i; cvl adebi, roml ebic gansazRvrul ia l okal urad B nawil Si da gamoiyeneba mxol od mis SigniT; gl obal uri cvl adebi, roml ebic gamoiyeneba sxvadasxva wesebs Soris monacemTa gasacvl el ad da maTi gamoyeneba SeiZl eba yvel a wesSi.

zemoT aRweril saSual ebebsa da meTodebze dayrdnobiT l ogikuri daskvnebis birTvi interpretacias ukeTebs wesis B nawil s da iRebs l ogikur gadawyvetil ebebs predikatebis l o-gikis meTodebze dayrdnobiT [14].

2.3 eleqtrogayvanilobis komponentebs Soris eleqtromagnituri urTierTqmedebis modelirebis meTodebis SemuSaveba

satransporto saSualebebis eleqtromagnituri Tavsebadobis potenciuri problemebis gamovlena SeuZlebelia maTi eleqtruli sistemebis komponentebs Soris eleqtromagnituri zemoqmedebis modelirebis gareSe. rogorc wina paragrafSi iyo aRniSnuli, eqspertuli sistemis birTvi iyenebs gare funqciebs, romlebic gamoiyeneba eleqtrogayvanilobis komponentebs Soris urTierTqmedebis iseTi eleqtromagnituri parametrebis da sidideebis gamosaTvlelad, rogoricaa mavTulebs Soris urTierTtevadobebi da urTierTinduqciurobebi, urTierTqmedebis kvazistatikuri denebi da Zabvebi, S parametrebi [15] da a.S.

qvemoT moyvanilia meTodebi, romlebic gamoiyenaba eleqtromagnituri paramtrebis gamosaTvlelad:

kvazistatikuri eqvivalenturi denis wyaros deni, romelic kvebavs antenas gamoiTvleba Semdegi formuliT:

$$I = C_m \frac{I_{\max}}{T_{\min}} \qquad (2.3.1)$$

C_m _ aris mavTulsa da antenas Soris urTierTtevadoba.

$I_{\max}$ _ maqsimaluri deni (parametri aRwerilia gayvanilobis modelSi).

$T_{\min}$ _ minimaluri gadasvlis dro (parametri aRwerilia gayvanilobis modelSi).

kvazistatikuri eqvivalenturi Zabvis wyaros Zabva, romelic kvebavs antenas, gamoiTvleba Semdegi formuliT:

$$V = L_m \frac{V_{\max}}{T_{\min}} \qquad (2.3.2)$$

L_m _ aris mavTulsa da antenas Soris urTierTinduqciuroba.

V_{max} — maqsimaluri Zabva (parametri aRwerilia gayvanilobis model Si).

T_{min} — minimaluri gadasvlis dro (parametri aRwerilia gayvanilobis model Si).

mavTulsa da antenas Soris urTierTtevadobisa da urTierTinduqtiurobis gamoTvlebisaTvis gamoiyeneba samganzomilebiani eleqtrostatikuri gaTvlebis birTvi **Static3D**, romelic calke programis saxiT aris realizebuli. antena da mavTuli eleqtrostatikuri gaTvlebis birTvs gadaecema nastranis [16] formatis mqone failis saxiT. Tu modelSi aRwerilia satransporto saSualebis Zara, maSin misi gaTval iswinebac xdeba gaTvlebisas. mavTulis izolaciis SeRwevadobis gaTval iswineba ar xdeba.

S parametrebis gamoTvlebisTvis mavTulsa da antenas Soris gamoiyeneba samganzomilebiani eleqtrodinamikuri gaTvlebis birTvi **TRiD**, romelic calke programis saxiTaa realizebuli. S11 parametris gamoTvlis procesi moicavs Semdeg bijebs:

1. unda ganisazRvros antenis porti. porti ganisazRvreba antenis segmentiT da winaRobiT am segmentze.

2. unda aigos modeli eleqtrodinamikuri gaTvlebisaTvis. mavTulis boloebze generirdeba damiwebis segmentebi, romlebic mavTulis boloebs aerTebs satransporto saSualebis Zaris triangulirebul badesTan. segmentisa da Zaris aRmweri badis SeerTebis wertilSi xdeba badis triangulireba ise, rom Sexebis wertili aRmoCndes samkuTxedis wveroSi. programaSi gansazRvruli wredi mieniWeba pirvel damiwebis segments, xolo meore damiwebis segments mieniWeba Zabvis wyaro (1 v) da winaRoba (50 omi).

3. dagenerirebuli modeli gadaecema eleqtrodinamikuri gaTvlebis birTvs gaTvlebis gansaxorcieleblad.

4. eleqtrodinamikuri gaTvlebis Sedegad viRebT:

dens mavTulis meore damiwebis segmentSi (porti 1) _ I1

Zabvas mavTulis meore damiwebis segmentSi (porti 1) _ V1

winaRobas mavTulis meore segmentSi (porti 1) _ Z1

miRebuli mniSvnelobebidan S11 parametri gamoiTvleba Semdegi formuliT:

$$Zin = \frac{V1}{I1} - Z1$$

$$S11 = \frac{Zin - Z1}{Zin + Z1} \qquad (2.3.3)$$

S12 parametris gamoTvlis procesi moicavs Semdeg bijebs:

1. unda ganisazRvros antenis porti. porti ganisazRvreba antenis segmentiT da winaRobiT am segmentze.

2. unda aigos modeli eleqtrodinamikuri gaTvlebisaTvis. mavTulis boloebze generirdeba damiwebis segmentebi, romlebic mavTulis boloebs aerTebs satransporto saSualebis Zaris triangulirebul badesTan. segmentisa da Zaris aRmweri badis SeerTebis wertilSi xdeba badis triangulireba ise, rom Sexebis wertili aRmoCndes samkuTxedis wveroSi. programaSi gansazRvruli wredi mieniWeba orive damiwebis segments, antenis ports mieniWeba Zabvis wyaro (1 v) da winaRoba (50 omi).

3. dagenerirebuli modeli gadaecema eleqtrodinamikuri gaTvlebis birTvs gaTvlebis gansaxorcieleblad.

4. eleqtrodinamikuri gaTvlebis Sedegad viRebT:

    dens mavTulis meore damiwebis segmentSi (porti 1) _ I1

    Zabvas antenis portis segmentSi (porti 2) _ V2

    winaRobas antenis portis segmentSi (porti 2) _ Z2

miRebuli mniSvnelobebidan S12 parametri gamoiTvleba Semdegi formuliT:

$$S12 = 2 * Z2 * \frac{I1}{V2} \qquad (2.3.4)$$

S21 parametris gamoTvl is procesi moicavs Semdeg bijebs:

1. unda ganisazRvros antenis porti. porti ganisazRvreba antenis segmentiT da winaRobiT am segmentze.

2. unda aigos modeli el eqtrodinamikuri gaTvl ebisaTvis. mavTul is bol oebze generirdeba damiwebis segmentebi, roml ebic mavTul is bol oebs aerTebs satransporto saSual ebis Zaris triangul irebul badesTan. segmentisa da Zaris aRmweri badis SeerTebis wertil Si xdeba badis triangul ireba ise, rom Sexebis wertil i aRmoCndes samkuTxedis wveroSi. programaSi gan-sazRvrul i wredi mieniWeba pirvel damiwebis segments, xol o meore damiwebis segments mieniWeba Zabvis wyaro (1 v) da winaRoba (50 omi).

3. dagenerirebul i model i gadaecema el eqtrodinamikuri gaTvl ebis birTvs gaTvl ebis gansaxorciel ebl ad.

4. el eqtrodinamikuri gaTvl ebis Sedegad viRebT:

   dens antenis portis segmentSi (porti 2) _ $I1$

   Zabvas mavTul is meore damiwebis segmentSi (porti 1) _ $V1$

   winaRobas mavTul is meore segmentSi (porti 1) _ $Z1$

miRebul i mniSvnel obebidan S21 parametri gamoiTvl eba Semdegi formul iT:

$$S21 = 2 * Z1 * \frac{I2}{V1} \qquad (2.3.5)$$

S22 parametris gamoTvl is procesi moicavs Semdeg bijebs:

1. unda ganisazRvros antenis porti. porti ganisazRvreba antenis segmentiT da winaRobiT am segmentze.

2. unda aigos modeli el eqtrodinamikuri gaTvl ebisaTvis. mavTul is bol oebze generirdeba damiwebis segmentebi, roml ebic mavTul is bol oebs aerTebs satransporto saSual ebis Zaris triangul irebul badesTan. segmentisa

da Zaris aRmweri badis SeerTebis wertil Si xdeba badis triangulireba ise, rom Sexebis wertili aRmoCndes samkuTxedis wveroSi. programaSi gansazRvruli wredi mieniWeba orive damiwebis segments, antenis ports mieniWeba Zabvis wyaro (1 v) da winaRoba (50 omi).

3. dagenerirebuli modeli gadaecema eleqtrodinamikuri gaTvlebis birTvs gaTvlebis gansaxorcieleblad.

4. eleqtrodinamikuri gaTvlebis Sedegad viRebT:

   dens antenis portis segmentSi (porti 2) _ $I2$

   Zabvas antenis portis segmentSi (porti 2) _ $V2$

   winaRobas antenis portis segmentSi (porti 2) _ $Z2$

miRebuli mniSvnelobebidan $S22$ parametri gamoiTvleba Semdegi formuliT:

$$Zin = \frac{V2}{I2} - Z2$$

$$S22 = \frac{Zin - Z2}{Zin + Z2} \qquad (2.3.6)$$

kvazistatikuri eqvivalenturi denis wyaros deni, romelic aRiZvreba erTi mavTulidan meore mavTulSi, gamoiTvleba Semdegi formuliT:

$$I = C_m \frac{I_{\max}}{T_{\min}} \qquad (2.3.7)$$

C_m _ aris mavTulebs Soris urTierTtevadoba.

$I_{\max}$ _ maqsimaluri deni (parametri aRwerilia gayvanilobis modelSi).

$T_{\min}$ _ minimaluri gadasvlis dro (parametri aRwerilia gayvanilobis modelSi).

kvazistatikuri eqvivalenturi Zabvis wyaros Zabva, romelic aRiZvreba erTi mavTulidan meore mavTulSi, gamoiTvleba Semdegi formuliT:

$$V = L_m \frac{V_{\max}}{T_{\min}} \qquad (2.3.8)$$

L_m – aris mavTul ebs Soris urTierTinduqtiuroba.

V_{max} – maqsimaluri Zabva (parametri aRweril ia gayvanil obis model Si).

T_{min} – minimaluri gadasvl is dro (parametri aRweril ia gayvanil obis model Si).

mavTul ebs Soris urTierTtevadobis da urTierTinduq-ciurobis martivi gaTvl ebisTvis vTvl iT, rom mxol od paral el uri mavTul ebi (mavTul ebi roml ebic erT segmentSi gadis) urTierTqmedeben miwis sibrtyis gaTval iswinebiT. jer xdeba mavTul ebis avtomaturi dal ageba TiToeul i segmentis kveTaSi da Semdeg urTierTtevadobebis da urTierTinduq-ciurobebis dadgena TiToeul segmentSi. sigrZis mniSvnel obebi **D**, **a** da **a'** aiReba rogorc mudmivi (nax. 4.). tevadobis da induqciurobebis mniSvnel obebi ikribeba sabol oo Sedegis misaRebad.

nax. 4. kveTa, romel zec xdeba urTierTtevadobebis gamoTvl a

mavTul ebis radiusebs vTvl iT erTnairad da mis mniSvnel obad viRebT yvel a mavTul is radiusebis saSual o mniSvnel obas. sigrZis erTeul ze tevadoba gamoiTvl eba Semdegi formul iT:

$$C = \frac{2pe_0 \ln(a'/a)}{\ln^2(D/d) - \ln^2(a'/a)} \qquad (2.3.9)$$

sigrZis erTeul ze urTierTinduqciurobebi gamoiTvl eba Semdegi formul iT:

$$M = \frac{m_0}{2p}\ln\left(\frac{a'}{a}\right) \qquad (2.3.10)$$

SesaZl ebel ia gamoTvl il i iqnes geometriis sami varianti: cudi, saSual o da kargi.

cudi: $D = 0.02$ m; a = 2.1*d; $a' = \sqrt{a^2 + D^2}$.

saSual o: $D = 0.02$ m; a = R Tu R > 2.1*d, winaaRmdeg SemTxvevaSi a=2.1*d sadac R – aris segmentis j amuri radiusi; $a' = \sqrt{a^2 + D^2}$.

kargi: $D = 0.02$ m; a = 2*R Tu 2*R > 2.1 d, winaaRmdeg SemTxvevaSi a=2.1*d sadac R – aris segmentis j amuri radiusi; $a' = \sqrt{a^2 + D^2}$.

sivrceSi nebismier or mavTul s Soris urTierTtevadobisa da urTierTinduqciurobis gamoTvl ebisaTvis gamoiyeneba samganzomil ebiani el eqtrostatikuri gaTvl ebis birTvi **Static3D**. mavTul ebi gaTvl ebis birTvs gadaecema nastranis formatis mqone fail is saxiT. winaswar xdeba mavTul ebis avtomaturi gadanawil eba segmentis kveTaSi (al goriTmi aRweril ia qvemoT). Tu model Si aRweril ia satransporto saSual ebis Zara, maSin misi gaTval iswinebac xdeba gaTvl ebisas. mavTul is izol aciis SeRwevadobis gaTval iswineba ar xdeba.

S parametris gamosaTvl el ad or mavTul s Soris gaoiyeneba samganzomil ebiani el eqtrodinamikuri gaTvl ebis birTvsi **TRiD**. **S11** parametris gamoTvl is procesi moicavs Semdeg bij ebs:

1. unda aigos model i el eqtrodinamikuri gaTvl ebisaTvis. mavTul ebis bol oebze generirdeba damiwebis segmentebi, roml ebic mavTul is bol oebs aerTeben satransporto saSual ebis Zaris triangul irebul badesTan. segmentisa da Zaris aRmweri badis SeerTebis wertil Si xdeba badis triangul ireba ise, rom Sexebis wertil i aRmoCndes samkuTxedis wveroSi. programaSi gan-sazRvrul i wredi mieniWeba meore mavTul is orive da pirvel i mavTul is pirvel damiwebis segments, xol o

pirvel i mavTul is meore damiwebis segments mieniWeba
Zabvis wyaro (1 v) da winaRoba (50 omi).

2. dagenerirebul i model i gadaecema el eqtrodinamikuri
   gaTvl ebis birTvs gaTvl ebis gansaxorciel ebl ad.

3. el eqtrodinamikuri gaTvl ebis Sedegad viRebT:

   dens pirvel i port 1-Si _ $I1$

   Zabvas port 1-Si _ $V1$

   winaRobas porti 1-Si _ $Z1$

miRebul i mniSvnel obebidan $S11$ parametri gamoiTvl eba
Semdegi formul iT:

$$Zin = \frac{V1}{I1} - Z1$$

$$S11 = \frac{Zin - Z1}{Zin + Z1}$$ (2.3.11)

$S12$ parametris gamoTvl is procesi moicavs Semdeg bij ebs:

1. unda aigos model i el eqtrodinamikuri gaTvl ebisaTvis.
   mavTul ebis bol oebze generirdeba damiwebis segmentebi,
   roml ebic mavTul is bol oebs aerTebs satransporto
   saSual ebis Zaris triangul irebul badesTan. segmentisa
   da Zaris aRmweri badis SeerTebis wertil Si xdeba
   badis triangul ireba ise, rom Sexebis wertil i
   aRmoCndes samkuTxedis wveroSi. programaSi gansazRvru-
   l i wredi mieniWeba pirvel i mavTul is orive damiwebis
   segments da meore mavTul is pirvel damiwebis segments.
   meore mavTul is meore damiwebis segments mieniWeba
   Zabvis wyaro (1 v) da winaRoba (50 omi).

2. dagenerirebul i model i gadaecema el eqtrodinamikuri
   gaTvl ebis birTvs gaTvl ebis gansaxorciel ebl ad.

3. el eqtrodinamikuri gaTvl ebis Sedegad viRebT:

   dens port 1-Si _ $I1$

   Zabvas port 2-Si _ $V2$

   winaRobas port 2-Si _ $Z2$

miRebuli mniSvnelobebidan $S12$ parametri gamoiTvleba Semdegi formuliT:

$$S12 = 2*Z2*\frac{I1}{V2}$$ (2.3.12)

$S21$ parametris gamoTvlis procesi moicavs Semdeg bijebs:

1. unda aigos modeli eleqtrodinamikuri gaTvlebisaTvis. mavTulebis boloebze generirdeba damiwebis segmentebi, romlebic mavTulis boloebs aerTebs satransporto saSualebis Zaris triangulirebul badesTan. segmentisa da Zaris aRmweri badis SeerTebis wertilSi xdeba badis triangulireba ise, rom Sexebis wertili aRmoCndes samkuTxedis wveroSi. programaSi gansazRvruli wredi mieniWeba meore mavTulis orive damiwebis segments da pirveli mavTulis meore damiwebis segments, xolo pirveli mavTulis meore damiwebis segments mieniWeba Zabvis wyaro (1 v) da winaRoba (50 omi).

2. dageneriirebuli modeli gadaecema eleqtrodinamikuri gaTvlebis birTvs gaTvlebis gansaxorcieleblad.

3. eleqtrodinamikuri gaTvlebis Sedegad viRebT:

   dens port 2-Si _ I2

   Zabvas porti 1-Si _ V1

   winaRobas port 1-Si _ Z1

miRebuli mniSvnelobebidan $S21$ parametri gamoiTvleba Semdegi formuliT:

$$S21 = 2*Z1*\frac{I2}{V1}$$ (2.3.13)

$S22$ parametris gamoTvlis procesi moicavs Semdeg bijebs:

1. unda aigos modeli eleqtrodinamikuri gaTvlebisaTvis. mavTulebis boloebze generirdeba damiwebis segmentebi, romlebic mavTulis boloebs aerTebs satransporto saSualebis Zaris triangulirebul badesTan. segmentisa da Zaris aRmweri badis SeerTebis wertilSi xdeba

badis triangulireba ise, rom Sexebis wertili aRmoCndes samkuTxedis wveroSi. programaSi gansazRvru-li i wredi mieniWeba pirveli mavTulis orive damiwebis segments da meore mavTulis pirvel damiwebis segments. meore mavTulis meore damiwebis segments mieniWeba Zabvis wyaro (1 v) da winaRoba (50 omi).

2. dagenerirebuli modeli gadaecema eleqtrodinamikuri gaTvlebis birTvs gaTvlebis gansaxorcieleblad.

3. eleqtrodinamikuri gaTvlebis Sedegad viRebT:

dens port 2-Si _ **I2**

Zabvas port 2-Si _ **V2**

winaRobas port 2-Si _ **Z2**

miRebuli mniSvnelobebidan **S22** parametri gamoiTvleba Semdegi formuliT:

$$Zin = \frac{V2}{I2} - Z2$$

$$S22 = \frac{Zin - Z2}{Zin + Z2} \qquad (2.3.14)$$

eleqtrostatikuri da eleqtrodinamikuri gaTvlebis birTvebi saWiroeben mavTulebis modelirebas sivrceSi. **KBL** standarti mavTulebis gatarebis traeqtorias sivrceSi aRwers segmentebis saSualebiT. TiToeul mavTuls mieTiTeba segmentebis mimdevroba, romel Sicigi gadis, xolo TviT segments aqvs RerZuli mrudi, romelic warmoadgens splains sivrceSi. mavTuls ar mieTiTeba misi mdebareoba segmentis kveTSi, ase rom yvela mavTulis gatarebis traeqtoria emTxveva segmentis RerZul xazs. e.i. segmentis kveTaSi, masSi gamaval yvela mavTuls aqvs pozicia (0,0). es imiT aris gamowveuli, rom **KBL** standarti Seqmnilia satransporto saSualebebis eleqtrogayva-nilobis topologiis warmosadgenad da ar aris gaTvalis-winebuli misi gamoyeneba eleqtrostatikiuri da eleqtrodinami-kuri gaTvlebisaTvis.

imisaTvis, rom ganvaxorciel oT eleqtrostatikuri da eleqtrodinamikuri gaTvl ebi, saWiroa mavTul ebi sivrceSi ar emTxveodes da ar kveTdes erTmaneTs. SemuSavebul i iqna al goriTmebi, rom ebic erTis mxriv mavTul ebs anawil ebs segmentis kveTSi ise, rom isini ar emTxveodes erTmaneTs, xol o meores mxriv, atarebs maT sivrceSi RerZul i traeqtoriis gaswvriv kveTaSi gadanawil ebiT miRebul manZil ze TanakveTebis gareSe (nax. 5.).

mavTul ebis segmentis kveTaSi gadanawil ebis al goriTmis mizania yvel a mavTul i rac SeiZl eba mWidrod gaanawil os segmentis or ganzomil ebian kveTaSi. mavTul is kveTa sibrtyeze warmoadgens wres. simWidrovis kriteriumad aRebul ia mavTul is centris siaxl ove ukve dal agebul i mavTul ebis centrebis simZimis centrTan. maSasadame, saWiroa wreebi ganval agoT rac SieZl eba mWidrod erTmaneTisgan gansazRvrul manZil ze. Semovitano T Semdegi aRniSvnebi: O – ukve dal agebul i mavTul ebis simravl e, U _ dasal agebel i mavTul ebis simravl e. Tavdapirvel ad O aris cariel i, xol o U moicavs kveTaSi arsebul yvel a mavTul s. al goriTmis muSaobis Semdeg ki O moicavs yvel a mavTul s, xol o U aris cariel i.

"mavTul Ta wyvil i" vuwodoT iseT or mavTul s, romel Tagan erT-erTma miiRo monawil eoba meoris mdebareobis gansazRvraSi da roml ebic mdebareoben uSual od erTmaneTis gverdiT. mavTul Ta wyvil i aRvniSno T Semdegnairad $Pair(o_i, o_j)$ $o_i \in O, o_j \in O, i \neq j$. mavTul Ta wyvil Ta simravl e aRvniSno T **P**-Ti. manZil i, romel ic unda iyos mavTul ebs Soris aRvniSno T **d**-Ti. ganl agebul i wreebis centrebis simZimis centri aRvniSno T **W**-Ti.

al goriTmis arsi mdgomareobs SemdegSi:

1. aviRoT dasal agebel i mavTul ebis **U** simravl idan pirvel i mavTul i, ganvaTavso T koordinatTa saTaveSi (0,0) da gadavitano T **O** dal agebul mavTul Ta simrav- l eSi.

pozicionirebamde 2D-Si   pozicionirebamde 3D-Si

pozicionirebis Semdeg 2D-Si   pozicionirebis Semdeg 3D-Si
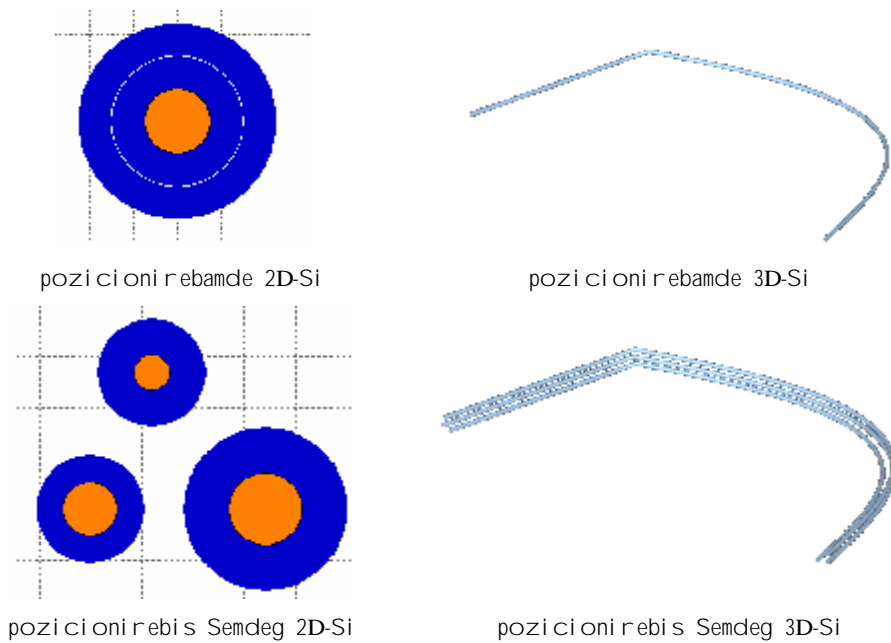
nax. 5. mavTulebis avtomaturi pozicionirebis algoriTmis muSaobis Sedegebi

2. aviRoT dasalagebeli mavTulebis U simravlidan meore mavTuli da ganvaTavsoT koordinatebiT $(R_1 + R_2 + d, 0)$, sadac R_1 aris pirveli wris radiusi, xolo R_2 _ meore wris. gadavitanoT O dalagebul mavTulTa simravleSi. SevqmnaT wyvili $Pair(o_1, o_2)$ da mivaniWoT P wyvilTa simravles.

3. gamoviTval oT simZimis centri W (nax. 6.).

4. aviRoT dasalagebeli mavTulebis simravlidan U erT-erTi mavTuli $u_k (u_k \in U)$.

5. P wyvilTa simravlidan aviRoT erT-erTi wyvili $Pair_t(o_i, o_j), o_i \in O, o_j \in O, i \neq j$ da vipovoT masSi Semavali mavTulebis gverdiT axali mavTulis SesaZlo ganlagebis ori wertili C_1 da C_2 (nax. 7.).

6. u_k wres ganvaTavsebT C1 wertilSi, O dalagebuli wreebis simravlidan mimdevrobiT viRebT yvela elements da vamowmebT, xom ar kveTen u_k wres. Tu

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TanakveTa ar moiZebna, maSin vpoul obT manZils C1 centrasa da **W** simZimis centrs Soris DistW. igives vimeorebT **C2** wertil isTvis.
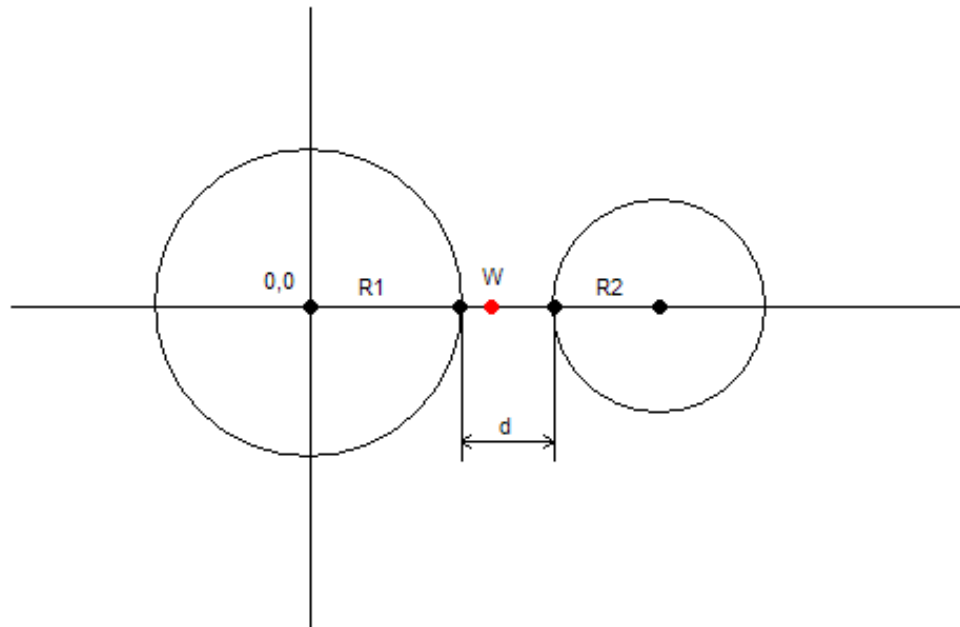
nax. 6. mavTulebis ganlageba pozicionirebis algoriTmis me-3 bijis Semdeg

7. Tu **DistW** naklebia aqamde ganxiluli sxva *Pair* (o_i, o_j) wyvilebisaTvis napovn minimalur manZilze **MinDistW**, maSin **MinDistW = DistW**.

8. gadavideT me-3 bijze vidre ar ganvixilavT **P** simravlis yvela elements.

9. u_k mavTulis Sesabamis wres ganvaTavsebT im centrSi **Cmin**, romlisTvisac dafiqsirda simZimis centramde minimaluri manZili **MinDistW**. u_k mavTuls viRebT dasalagebeli mavTulebis **U** simravlidan da gadagvaqvs dalagebuli mavTulebis **O** simravleSi.

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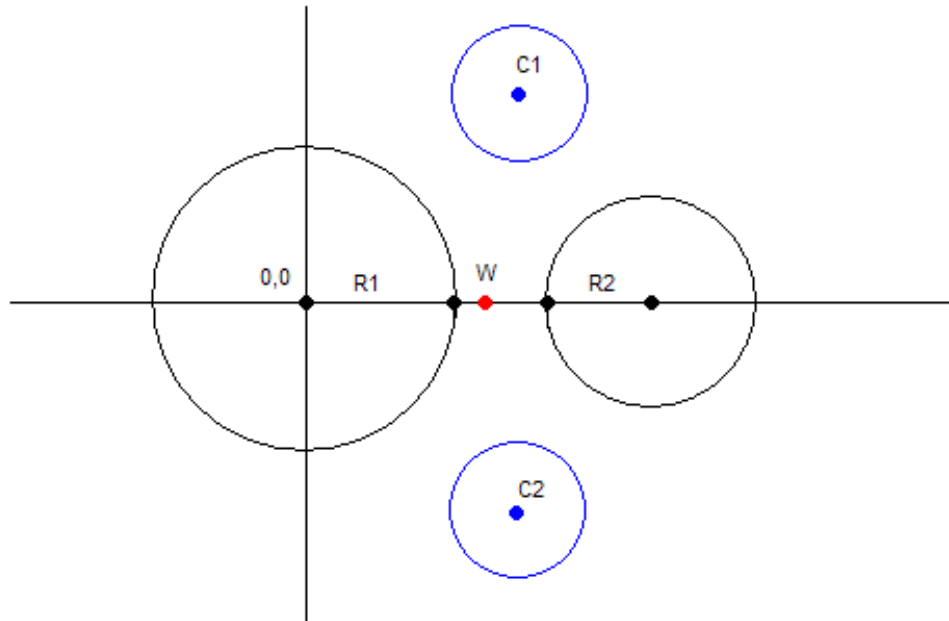
nax. 7. mavTulebis SesaZlo ganlagebis wertilebi

10. viRebT im wyvils $Pair_{min}(o_m, o_n)$, romel mac monawil oeoba miiRo mavTulis centris formirebaSi da vaformirebT axal wyvilebs axlad ganTavsebuli $o_k \in O$ mavTuli-saTvis: $Pair(o_k, o_m)$ da $Pair(o_k, o_n)$. vamatebT maT **P** wyvilTa simravleSi.

11. vpouolobT axal simZimis centrs **W** (nax. 8.).

12. gadavdivarT me-4 bijze vidre dasalagebeli mavTulebis **U** simravle ar gaxdeba carieli.

am algoriTmSi gamoyenebuli iyo wreebis wyvilis maxloblad mocemul manZilze mesame wris ganTavsebis wertilebis (**C1, C2**) povna da wreebis centrTa **W** simZimis centris povna.

vTqvaT, gvaqvs ori wre: centriT (**x1,y1**), radiusiT **R1** da centriT (**x2,y2**), radiusiT **R2**. gvinda vipovoT centrebi wrsiTvis radiusiT **R3** ise rom igi exebodes orive wres (nax. 9.).
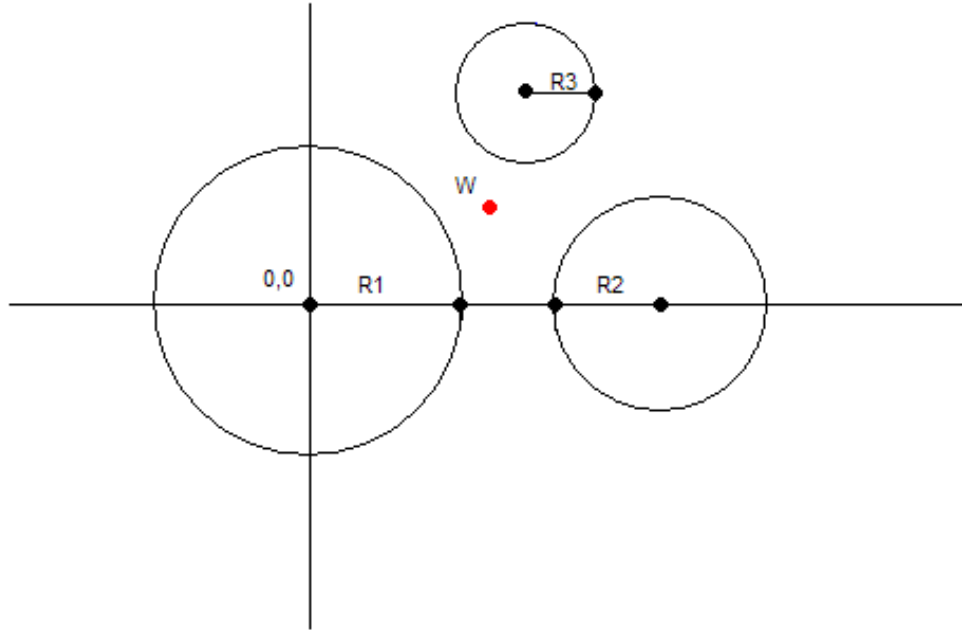
nax. 8. mavTulebis ganlageba da simZimis centri pozicionirebis
al goriTmis me-11 bijis Semdeg
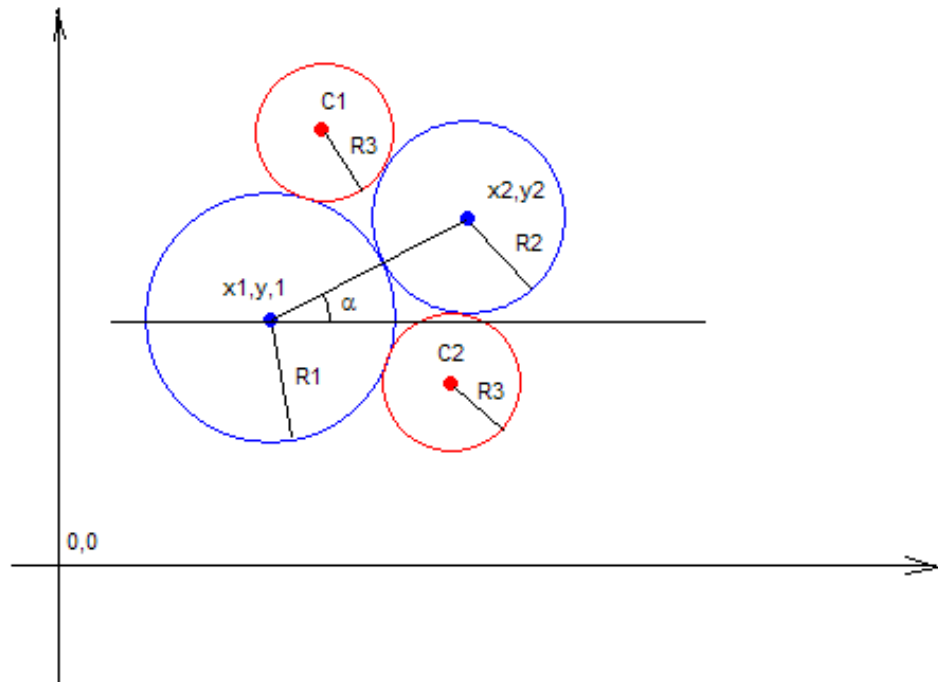
nax. 9. mxebi wreebis centrebis gansazRvra

C1 da C2 wertilebis koordinatebi gamoiTvleba Semdegi formulebiT:

$$X3_{11} = X3_{12} = \frac{(R1+R3)^2 + (R1+R2)^2 - (R2+R3)^2}{2*(R1+R2)}$$

$$Y3_{11} = \sqrt{(R1+R3)^2 - X3_{11}^2}$$

$$Y3_{12} = -Y3_{11}$$

$$\cos(a) = \frac{X2-X1}{R1+R2}$$ (2.3.15)

$$\sin(a) = \frac{Y2-Y1}{R1+R2}$$

$$C1.x = X1 + X3_{11}*\cos(a) - Y3_{11}\sin(a)$$

$$C1.y = X1 + X3_{11}*\sin(a) + Y3_{11}\cos(a)$$

$$C2.x = X1 + X3_{12}*\cos(a) - Y3_{12}\sin(a)$$

$$C2.y = X1 + X3_{12}*\sin(a) + Y3_{12}\cos(a)$$

vTqvaT mocemuli gvaqvs wreebis centrebis mimdevroba $(x_1, y_1),(x_2, y_2),...(x_n, y_n)$. maTi simZimis centri moiZebneba Semdegi formuliT:

$$x = \frac{\sum_{i=1}^{n} x_i}{n}$$ (2.3.16)

$$y = \frac{\sum_{i=1}^{n} y_i}{n}$$

mas Semdeg, rac mavTulebi gadanawildeba segmentis or ganzomilebian kveTaSi, saWiroa kveTaSi segmentis centridan mavTulis centrebis daSorebebis gaTvaliswinebiT gavataroT isini segmentTa mimdevrobis centraluri RerZebis gaswvriv sam ganzomilebian sivrceSi (nax. 10.).

segmentebis RerZuli xazis traeqtoria Sedgeba erTmaneTze gadabmuli monakveTebisagan. mavTulebi unda gavataroT am monakveTebis paralelurad ise, rom Tu aviRebT TiToeuli monakveTis perpendikularul kveTas, miviRoT segmentis kveTaSi mavTulebis ganTavsebis suraTi.
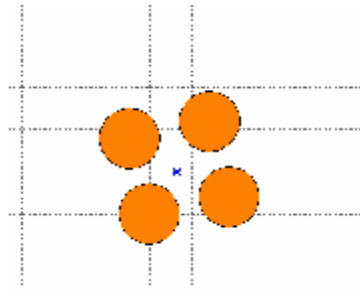
mavTulebis gadanawileba kveTaSi
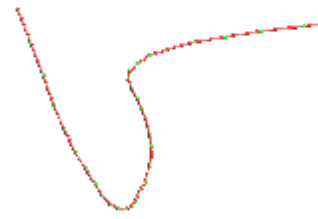
segmentebis RerZuli xazebis
traeqtoria

mavTulebi, romelic gatarebulia segmentebis RerZuli xazebis gaswvriv kveTaSi
arsebuli gadanawilebis mixedviT

nax. 10. mavTulebis gatareba sivrceSi

mavTulebis sivrceSi gatarebis algoriTmi Sedgeba sami etapisagan:

1. ganisazRvros iseTi veqtori, romelic RerZuli xazis TiToeul segments gadaitans sivrceSi ise, rom Tu aviRebT segmentis perpendikularul kveTs, axali segmenti ganTavsebuli iqnes mavTulis ganTavsebis adgilas.

2. traeqtoriis Semadgeneli yvela segmentis paralelurad gavataroT axali segmentebi sivrceSi ise, rom isini miRebuli iqnes traeqtoriis Semadgeneli segmentis paralelurad gadataniT wina punqtSi miRebuli veqtoriT.

3. miRebuli segmentebi SevaerToT erTmaneTTan.

vTqvaT mocemuli aris nax. 11.-ze gamosaxuli traeqtoria da organzomilebiani kveTa.

imisaTvis, rom vipovoT gadatanis veqtori, saWiroa pirvel segments mivabaT koordinatTa sistema ise, rom Z RerZi emTxve-

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odes segments, xol o koordinatTa saTave _ **P1** wertil s. am SemTxvevaSi, **XoY** sibrtye daemTxveva kveTas (nax. 12.)
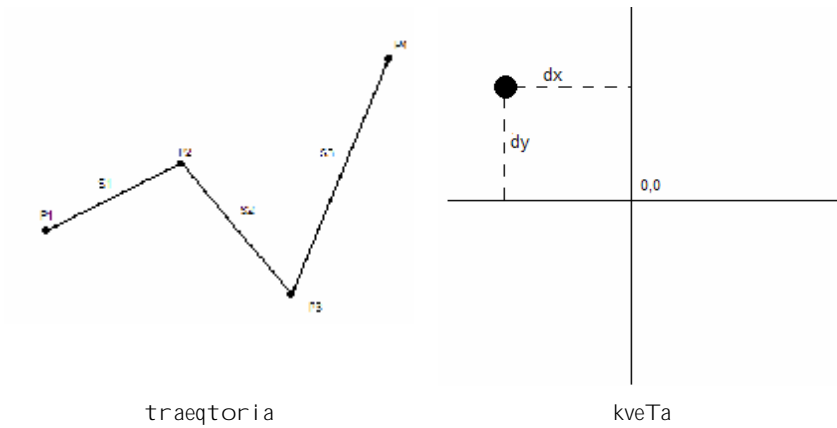
traeqtoria   kveTa

nax. 11. mavTul ebis sawyisi traeqtoria da kveTa
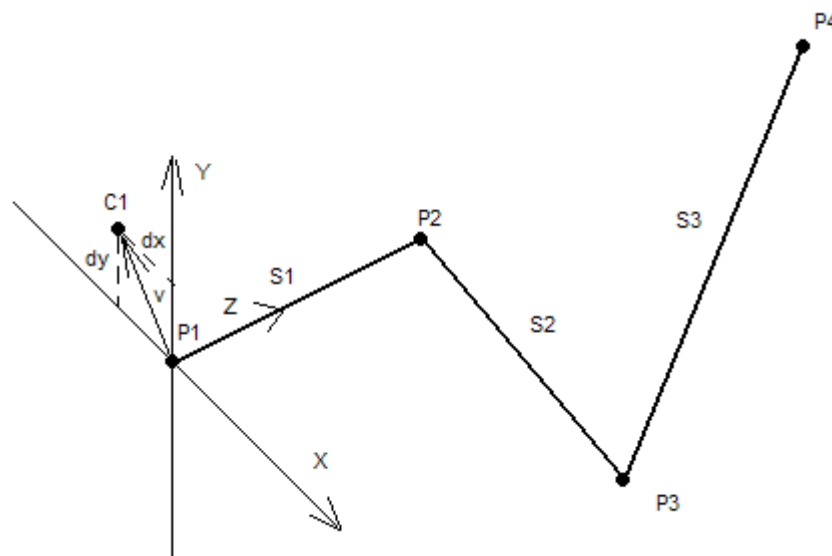
nax. 12. koordinatTa sistemis gansazRvra

$\vec{v}$ veqtori iqneba saZiebel i gadatanis veqtori. mis sapovnel ad viqceviT Semdegnairad: jer vsazRvravT mas standartul koordinatTa sistemaSi. igi iqneba $\vec{v} = (dx, dy, 0)$. Semdeg ki standartul i koordinatTa sistemis transformacias

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vaxdenT ise, rom misi Z RerZi daemTxves traeqtoris segmentis Sesabamis $\overrightarrow{P1P2}$ veqtors.

maSasadame, am bijis Semdeg miRebuli gvaqvs gadatanis $\vec{v}$ veqtori traeqtoriis pirveli P1P2 segmentisTvis. Tu segments paralelurad gadavitanT am veqtoriT, miviRebT saZiebeli traeqtoriis pirvel segments C1C2 (nax. 13.).
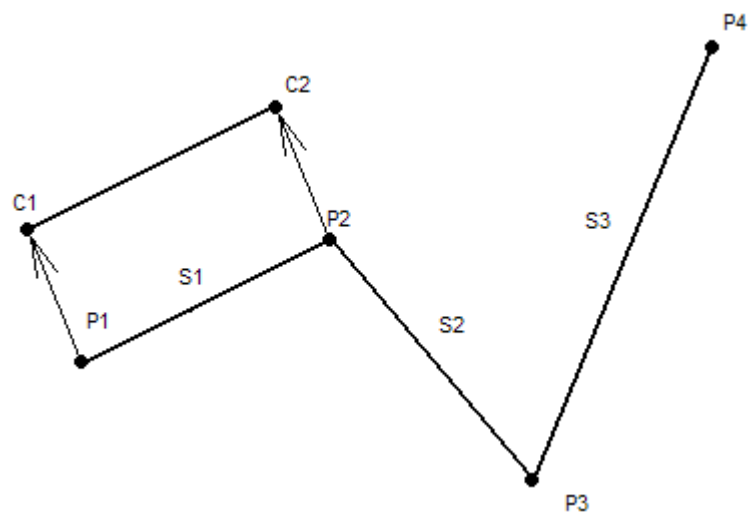
nax. 13. traeqtoriis segmentis paralelurad gadatana
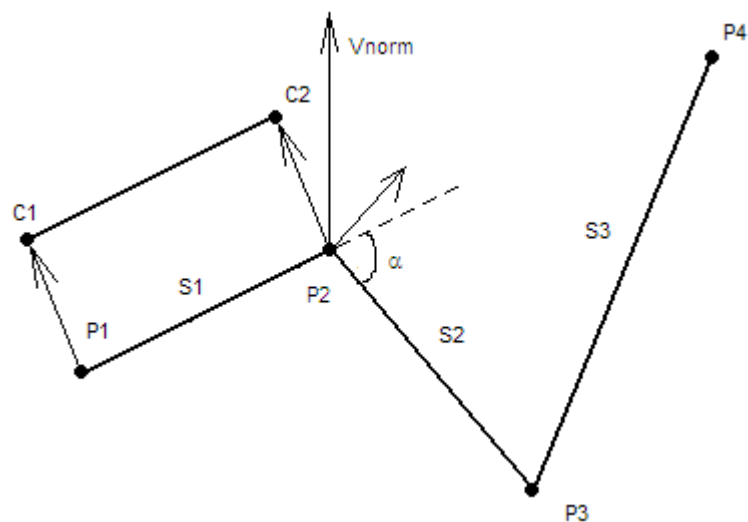
nax. 14. gadtanis veqtoris formireba meore segmentisTvis

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amis Semdeg saWiroa ganisazRvros gadatanis veqtori meore segmentisTvis. amisaTvis gadatanis veqtors vabrunebT **S1** da **S2** segmentebs Soris arsebuli kuTxiT **P1P2P3** sibrtyis perpendikul aris irgvliv (nax. 14.).

veqtoris mobruneba meore veqtoris irgvliv xdeba misi gadamravlebiT mobrunebis matricaze. mobrunebis matrica aris 3X3 ganzomilebis da misi elementebia:

$$
\begin{aligned}
a_{11} &= \cos(a) + (1 - \cos(a)) * x^2 \\
a_{12} &= (1 - \cos(a)) * x * y - \sin(a) * z \\
a_{13} &= (1 - \cos(a)) * x * z + \sin(a) * y \\
a_{21} &= (1 - \cos(a)) * x * y + \sin(a) * z \\
a_{22} &= \cos(a) + (1 - \cos(a)) * y^2 \\
a_{23} &= (1 - \cos(a)) * y * z - \sin(a) * x \\
a_{31} &= (1 - \cos(a)) * x * z - \sin(a) * y \\
a_{32} &= (1 - \cos(a)) * y * z + \sin(a) * x \\
a_{33} &= \cos(a) + (1 - \cos(a)) * z^2
\end{aligned}
\tag{2.3.17}
$$

sadac (x,y,z) aris veqtori, romlis irgvlivac xdeba mobruneba, xolo α aris mobrunebis kuTxe.

amis Semdeg vaxdenT RerZuli traeqtoriis segmentis gadatanas igive principiT rogorc pirveli segmentisTvis (nax. 15.)
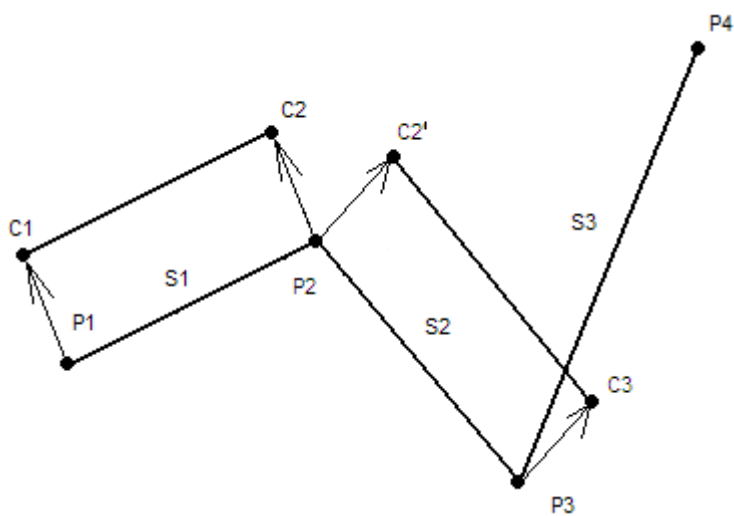
nax. 15. traeqtoriis segmentis paralelurad gadatana

igive proceduras vimeorebT traeqtoriis Semadgeneli yvela segmentisTvis.

rogorc vxedavT, mxolod segmentebis gadatana sakmarisi ar aris, radgan warmoiqmneba segmentebs Soris wyvetebi da TanakveTebi (nax. 16.). saWiroa traeqtoriis kuTxeebSi miRebuli segmentebis erTmaneTTan SeerTeba.

SeerTebis wertilis povnis algoriTmi ganvixilOT nax. 17.-is mixedviT.

nax. 16. segmentebis SeerTebis wertilebi

nax. 17. segmentebis SeerTebis wertilebis povna

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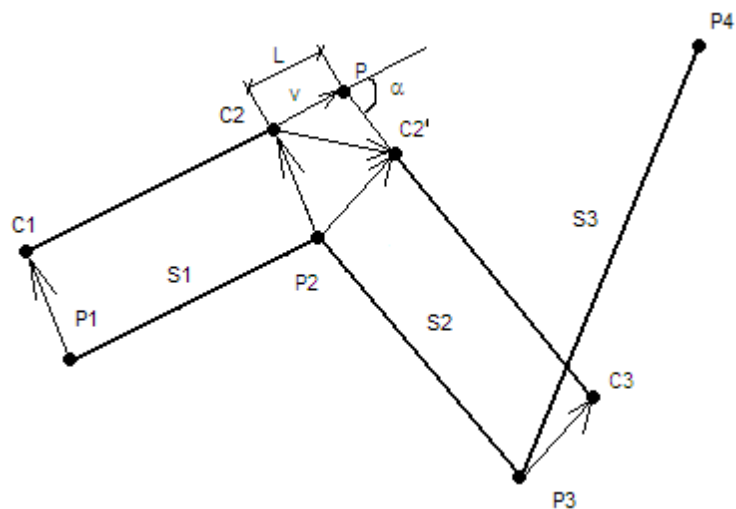
Cvens mizans warmoadgens **P** SeerTebis wertilis povna. amisaTvis saWiroa vipovoT $\vec{v}$ veqtori, radgan $P = C2 + \vec{v}$, **C2**-is koordinatebi ki ukve cnobilia. saWiroa davadginoT $\vec{v}$ veqtoris mimarTuleba da sigrZe. radgan $\vec{v}$ veqtori warmoadgens **C1C2** monakveTis gagrZelebas, amitom misi mimarTuleba iqneba: (**C2.x-C1.x,C2.y-C1.y,C2.z-C1.z**) veqtoris kolinearuli.

$\vec{v}$ veqtoris sigrZis gansazRvrisaTvis gamoviyenoT is faqti, rom **C1PC2** samkuTxedi aris tolferda da cnobilia α kuTxe. veqtoris sigrZe **L**, iqneba:

$$L = \frac{\sqrt{(C2'.x - C2.x)^2 + (C2'.y - C2.y)^2 + (C2'.z - C2.z)^2}}{2 * \cos(\dfrac{a}{2})} \qquad (2.3.18)$$

im SemTxvevaSi, roca segmentebs Soris arsebobs TanakveTa (meore wertili Cvens magalITSi), $\vec{v}$ veqtors vpoulobT igive gziT, mxolod mimarTulebas viRebT sapirispiros.

amrigad, samive bijis gavlis Semdeg viRebT mavTulis gatarebis traeqtorias, romelic parallelurad miyveba RerZul xazs (nax. 18.).
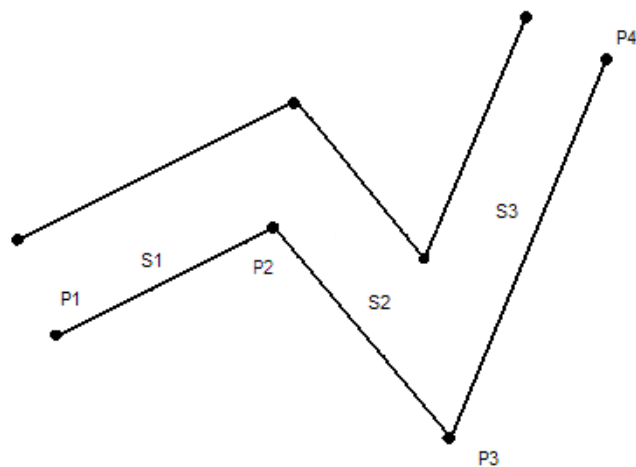
nax. 18. mavTulis miRebuli traeqtoria

rogorc zemoT iyo aRniSnuli, mavTulebs Soris da mavTulsa da antenas Soris urTierTtevadobebisa da urTierTinduqciurobis dasadgened gamoiyeneba gamoTvlebis birTvi **Static3D**, romelic calke programis saxiT aris realizebuli. gamoTvlebis birTvi dafuZnebulia momentebis meTodze (**MoM**) eleqtruli velebis integraluri gantolebebis (**EFIE**) ricxviTi meTodebiT amosaxsnelad [17]. Tu mavTulebi erTmaneTTan an zedapirTan Zalian axlosaa ganlagebuli, maSin gamoiyeneba momentebis meTodisa da damxmare wyaroebis meTodis (**MAS**) kombinacia. induqciurobebi ganisazRvreba eleqtrostatikur da magnitostatikur problemebs Soris analogiis safuZvelze. mTlian struqturaze muxtebis ganawilebis aproqsimaciisaTvis gamoiyeneba bijuri bazisuri funqciebi. Tavdapirvelad xdeba muxtebis gabnevis koeficientebis dadgena wrfivi gantolebebis sistemis amoxsnis meSveobiT, xolo Semdeg am koeficientebze dayrdnobiT xdeba muxtebis ganawilebis povna da mTliani sistemis saWiro parametrebis gansazRvra [18].

programis muSaoba damyarebulia Semdeg meTodebze: zedapirebi modelirebulia samkuTxedebis badis meSveobiT. Tvlian, rom TiToeul samkuTxedze muxtis simkvrive mudmivia [17][19].

jer ganisazRvreba zedapiruli muxtebis ganawileba TiToeuli obieqtisTvis integraluri gantolebebis **MoM** meTodiT amoxsnis meSveobiT, Semdeg generirdeba momentebis matrica, romelic Seesabameba potencials TiToeuli samkuTxa patCis centroidSi. saboloo gantolebaTa sistemis amoxsnas mivyavrT centroidebSi muxtis simkvrivis povnamde [20].

N gamtari obieqtisaTvis viRebT gantolebaTa sistemas. sabolood vpoulobT muxtebs obieqtebze potencialebis TiToeuli ganawilebisaTvis [20].

rodesac obieqtebi erTmaneTTan Zalian axlosaa ganlagebuli, isini ufro Zlierad urTierTqmedeben erTmaneTze,

rac iwvevs muxtebis ufro araTanabar ganawilebas. aseT SemTxvevaSi muxti icvleba TiToeuli elementis SigniT, amitom Tu gamoviyenebT **MoM** meTods, saWiro gaxdeba elementebis zomis Zlier Semcireba. samkuTxedebis badis SemTxvevaSi saWiro iqneba samkuTxedebis zomis iqamde Semcireba, vidre TiToeul maTganze muxti Tanabrad ar iqneba ganawilebuli. magram aseTi midgoma SeuZlebelia mavTulis SemTxvevaSi, am dros muxtebi araTanabradaa ganawilebuli mis perimetrze. aseT SemTxvevaSi, mavTulis zedapiri unda daiyos zolebad da muxtebi ganisazRvros TiToeuli maTganisTvis damoukidebladd (nax. 19.). am dros gamoiyeneba damxmare wyaroebis meTodi.

a) φ- damoukidebeli *MAS* segmenti   b) standartuli *MAS* segmenti
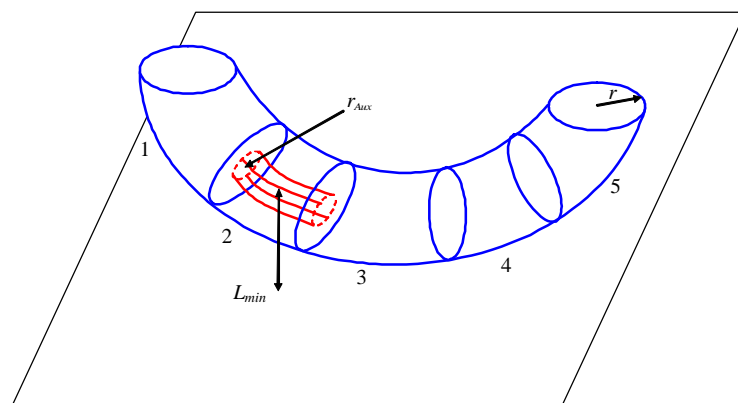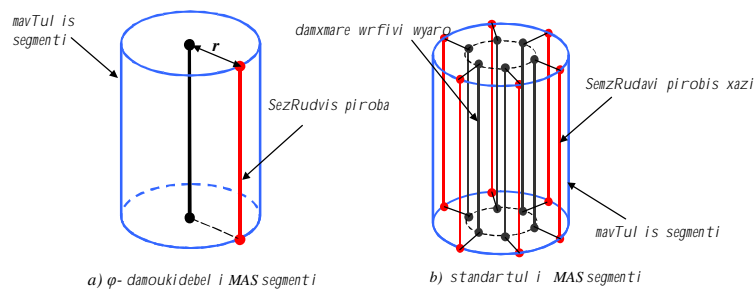
nax. 19. damxmare wyaroebi

TiToeul damxmare segmentze vaTavsebT M^{aux} wrfiv damxmare wyaros. TiToeuli damxmare wyaro Sedgeba Tanabrad

damuxtuli zolisagan, romelic segmentis sigrZisaa. TiToeuli damxmare wyarosaTvis vagenerirebT Sesabamis xazs mavTulis zedapirze. aseTi xazebis raodenoba tolia damxmare wyaroebis raodenobisa. m-uri mavTulis segmentis potenciali gani-sazRvreba Semdegi formuliT:

$$j_m(x,y) = \sum_{n=1}^{M_m^{aux}} q_n^m j_n^m(x,y) \qquad (2.3.25)$$

sadac, q_n^m aris muxti n damxmare wyarosi, romelic asocirebulia m mavTulis segmentTan. $j_n^m(x,y)$ aris damxmare wyaros potenciali [21].

eqspertuli sistemis gaTvlebis modulis kidev erT-erTi umniSvnelovanesi nawilia magnituri velebis gamoTvla sivrcis mocemul wertilSi.

magnituri velebis gaTvlebisaTvis gamoiyeneba biot-savaris meTodi [22].

$$\vec{H} = \frac{I}{4p} \sum \frac{\Delta \vec{l} \, \vec{r}}{r^3} \qquad (2.3.29)$$

sadac, I aris maqsimaluri deni mavTulis kveTaSi, $\Delta \vec{l}$ veqtori, romelsac qmnis mavTulis segementi, $\vec{r}$ aris veqtori mavTulis segmentis centridan im wertil amde sadac vzomavT magnitur vels (nax. 20.).

nax. 20. magnituri velis gamoTvla

2.4 daskvna meore Tavis Sesaxeb

1. SemuSavebuli iqna saproblemo aris modeli, romelic aRwers satransporto saSualebis eleqtrul sistemas. es modeli aRwers, erTis mxriv, TviT komponentebs da maT Soris eleqtrul kavSirebs, xolo, meores mxriv, maT ganlagebas sivrceSi da daj gufebas funqcionaluri daniSnulebis mixedviT. igi saSualebas iZleva, swrafad da efeqturad moxdes rogorc yvela saxis monacemis mopoveba satransporto saSualebis eleqtrul sistemaze, aseve didi Zalisxmevis gareSe ganxorcieldes masSi cvlilebebi.

2. SemuSavebuli iqna codnis warmodgenisa da gadawyveti-lebebis miRebis meTodebi, romlebic damyarebulia freimebis, produqciebisa da predikatebis gamoyenebaze.

3. SemuSavebuli iqna meTodebi, romlebic saSualebas iZleva movaxdinoT eleqtromagnituri urTierTqmedebis modeli-reba eleqtrostatikuri da eleqtrodinamikuri gaTvlebis saSualebiT, romlebic Tavis mxriv momentebis meTodsa da damxmare wyaroebis meTods eyrdnobian.

3 eqspertuli sistemis sainJinro realizacia

3.1 eqspertuli sistemis Semadgeneli modulebi da maT Soris kavSirebi

satransporto saSual ebebSi eleqtromagnituri Tavsebado-
bis diagnostikisa da analizis eqspertuli sitema warmoadgens
rTul programul kompleqss, romelic damuSavebulia obieqtze
orientirebuli teqnologiis gamoyenebiT [23]. igi Sedgeba
mravali modulisagan, rogoricaa: satransporto saSualebis
eleqtruli sistemebis monacemTa baza, eqspertuli codnis baza,
eleqtruli sistemis Semadgeneli komponentebis momxmarebl is-
Tvis cxriluri saxiT warmodgenis moduli, interfeisebi
sxvadasxva komponentebis warmodgenisa da modificirebisaTvis,
samganzomilebiani vizualizatori, sqematuri vizualizatori,
wesebis redaqtirebis moduli, interfeisebi codnis bazasTan
muSaobisaTvis, logikuri gadawyvetilebebis birTvi, cvlilebaTa
istoriis moduli, triangulirebul badeebTan muSaobis moduli,
logikuri gadawyvetlebebis birTvi, Sedegebis post-procesori,
angariSebis formirebis moduli da programis centraluri
marTvis moduli.

TiToeuli zemoT aRweril moduli warmoadgens rTul
klasebis struqturas. maTSi realizebulia sxvadasxva algoriT-
mebi da gamoiyeneba iseTi biblioTekebi, rogoricaa OpenGL, CLIPS,
LibXML. programis zogadi struqtura mocemulia nax. 21.-ze.

zogadad, programis modulebis daniSnuleba da maTi
urTierTkavSiri SeiZleba Semdegi saxiT warmovidginoT:

programis mTavari birTvi aris centraluri marTvis
moduli, igi koordinacias uwevs yvela sxva modulis muSaobas
da warmoadgens programis Semkvrel ZiriTad ConCxs. satran-
sporto saSualebis eleqtruli sistemis kompiuteruli modeli
realizebulia gayvanilobis monacemTa bazis saxiT, masSi inaxeba

eleqtrogayvanilobis sruli aRwera. aRsaniSnavia, rom erTdroulad programaSi SesaZlebelia CaitvirTos ramdenime gayvanilobis modeli, SesaZlebelia komponentebis gadatana erTi modelidan meoreSi. realizebulia informaciis Zebnis algoriTmebi. gayvanilobis bazaSi informaciis Semotana xorcieldeba **XML** da **ASC** formatis mqone failebidan [24]. bazas gaaCnia relaciuri da obieqtze orientirebuli struqtura [23][25][26].
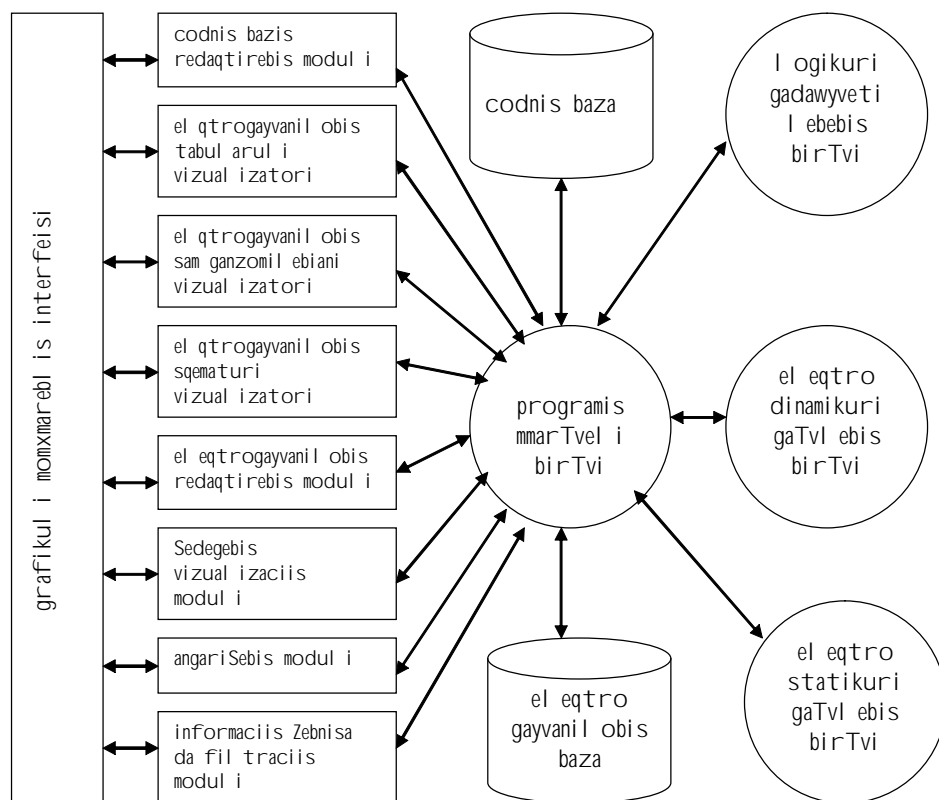
nax. 21. programis zogadi struqtura

satransporto saSualebis eleqtruli sistemis modeli eqspertuli sistemis momxmarebels waredgineba sami sxvadasxva saxiT: cxrilurad, samganzomilebaSi da sqematurad.

gayvanilobis monacemTa bazaSi arsebuli informaciis momxmareblisaTvis cxriluri saxiT warmodgenas uzrunvelyofs

cxriluri warmodgenis moduli. eleqtruli sistemis Semadgenel TiToeuli tipis komponents Seesabameba TiTo cxrili. esenia: modulebis ojaxebi, modulebi, koneqtorebi, mavTulebi, mraval guliani mavTulebi, terminalebi, kontaqtis terminelebi, kontaqtis SemamWidroveblebi, kontaqtis sarqvelebi, damxmare komponentebi, damatebiTi komponentebi, fiqsatorebi, anakrebi komponentebi, mavTulis dacvebi, segmentebi, kvanZebi, magnituri velis mzomebi, triangulirebuli badeebi, antenebi, kontaqtebi, qselis klasebi. TiToeuli cxrili ganTavsebulia TiTo gverdze. cxrilis TiTo sveti Seesabameba Sesabamisi tipis komponentis TiTo parametrs. SesaZlebelia cxrilebSi informaciis Zebna sxvadasxva parametrebis an maTi kombinaciis mixedviT. SesaZlebelia informaciis sortireba sxvadasxva svetebis mixedviT rogorc zrdadobiT, aseve klebadobiT. SesaZlebelia gamoCndes mxolod moniSnuli xazebi. agreTve SesaZlebelia kavSirebis dadgena komponentebs Soris. magaliTad, momxmarebels SeuZlia moniSnos mavTulebi, airCios menius Sesabamisi punqti da moZebnos am mavTulebis Sesabamis koneqtorebi da a.S.

TiToeuli tipis komponentis parametrebis modificirebi-saTvis da maTi ganxilvisaTvis damuSavebulia dialoguri fanjrebi. momxmarebels SeuZlia moniSnos komponenti da Sesabamisi dialoguri fanjris saSualebiT modifikacia gaukeTos mis parametrebs.

eleqtruli sistemis momxmarebl isaTvis warmodgenis kidev erTi saSualebaa misi samganzomilebiani vizualizacia, romel sac uzrunvelyofs samganzomilebiani vizualizaciis moduli. igi **OpenGL** biblioTekis gamoyenebiT iqna realizebuli [27][28]. vizualizatoris saSualebiT momxmarebels waredgineba satransporto saSualebis realuri modeli, SesaZlebelia misi Semobruneba sxvadasxva kuTxiT, miaxloeba da daSoreba, kveTis sibrtyeebiT manipulireba da a.S. agreTve masSi SesaZlebelia komponentebis moniSvna da igive operaciebis ganxorcieleba rac cxriluri warmodgenis moduldanaa SesaZlebeli.

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damatebiT moxerxebul saSualebas warmoadgens gayvanilobis sqematuri vizualizacia, romelic realizebulia sqematuri warmodgenis modulis saSualebiT. SesaZlebelia sqemis miaxloeba-daSoreba, masSi komponentebis moniSvna da igive moqmedebebis ganxorcieleba, rac cxriluri da samganzomile-biani vizualizaciis modulebidanaa SesaZlebeli.

amrigad, cxriluri, samganzomilebiani da sqematuri vizualizaciis modulebi saSualebas aZleven momxmarebels mosaxerxebeli formiT ganixilos da redaqtireba gaukeTos satransporto saSualebis eleqtrogayvanilobis models.

eqspertul sistemaSi satransporto saSualebis Zara warmodgenilia triangulirebuli badis, e.w. meSis saSualebiT. meSebTan muSaoba uzrunvelyofilia specialuri modulis saSualebiT. igi uzrunvelyofs triangulirebuli badeebis imports **NAS** da **STL** failebidan [16][29]. uzrunvelyofs samkuTxedebze Tvisebebis miniWebas da a.S.

eqspertis codnis warmodgena realizebulia codnis bazis saxiT. TviT codna warmodgenilia **CLIPS_is** enaze Cawerili wesebis sSualebiT [30][31]. codnis bazaSi realizebulia wesebis dajgufebis da Zebnis algoriTmebi. codnis baza dayofilia or nawilad: biblioTekad, romelSic wesebi inaxeba mudmivad, da proeqtul nawilad. proeqtul nawilSi ganTavsebuli wesebi inaxeba proeqtTan erTad, SesaZlebelia biblioTekasa da proeqts Soris wesebis ormxrivi gacvla. amisaTvis SemuSavebulia specialuri interfeisebi.

wesebis Seqmna da codnis bazaSi Senaxva xorcieldeba wesebis redaqtirebis modulis meSveobiT. igi warmoadgens teqstur redaqtors da gaaCnia damxmare saSualebebi, romelic uadvilebs momxmarebels **CLIPS–is** enaze Caweros wesebis logika. es damxmare saSualebebia sintaqsis Seferadeba, frCxilebis gamoyofa, blokebis gamoyofa da xe_asistansi. asistansSi mocemulia yvela obieqti da funqcia, romelic SesaZlebelia

gamoyenebul iqnas wesSi. aseve SesaZlebelia daxmarebis gamoZaxeba TiToeuli funqciis Sesaxeb.

logikuri gadawyvetilebebis birTvis uzrunvelyofis modulis daniSnulebaa gayvanilobis bazaSi arsebuli informaciis safuZvelze moaxdinos faqtebis formireba, codnis bazidan aiRos wesebi, gadasces isini logikuri gadawyveti-lebebis birTvs da aamuSaos igi.

logikuri birTvi arsebul faqtebze dayrdnobiT axorcielebs wesebSi gansazRvrul moqmedebebs da aformirebs fails, romelsac SemdgomSi iyenebs post-procesori, raTa Sedegebi warudginos eqspertul i sistemis momxmarebels da ganaxorcielos cvlilebebi satransprto saSualebis eleqtrul sistemaSi. logikuri daskvnebis birTvi realizebulia **CLIPS** biblioTekis gamoyenebiT.

post-procesoris daniSnulebaa logikuri daskvnebis birTvis muSaobis Sedegebi warudginos momxmarebels da ganaxorcielos cvlilebebi eleqtrogayvanilobis bazaSi. Sede-gebi momxmarebels waredgineba cxrilebisa da grafikebis saxiT.

istoriis Senaxvis moduli uzrunvelyofs proeqtis arsebuli mdgomareobis damaxsovrebas wesebis Sesrulebaze gaSvebis yovel sesiis win. igi saSualebas iZleva aRdges proeqti nebismier etapze arsebul mdgomareobaSi.

angariSebis generirebis moduli saSualebas iZleva formirebuli iqnes Semdegi saxis angariSebi **Excel**-Si: cxrilebi, detaluri informacia, jamuri informacia, informacia komponentebis gamoyenebaze (**BOM**), angariSi proeqtis Sesaxeb.

amrigad, sistema realizebulia erTmaneTTan dakavSirebuli sxvadasxva modulebis saxiT, romel Tagan TiToeuls gaaCnia mkveTrad gansazRvruli funqcia. sistemis muSaoba uzrunvel -yofilia maTi muSaobis koordinaciiT da maT Soris informaciis gacvliT.

3.2 satransporto saSualebis eleqtruli sistemis monacemTa bazis realizacia

satransporto saSualebebis eleqtruli sistemebi metad rTulia da moicaven didi raodenobiT komponentebs, romlebic Tavis mxriv warmoadgenen kompleqsur mowyobilobebs mravali maxasiaTebliT. eleqtrogayvanilobis informaciuli modeli SemuSavebul iqna firma **VDA**-s mier Seqmnil **KBL** standartze dayrdnobiT [10]. es aris standarti, romelic gamoiyeneba germaniis avto mwarmoeblebis mier eleqtruli sistemebis Sesaxeb informaciis gasacvlelad. misi arCevis mizezi iyo is, rom igi gavrcelebulia evropis umsxviles saavtomobilo sawarmoebs Soris da lakonurad aRwers satransporto saSualebebis eleqtrul sistemebs. unda aRiniSnos, rom es standarti aRwers eleqtrogayvanilobis mxolod topologias, amitom agreTve SemuSavebuli iqna damatebiTi parametrebi gayvanilobis eleqtruli maxasiaTeblebis aRsawerad.

qvemoT aRwerilia komponentebi, romlebic qmnian satran- sporto saSualebis eleqtrul sistemas da romlebic aRwerilia **KBL** standartiT. eleqtruli sistemis aRweraSi SeiZleba gamovyoT ramdenime ZiriTadi Semadgeneli nawili:

1. komponentebis saerTo atributebi da maxasiaTeblebi – aRweriliaa eleqtrogayvanilobis Semadgeneli komponen- tebis is maxasiaTeblebi, romlebic saerToa yvela- saTvis.

2. gayvaniloba da modulebi – aRweriliaa gayvanilobis, rogorc obieqtis maxasiaTeblebi da agreTve is modulebi, romlebadac is aris dayofili.

3. komponentebi – aRweriliaa gayvanilobis Semadgeneli komponentebi: mavTulebi, koneqtorebi, terminalebi da a.S.

4. kavSirebi – aRwers komponentebs Soris eleqtrul kavSirebs.

5. komponentTa gamoyeneba – aRwers Tu romeli komponenti sad da rogor aris gamoyenebuli gayvanil obaSi.

6. topologia _ aRwers komponentebis ganlagebas sivrce-Si. magaliTad, mavTulebis gayvanis gzebs, koneqtorebis mdebareobas da a.S.

7. damxmare saSualebebi – damatebiTi saSualebebi, romlebic gamoiyeneba ZiriTadi informaciis warmosadgenad. magaliTad, bisplain mrudebi, ganzomilebebi da a.S.

rogorc zemoT iyo aRniSnuli, mocemuli aRweris safuZvelze SesaZlebelia satransporto saSualebis eleqtruli mowyobilobis mxolod topologiuri modelis Seqmna. amitomigi ar aris sakmarisi. mis safuZvelze eqspertuli sistema sakvlevi obieqtis mxolod topologiur problemebs da **EMC** problemebis umciresiR nawils aRmoaCenda. vinaidan sistemis ZiriTadi daniSnulebaa eleqtrogayvanilobis eleqtromagnituri Tavsebadobis Seswavla, aucilebeli gaxda damatebiTi parametrebis SemoReba, romlebic aRweren komponentebis eleqtromagnitur maxasiaTeblebs.

standartSi aRweril TiToeuli komponenti sistemaSi realizebulia konkretuli klasis saxiT.

moklRed ganvixiloT standartSi aRwerili obieqtebi da maTi maxasiaTeblebi:

komponentebis saerTo atributebi da maxasiaTeblebi:

"sxva komponenti" (**Alias Part**) – aris meqanizmi, romelic komponentTan asociacias ukeTebs sxva komponentis nomers (**Part Number**), romelic gamoiyeneba sxva kompaniaSi. misi parametrebia: kompaniis dasaxeleba, komponenti da komponentis nomeri.

"damtkiceba" (**Approval**) _ amtkicebs im komponentebis da modulebis xarisxs, romel sac igi Seexeba. misi parametrebia: TariRi, ganyofileba, saxeli, tipi da damtkicebis obieqti.

"cvlileba" (**Change**) _ aris meqanizmi, romelic saSualebas gvaZlevs davafiqsiroT cvlilebebi konstruqciaSi. misi parametrebia: damamtkicebeli ganyofileba, damamtkicblis

saxeli, cvlilebis TariRi, cvlilebis moTxovna, aRwera, dizainis ganyofileba, komponenti, inJinris saxeli.

"Seqmna" (Creation) – moduls an gayvanilobas aniWebs informacias Seqmnis Sesaxeb. misi paramatrebia: TariRi, ganyofileba, komponenti, dasaxeleba.

"gare mimarTvebi" (External References) – aris meqanizmi, romelic saSualebas iZleva komponentTan davakavSiroT is dokumentebi, romlebic mas Seexeba. misi parametrebia: dokumentis versia, sistema romel zedac Seqmnilia dokumenti, monacemTa formati, dokumentis nomeri, dokumentis tipi, failis saxeli, dokumentis mdebareoba.

"damontaJebis instruqcia" (Installation Instruction) – aRwers komponentis damontaJebis meTodebs. misi parametrebia: montaJis tipi, montaJis mniSvneloba.

"masala" (Material) – masala, romlisganac komponentia Seqmnili. misi parametrebia: masalis kodi, masalis kodis gansazRvris sistema.

"komponenti" (Part) – warmoadgens im saerTo nawils, romelic yvela konkretuli saxis komponents (koneqtors, mavTuls da a.S.) gaaCnia. misi parametrebia: mokle dasaxeleba, saavtoro ufleba, dasrulebulobis xarisxi, aRwera, informacia cvlilebebze, dakavSirebuli dokumentebi, masa, informacia masalaze, komponentis nomeri, wina komponentis nomeri, informacia damuSavebaze, versia.

"komponenti dasaTaurebiT" (Part with Title Block) _ aris meqanizmi, romelic aniWebs damatebiT informacias gayvanilobas an moduls. misi parametrebia: klasifikaciis me-2 done, klasifikaciis me-3 done, klasifikaciis me-4 done, kompaniis dasaxeleba, samodelo weli, proeqtis nomeri.

"damuSavebis instruqcia" (Processing Instruction) – aRwers meTodebs romlebic gamoiyeneba komponentis Sesaqmnelad. misi parametrebia: instruqciis tipi, instruqciis mniSvneloba.

"mavTulis sigrZe" (Wire Length) _ mavTulis sigrZe aris meqanizmi, romelic gansazRvravs mavTulis sigrZes sigrZis tipTan erTad. misi parametrebia: tipi, mniSvneloba.

gayvaniloba da modulebi:

"gayvaniloba" (Harness) – gayvaniloba aris awyobili komponentebis erToblioba, romlebic qmnian satransporto saSualebis eleqtrul sistemas. igi dasaTaurebis mqone komponentis tipisaa da "komponenti dasaTaurebiT"-Si aRwerili parametrebis garda gaaCnia parametri _ Sinaarsi.

"gayvanilobis konfiguracia" (Harness Configuration) – aris gayvanilobis varianti. misi parametrebia: logistikuri informacia, Semadgeneli modulebi, mis mier gansazRvruli gayvanilobis identifikatori.

"gayvanilobis komponenti" (Harness Part) – gayvaniloba, romelic SeiZleba iqnes SekveTili. igi aris komponentis tipis da "komponentSi" gansazRvruli parametrebis garda gaaCnia parametri _ konfiguracia.

"moduli" (Module) – moduli aris gayvanilobis nawili, romelsac gaaCnia funqcionaluri daniSnuleba. igi aris "komponenti dasaTaurebiT" tipis da garda parametrebisa, romlebic gansazRvrulia "komponenti dasaTaurebiT"-Si, gaaCnia Semdegi parametrebi: konfiguracia, Sinaarsi, modulTa ojaxis identifikatori romelsac igi ekuTvnis, gayvanilobis identifi-katori romelsac igi ekuTvnis.

"modulis konfiguracia" (Module Configuration) – aris komponentebis erToblioba, romlebic qmnian moduls da aqvT gansazRvruli funqcionaluri daniSnuleba gayvanilobaSi. misi parametrebia: konfiguraciis tipi, masSi Semavali komponentebi, logistikuri kontrolis informacia.

"modulebis ojaxi" (Module Family) – aris meqanizmi, romelic ajgufebs modulebs. misi parametrebia: identifikatori, aRwera.

komponentebi:

"damxmare komponenti" (Accessory) – damxmare komponenti aris nebismieri komponenti, romelic Tan erTvis koneqtors da exmareba gayvanil obas Tavisi funqciis Sesrul ebaSi. igi aris "komponentis" tipis da masSi gansazRvrul i parametrebis garda aqvs parametri _ damxmare mowyobil obis tipi.

"anakrebi komponenti" (Assembly Part) – anakrebi komponenti aris komponenti, romelic awyobil ia sxva komponentebisagan. igi aris "komponentis" tipis da damatebiT gaaCnia parametri _ komponentis tipi.

"kontaqtis sarqvel i" (Cavity Plug) – kontaqtis sarqvel i aris wyal gaumtari arael eqtrul i komponenti, romelic faravs Tavisufal kontaqts. igi aris "komponentis" tipis da damatebiT gaaCnia Semdegi parametrebi: feri da sarqvel is tipi.

"kontaqtis SemamWidrovebel i" (Cavity Seal) – kontaqtis SemamWidrovebel i aris wyal gaumtari arael eqtrul i mowyobi-l oba, romelic faravs ara Tavisufal kontaqts. igi aris "komponentis" tipis da damatebiT gaaCnia Semdegi parametrebi: feri, SemamWidrovebel is tipi, mavTul is zoma.

"damatebiTi komponenti" (Co Pack Part) _ damatebiTi kompo-nenti aris mowyobil oba, romelic Tan mohyveba gayvanil obas da ar gaaCnia el eqtrul i kavSiri. igi aris "komponentis" tipis da damatebiT gaaCnia parametri _ komponentis tipi.

"koneqtoris korpusi" (Connector Housing) _ koneqtoris korpusi aris koneqtori Casmul i kontaqtebis gareSe. igi aris "komponentis" tipis da gaaCnia damatebiTi parameterebi: korpusis kodi, korpusis feri, korpusis tipi.

"mavTul is gul i" (Core) _ mavTul is gul i aris mraval gu-l iani mavTul is Semadgenel i gamtari izol aciiT. misi paramet-rebia: moRunvis radiusi, mavTul is mimTiTebel i, feri, kveTis farTobi, identifikatori, gare diametri.

"samagri" (Fixing) _ samagri aris komponenti romelic gamoiyeneba gayvanil obis dasamagrebl ad. igi aris "komponentis" tipis da gaaCnia damatebiTi parametri _ samagris tipi.

"terminali" (General Terminal) _ terminali aris mowyobiloba, romelic magrdeba gamtaris boloze, raTa Sewyvitos kontaqti an miuerTos sxva gamtars. igi aris "komponentis" tipis da gaaCnia Semdegi damatebiTi parametrebi: kveTis farTobi, gare diametri, dafarvis masala, terminalis tipi.

"mavTuli" (General Wire) _ mavTuli aris fizikuri komponenti, romelic qmnis SeerTebas. igi SeiZleba iyos erT an mraval guliani. igi aris "komponentis" tipis da gaaCnia Semdegi damatebiTi parametrebi: moRunvis radiusi, mavTulis mimTiTebeli, feri, kveTis farTobi, gare diametri, mavTulis tipi.

"sloti" (Slot) _ sloti aris meqanizmi, romelic ajgufebs kontaqtebs koneqtoris korpusSi.

"mavTulis feri" (Wire Color) _ mavTulis feri aris meqanizmi, romelic gansazRvravs mavTulis fers feris tipTan erTad. misi parametrebia: feri, feris tipi.

"mavTulis dacva" (Wire Protection) _ mavTulis dacva aris meqanizmi, romelic aRwers mavTulebis SefuTvas. igi aris "komponentis" tipis da gaaCnia damatebiTi parametrebi: tipi, tipze damokidebuli parametri.

kavSirebi:

"kontaqti" (Cavity) _ kontaqti aris Casmuli koneqtoris korpusSi da mas uerTdeba mavTuli. misi parametrebia: dakavSirebuli komponentebi, identifikatori, koneqtoris identifikatori, pozicia mavTulze, sloti romelsac igi ekuTvnis.

"kavSiri" (Connection) _ kavSiri aris meqanizmi, romelic gansazRvravs eleqtrul kavSirs or kontaqtis wertils Soris. misi parametrebia: gayvanilobis identifikatori, identifikatori, dakavSirebuli kontaqtebi, damontaJebis informacia, Seqmnis informacia, signalis saxeli, mavTulis identifikatori.

"mavTulis gulis arseboba" (Core Occurrence) _ mavTulis gulis arseboba aris mavTulis gulis gamoyeneba mraval gulian mavTulSi. misi parametrebia: mavTulis gulis komponenti,

mraval guliani mavTulis gamoyenebis identifikatori, mavTulis nomeri.

"komponentis Secvla" (Part Substitution) _ komponentis Secvla aris meqanizmi, romelic aRwers kontaqtis sarqvelis Secvlas terminaliT. misi parametrebia: Sesacvleli komponenti, Semcvleli komponenti.

"mraval guliani mavTulis arseboba" (Special Wire Occurrence) _ mraval guliani mavTulis arseboba aris mraval guliani mavTulis gamoyeneba modulSi. igi aris zogadi mavTulis arsebobis (ganxiluli a qvemoT) tipis da damatebiT gaaCnia parametrebi: mavTulis identifikatori, gulebis sia.

"mavTulis arseboba" (Wire Occurrence) _ mavTulis arseboba aris erTguliani mavTulis gamoyeneba modulSi. igi aris zogadi mavTulis arsebobis tipis da damatebiT gaaCnia parametri _ mavTulis nomeri.

komponentTa gamoyeneba:

"damxmare komponentis arseboba" (Accessory Occurrence) _ damxmare komponentis arseboba aris damxmare komponentis gamoyeneba modulSi. misi parametrebia: damatebiTi identifikatorebi, gayvanilobis identifikatori, identifikatori, instalaciis informacia, komponenti, mdebareoba, elementi _ romel zedacigia mimagrebuli.

"damxmare komponentis specifiuri arseboba" (Specified Accessory Occurrence) _ damxmare komponentis specifiuri arseboba aris misi gamoyeneba anakrebSi. misi parametrebia: dakavSirebuli arseboba, dakavSirebuli anakrebi.

"anakrebi komponentis arseboba" (Assembly Part Occurrence) _ anakrebi komponentis arseboba aris anakrebi komponentis gamoyeneba modulSi. misi parametrebia: damatebiTi identifika-torebi, gayvanilobis identifikatori, identifikatori, instala-ciis informacia, komponenti, mdebareoba.

"kontaqtis sarqvelis arseboba" (Cavity Plug Occurrence) _ kontaqtis sarqvelis arseboba aris kontaqtis sarqvelis

gamoyeneba modul Si. misi parametrebia: gayvanil obis identifi-
katori, komponenti.

"kontaqtis sarqvel is specifiuri arseboba" (Specified Cavity
Plug Occurrence) _ kontaqtis sarqvel is specifiuri arseboba aris
mis gamoyeneba anakrebSi. misi parametrebia: dakavSirebul i
arseboba, dakavSirebul i anakrebi.

"kontaqtis SemamWidrovebl is arseboba" (Cavity Seal Occurrence)
_ kontaqtis SemamWidrovebl is arseboba aris kontaqtis Sema-
mWidrovebel is gamoyeneba modul Si. misi parametrebia: gayvani-
l obis identifikatori, komponenti.

"kontaqtis SemamWidrovebl is specifiuri arseboba" (Specified
Cavity Plug Occurrence) _ kontaqtis SemamWidrovebl is specifiuri
arseboba aris misi gamoyeneba anakrebSi. misi parametrebia:
dakavSirebul i arseboba, dakavSirebul i anakrebi.

"damatebiTi komponentis arseboba" (Co Pack Occurrence) _
damatebiTi komponentis arseboba aris damatebiTi komponentis
gamoyeneba modul Si. misi parametrebia: gayvanil obis identifi-
katori, identifikatori, instal aciis informacia, komponenti.

"damatebiTi komponentis specifiuri arseboba" (Specified Co
Pack Occurrence) _ damatebiTi komponentis specifiuri arseboba
aris misi gamoyeneba anakrebSi. misi parametrebia: dakavSirebul i
arseboba, dakavSirebul i anakrebi.

"koneqtoris arseboba" (Connector Occurrence) _ koneqtoris
arseboba aris koneqtoris korpusis gamoyeneba modul Si. misi
parametrebia: damatebiTi identifikatorebi, gayvanil obis iden-
tifikatori, identifikatori, instal aciis informacia, kompone-
nti, mdebareoba, gamoyeneba.

"koneqtoris specifiuri arseboba" (Specified Connector
Occurrence) _ koneqtoris specifiuri arseboba aris misi gamoyeneba
anakrebSi. misi parametrebia: dakavSirebul i arseboba, dakavSi-
rebul i anakrebi.

"samagris arseboba" (Fixing Occurrence) _ samagris arseboba aris samagris gamoyeneba modul Si. misi parametrebia: damatebiTi identifikatorebi, gayvanil obis identifikatori, identifikatori, instalaciis informacia, komponenti, mdebareoba, gamoyeneba.

"samagris specifiuri arseboba" (Specified Fixing Occurrence) _ samagris specifiuri arseboba aris misi gamoyeneba anakrebSi. misi parametrebia: dakavSirebul i arseboba, dakavSirebul i anakrebi.

"zogadi mavTul is arseboba" (General Wire Occurrence) _ zogadi mavTul is arseboba aris mraval gul iani an erTgul iani mavTul is gamoyeneba gayvanil obaSi. misi parametrebia: gayvanil obis identifikatori, instalaciis informacia, sigrZe, mavTul is komponenti.

"special uri terminal is arseboba" (Special Terminal Occurrence) _ special uri terminal is arseboba aris terminal is gamoyeneba modul Si identifikatoriT. misi parametrebia: damatebiTi identifikatorebi, gayvanil obis identifikatori, identifika-tori, instalaciis informacia, komponenti, mdebareoba.

"special uri terminal is specifiuri arseboba" (Specified Special Terminal Occurrence) _ special uri terminal is specifiuri arseboba aris misi gamoyeneba anakrebSi. misi parametrebia: dakavSirebul i arseboba, dakavSirebul i anakrebi.

"terminal is arseboba" (Terminal Occurrence) _ terminal is arseboba aris terminal is gamoyeneba modul Si. misi parametrebia: damatebiTi identifikatorebi, gayvanil obis identifikatori, identifikatori, instalaciis informacia, komponenti, mdebareoba.

"terminal is specifiuri arseboba" (Specified Terminal Occurrence) _ terminal is specifiuri arseboba aris misi gamoyeneba anakrebSi. misi parametrebia: dakavSirebul i arseboba, dakavSi-rebul i anakrebi.

"mavTul is dacvis arseboba" (Wire Protection Occurrence) _ mavTul is dacvis arseboba aris mavTul is dacvis gamoyeneba modul Si. misi parametrebia: damatebiTi identifikatorebi,

gayvanilobis identifikatori, identifikatori, dacvis sigrZe, instalaciis informacia, komponenti.

"mavTulis dacvis specifiuri arseboba" (Specified Wire Protection Occurrence) _ mavTulis dacvis specifiuri arseboba aris misi gamoyeneba anakrebSi. misi parametrebia: dakavSirebuli arseboba, dakavSirebuli anakrebi.

"mavTulis specifiuri arseboba" (Specified Wire Occurrence) _ mavTulis specifiuri arseboba aris misi gamoyeneba anakrebSi. misi parametrebia: dakavSirebuli arseboba, dakavSirebuli anakrebi.

topologia:

"samagris miniWeba" (Fixing Assignment) _ samagris miniWeba amyarebs kavSirs samagris arsebobasa da segments (aRwerilia qvemoT) Soris. misi parametrebia: samagris arsebobis identifikatori, segmentis identifikatori, mdebareoba, orientacia.

"kvanZi" (Node) _ kvanZi warmoadgens segmentis bolos an sxva komponentis mdebareobis ganmsazRvrel sayrdens. misi parametrebia: koordinatebi, identifikatori, damuSavebis informacia, masze dayrdnobili komponentebi.

"dacvis are" (Protection Area) _ dacvis are aris meqanizmi, romelic gansazRvravs mavTulis dacvis arsebobiT dafarul segmentis zedapirs. misi parametrebia: mavTulis dacvis arsebobis identifikatori, segmentis identifikatori, damuSavebis informacia, sawyisi pozicia, saboloo pozicia, dafenis mimarTuleba, gradienti.

"gayvanis traeqtoria" (Routing) _ gayvanis traeqtoria gansazRvravs mavTulis gzas segmentebSi. misi parametrebia: mavTulis identifikatori, segmentebis sia.

"segmenti" (Segment) _ segmenti aris virtualuri traeqtoriis monakveTi sivrceSi romel Sic gadis eleqtruli kavSirebi. misi parametrebia: identifikatori, centraluri mrudi,

sawyisi kvanZi, sawyisi veqtori, sabol oo kvanZi, sabol oo veqtori., real uri sigrZe, warmosaxviTi sigrZe.

damxmare saSual ebebi:

"bi splainuri mrudi" (B_Spline Curve) _ parametrebia: sakontrolo wertilebis sia, xarisxi.

"kartezianuli wertili" (Cartesian Point) _ parametrebia: koordinatebi.

"ricxviTi mniSvneloba" (Numerical Value) _ ricxviTi sididis da misi ganzomilebis gaerTianeba. parametrebia: mniSvneloba, ganzomileba.

"transformacia" (Transformation) _ geometriuli transformacia. parametrebia: koordinatebi, mobrunebis kuTxeebi.

"ganzomileba" (Unit) _ parametrebia: prefiqsi SI sistemaSi, aRniSvna SI sistemaSi, aRniSvna ara SI sistemaSi.

"mniSvnelobaTa are" (Value Range) _ parametrebia: minimaluri mniSvneloba, maqsimaluri mniSvneloba, ganzomileba.

Tu davakvirdebiT obieqtebs, romlebic aRweren satransporto saSualebis eleqtrogayvanilobas, SesaZlebelia maT Soris, erTis mxriv, relaciuri, xolo, meores mxriv, memkvidreobiTi kavSirebis dadgena. magaliTad, erTi mraval Tan relaciuri kavSirebi arsebobs komponentebsa da maT arsebobebs Soris, vinaidan erTi da igive komponenti mraval jer gamoiyeneba gayvanilobaSi. meores mxriv, memkvidruli kavSiri arseobs zogad koponentsa da konkretul komponentebs Soris.

eleqtrogayvanilobis modelirebisaTvis gamoviyenoT obieqt-orientirebuli proeqtireba [23][25]. zemoT aRwerili TiToeul komponenti aRvweroT Sesabamisi klasiT. klasebs Soris arsebobs Semdegi saxis damokidebulebebi: asociaciuri (relaciuri), memkvidreobiTi, agregacia, gamoyenebiTi, instancireba. es damokidebulebebi klasebs Soris sakmarisia gayvanilobis modelirebisaTvis. standartSi aRweril TiToeul obieqts warmovadgenT klasis saxiT da maT Soris vamyarebT memkvidreobiT, asociaciur da agregaciul damokidebulebebs.

memkvidreobiToba aris klasebs Soris iseTi damokidebuleba, roca erTi klasi imeorebs meoris qcevasa da struqturas [23]. rogorc zemoT moyvanili obieqtebis aRweridan Cans, yvela konkretuli komponenti aris zogadi komponentis tipis, e.i. gaaCnia zogadi komponentis yvela Tviseba da damatebiT afarToebs mas sakuTari TvisebebiT. es aris memkvidreobiTi damokidebulebis tipiuri magaliTi, amitom zogadi komponentisa da konkretuli komponentebis klasebs Soris vamyarebT memkvidreobiT damokidebulebas (nax. 22.).

relaciuri kavSiri arsebobs komponentis klasebsa da maT arsebobebs Soris. es kavSirebi ZiriTadad aris erTi mraval Tan, Tumca gvxvdeba sxva tipis kavSirebic. magaliTad, erTi tipis mavTuli (komponenti "mavTuli") mravaljer SeiZleba iqnes gamoyenebuli ("mavTulis arseboba") gayvanilobaSi, amitom "mavTulsa" da "mavTulis arsebobas" Soris aris relaciuri kavSiri erTi mraval Tan. "mavTulis arseboba" SeiZleba ekuTvnodes ramdenime "moduls", aseve erT modulSi SeiZleba iyos mravali "mavTulis arseboba", amitom "modulsa" da "mavTulis arsebobas" Soris aris mravali mraval Tan relaciuri kavSiri. es msjeloba SeiZleba gavavrceloT sxva obieqtebzec.

arsebuli relaciebi SeiZleba davyoT Semdeg nawilebad:
1. kavSirebi komponentebsa da maT arsebobebs Soris (1-N).
2. kavSirebi komponentis arsebobebsa da modulis konfiguraciebs Soris (N-N).
3. kavSirebi komponentebis arsebobebs, komponentebis specifikur arsebobebs da anakrebi komponentebis arsebobebs Soris (1-N-1)
4. sxva relaciuri kavSirebi.

nax. 23.-ze mocemulia obieqtebs Soris relaciuri kavSirebi.

agregacia aris klasebs Soris iseTi damokidebuleba, roca erTi klasi Seicavs meores. Cvens SemTxvevaSi, magaliTad, "mravalguliani mavTuli" Seicavs "mravalguliani mavTulis gulebs", "gayvaniloba" Seicavs yvela komponentis "arsebobas" da

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a.S. klasebs Soris arsebuli ZiriTadi agregaciuli damokidebu-
lebebi mocemulia nax. 24.-ze.

stransporto saSualebis model Si, garda gayvanilobisa,
warmodgenilia antenebi da Zaris triangulirebuli bade. isinic
Sesabamisi klasebiTaa realizebuli.
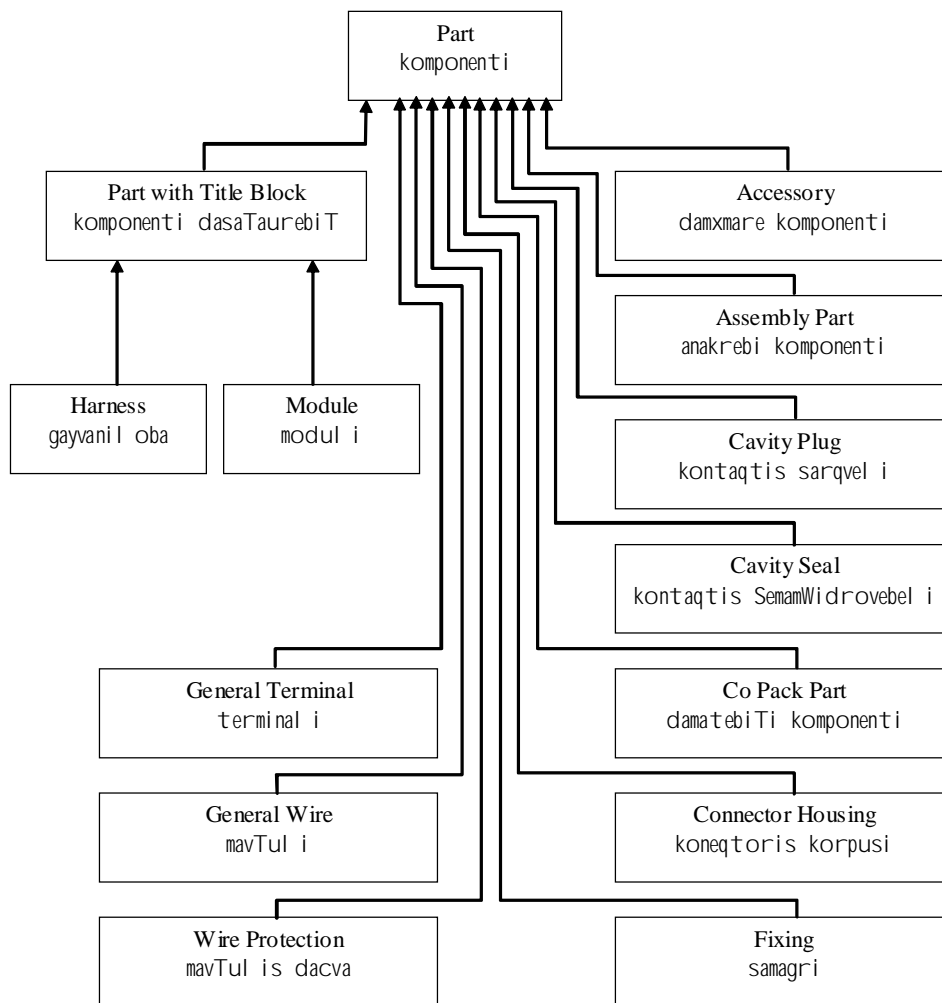
nax. 22. komponentebis klasebis ierarqia

Accessory Occurence damxmare komponentis arseboba	N	1	Accessory damxmare komponenti
Assembly Part Occurence anakrebi komponentis arseboba	N	1	Assembly Part anakrebi komponenti
Cavity Plug Occurrence kontaqtis sarqvel is arseboba	N	1	Cavity Plug kontaqtis sarqvel i
Cavity Seal Occurrence kontaqtis SemamWidrovebel is arseboba	N	1	Cavity Seal kontaqtis SemamWidrovebel i
Co Pack Part Occurrence damatebiTi komponentis arseboba	N	1	Co Pack Part damatebiTi komponenti
Connector Occurrence koneqtoris arseboba	N	1	Connector Housing koneqtoris korpusi
Fixing Occurrence samagris arseboba	N	1	Fixing samagri
Terminal Occurrence terminal is arseboba	N	1	General Terminal terminal i
Special Terminal Occurrence terminal is arseboba identifikatoriT	N	1	
General Wire Occurrence zogadi mavTul is arseboba	N	1	General Wire mavTul i
Wire Protection Occurrence mavTul is dacvis arseboba	N	1	Wire Protection mavTul is dacva

Specified	Occurrence

Assembly Part Occurrence
anakrebi komponentis arseboba

N

1 — **Specified Accessory Occurrence**
specifiuri damxmare komponentis arseboba
— 1 N — **Accessory Occurrence**
damxmare komponentis arseboba

1 — **Specified Cavity Plug Occurrence**
specifiuri kontaqtis sarqvel is arseboba
— 1 N — **Cavity Plug Occurrence**
kontaqtis sarqvel is arseboba

1 — **Specified Cavity Seal Occurrence**
specifiuri kontaqtis SemamWidrovebel is arseboba
— 1 N — **Cavity Seal Occurrence**
kontaqtis SemamWidrovebel is arseboba

1 — **Specified Co Pack Part Occurrence**
specifiuri damatebiTi komponentis arseboba
— 1 N — **Co Pack Part Occurrence**
damatebiTi komponentis arseboba

1 — **Specified Connector Occurrence**
specifiuri koneqtoris arseboba
— 1 N — **Connector Occurrence**
koneqtoris arseboba

1 — **Specified Fixing Occurrence**
specifiuri samagris arseboba
— 1 N — **Fixing Occurrence**
samagris arseboba

1 — **Specified Terminal Occurrence**
specifiuri terminal is arseboba
— 1 N — **Terminal Occurrence**
terminal is arseboba

1 — **Specified Special Terminal Occurrence**
spec. terminal is arseboba identifikatoriT
— 1 N — **Special Terminal Occurrence**
terminal is arseboba identifikatoriT

1 — **Specified General Wire Occurrence**
specifiuri zogadi mavTul is arseboba
— 1 N — **General Wire Occurrence**
zogadi mavTul is arseboba

1 — **Specified Wire Protection Occurrence**
specifiuri mavTul is dacvis arseboba
— 1 N — **Wire Protection Occurrence**
mavTul is dacvis arseboba

```
┌─────────────────────┐  1          1  ┌─────────────────────┐
│    Connection       │────────────────│   Wire Occurrence   │
│     kavSiri         │  1             │  mavTul is arseboba │
│                     │  1             └─────────────────────┘
└─────────────────────┘
         1
         1
┌─────────────────────┐                ┌─────────────────────┐
│     Routing         │          1     │   Core Occurrence   │
│ gayvanis traeqtoria │────────────────│   mavTul is gul is  │
│                     │  N             │      arseboba       │
└─────────────────────┘                └─────────────────────┘

                              N     ┌─────────────────────┐
┌─────────────────────┐       ────  │      Segment        │
│ Fixing Assignment   │  N        1 │      segmenti       │
│  samagris miniWeba  │────────────│                     │
│                     │          1  └─────────────────────┘
└─────────────────────┘                       N
         1                          ┌─────────────────────┐
         1                          │       Node          │
┌─────────────────────┐             │      kvanZi         │
│  Fixing Occurrence  │             │                     │
│  samagris arseboba  │             └─────────────────────┘
│                     │                       N
└─────────────────────┘             ┌─────────────────────┐
                                    │ Connector Occurrence│
┌─────────────────────┐  N          │ koneqtoris arseboba │
│  Protection Area    │──────────  1│                     │
│     dacvis are      │             └─────────────────────┘
│                     │                       N
└─────────────────────┘             ┌─────────────────────┐
         1                          │ Accessory Occurrence│
         1                          │ damxmare komponentis│
┌─────────────────────┐             │      arseboba       │
│Wire Protection Occur│             └─────────────────────┘
│  mavTul is dacvis   │
│     arseboba        │
└─────────────────────┘
```

nax. 23. relaciuri kavSirebi komponentebis klasebs Soris

Left column boxes:

- Accessory Occurrence
  damxmare komponentis
  arseboba
- Assembly Part Occurrence
  anakrebi komponentis
  arseboba
- Cavity Plug Occurrence
  kontaqtis sarqvel is
  arseboba
- Cavity Seal Occurrence
  kontaqtis
  SemamWidrovebel is arseboba
- Co Pack Part Occurrence
  damatebiTi komponentis
  arseboba
- Connector Occurrence
  koneqtoris arseboba
- Fixing Occurrence
  samagris arseboba
- Terminal Occurrence
  terminal is arseboba
- Special Terminal Occurrence
  terminal is arseboba
  identifikatoriT
- General Wire Occurrence
  zogadi mavTul is arseboba
- Wire Protection Occurrence
  mavTul is dacvis arseboba

Right column boxes:

- Harness
  gayvanil oba
- Special Wire Occurrence
  mraval gul iani mavTul is
  arseboba
- Core Occurrence
  mavTul is gul is arseboba
- General Wire
  mavTul i
- Core
  mavTul is gul i
- Connector Occurrence
  koneqtoris arseboba
- Slot
  sl oti
- Cavity
  kontaqti

nax. 24. komponentebis kl asebs Soris agregaciul i damokidebul eba

rogorc zemoT iyo aRniSnul i, **KBL** standartSi
warmodgenil TiToeul obieqts Seesabameba kl asi, roml is
atributebic zemoT aRweril i obieqtebis parametrebia. agreTve
naCvenebi iyo kl asebs Soris arsebul i sxvadasxva tipis
damokidebul ebebi da kavSirebi. magram **KBL** standarti ar aRwers
obieqtebis el eqtrul maxasiaTebl ebs, amitom, zogierTi obieqtis
kl asSi damatebul i iqna special uri atributebi el eqtrul i
maxasiaTebl ebis aRsawerad. es atributebia:

"koneqtoris arseboba" _ zogadi klasi, manZili damiwe-
bamde, damiwebasTan SeerTebis done, infotainmenti, mosti.

"kontaqti" _ zogadi klasi, qselis identifikatori,
sayrdeni kontaqti, kontaqtis klasifikacia, utilizacia, tipiuri
winaRoba, tipiuri, minimaluri da maqsimaluri Zabva, tipiuri,
minimaluri da maqsimauliri deni, daSlis Zabva, daSlis deni,
damcavi wredi, signalis klasi, maqsimaluri sixSire, dakavebis
ciklis minmaluri da maqsimaluri mniSvnelobebi, gamosxivebis
Zabvis amplituda, zrda da dacema, gamosxivebis denis amplituda,
zrda da dacema, tevadoba, induqciuroba, winaRoba, done, manZili
saTavemde.

"mavTulis arseboba", "mavTulis gulis arseboba" _
zogadi klasi, qveklasi, signalis klasi, mgrZnobiarobis klasi,
gamosxivebis klasi, sawyisi koneqtori, saboloo koneqtori,
maqsimaluri sixSire, gadacemis minimaluri dro, winaRoba,
induqtiuroba, tipiuri, minimaluri da maqsimaluri Zabva,
tipiuri, minimaluri da maqsimauliri deni, agreTve kontaqtis
yvela atributi.

amrigad, monacemTa struqtura, romelic damuSavebuli iqna
satransporto saSualebis eleqtrogayvanilobis kompiuteruli
modelis Sesaqmnelad, aris obieqtze orientirebuli da efuZneba
eleqtrogayvanilobis aRweris **KBL** standarts. klasebs Soris
arsebobs memkvidreobiTi, asociaciuri (relaciuri) da
agregaciuli damokidebulebebi. modeli optimaluria obieqtis
aRweris sizustiT, obieqtze nebismieri informaciis miRebis
siadviliT da siswrafiT, resursebze minimaluri moTxovniT. igi
advilad gamoyenebadia programaSi arsebuli sxvadasxva
funqcionalobis uzrunvelsayofad: martivia axali obieqtebis
damateba, arsebulis waSla da modificireba, monacemTa Zebna da
filtracia, obieqtebs Soris urTierTkavSiris gansazRvra,
mTliani modelis da misi nawilebis samganzomilebiani
vizualizacia da sqematuri warmodgena, faqtebis generacia
eqspertuli sistemis birTvisTvis.

3.3 eqspertuli sistemis birTvis realizacia

eqspertul sistemaSi mTavari adgili ukavia logikuri daskvnebis birTvs, radgan igi gansazRvravs, erTis mxriv, codnis bazis warmodegnis meTodebs (wesebis sintaqsi, wesebis Seqmnis logika da a.S.), xolo, meores mxriv, faqtebis formirebebis wessac.

zogadad rom iTqvas, logikuri daskvnebis birTvi warmoadgens interpretators, romelic interpretacias ukeTebs garkveul enaze Caweril wesebs da asrulebs garkveul moqmedebebs maTi mixedviT.

arsebobs codnis warmodgenis sxvadasxva enebi, romlebic gamoiyeneba eqspertuli sistemebis daskvnebis birTvebis Seqmnisas. magaliTad: **OPS5**, **ART**, **LISP** da a.S. satransporto saSualebebis eleqtromagnituri Tavsebadobis kvlevis eqspertuli sistemis logikuri daskvnebis birTvis SeqmnisaTvis arCeul iqna codnis warmodgenis ena **CLIPS**.

CLIPS aris codnis warmodgenis ena, romelic Semdegnairad iSifreba: **C Language Integrated Production System**. igi SemuSavebuli **NASA**-s kosmosuri kvlevis centrSi 80-iani wlebSi. misi interpretatori realizebulia **C** daprogramebis enaze, rac imiT aris gamowveuli, rom misi integracia ufro advili xdeba sxvadasxva platformebsa da sxvadasxva daprogramebis enaze Seqmnil programul produqtebSi [6]. igi aris kargad dokumentirebuli produqti, romelic farTod gamoiyeneba eqspertuli sistemebis Seqmnisas.

logikuri daskvnebis birTvis bazisad **CLIPS**-is arCeva ganapiroba Semdegma faqtorebma:

- masSi realizebulia saSualebebis farTo speqtri.
- mas aqvs sakmaod mkafiod gansazRvruli sintaqsi, romelic aRebulia **LISP**-dan.

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- mis bazaze Seqmnil sistemebs gaaCniaT kargi warmadoba da muSaoben swrafad.

- masSi realizebulia gare funqciebis (sxva programirebis enaze dawerili) gamoZaxebis SesaZlebloba, rac aucilebelad gvWirdeba Cvens SemTxvevaSi.

- mas aqvs saSualebebi, romlebic SesaZleblobas iZleva wesebisa da obieqtebis kombinirebisa.

mokled ganvixiloT **CLIPS_is** ZiriTadi maxasiaTeblebi: rogorc zemoT iyo aRniSnuli, **CLIPS** aris wesebis aRweris ena, romel sac Semdeg interpretacias ukeTebs interpretatori, amiT igi garkveulwilad mogvagonebs daprogramebis enas. mas gaaCnia sami ZiriTadi elementi wesebis dasawerad: monacemTa tipebi, funqciebi monacemebTan muSaobisaTvis, konstruqciebi codnis bazis formirebisaTvis [30].

CLIPS_Si gansazRvrulia Semdegi monacemTa tipebi: ricxvi (number), simbolo (symbol), striqoni (string), gare misamarTi (external adress), faqtis misamarTi (fact adress), egzemplaris saxeli (instance name) da egzemplaris misamarTi (instance adress) [31].

funqciebi aris saxeliT identificirebadi Sesrulebadi kodi, romelic abrunebs riame sidides an asrulebs raime moqmedebas. **CLIPS_Si** arsebobs ori saxis funqciebi: sistemuri da momxmareblis mier gansazRvruli. sistemuri funqciebi iseTi funqciebia, romlebic **CLIPS**-is garemoSia gansazRvruli, xolo momxmareblis mier gansazRvruli funqciebi ki **CLIPS**-is garemos gareT ganisazRvreba.

funqciebi **CLIPS**-Si gamoiZaxeba prefiqsuli notaciiT, rac imas niSnavs, rom jer iwereba funqciis saxeli, Semdeg argumentebi da es yvela aferi frCxilebSia Casmuli. argumentebi erTmaneTisgan da funqciis saxelisgan gamoiyofa Tavisufali ariT. argumentad SesaZlebelia gadacemuli iqnes sxva funqcia. magaliTad: (+ 3 2), (* 3 (+ 5.5 2)).

konstruqciebi, romlebic CLIPS-Si gamoiyeneba, aris wesebi, faqtebi, Sablonebi, modulebi, globaluri cvladebi, funqciebi, klasebi, egzemplarebi, Setyobinebebis dammuSaveblebi da a.S. konstruqciebic moTavsebulia frCxilebSi.

codnis warmosadgenad CLIPS-i produqciebs iyenebs [13]. produqcia CLIPS-Si warmodgenialia wesiT (**Rule**). wesi gamoiyeneba evristikis warmosadgenad, romelic gansazRvravs moqmedebaTa simravles konkretuli situaciisaTvis [31]. radgan wesi aris produqcia, igi Sedgeba ori nawilisagan: marcxena nawili (**LHS**), romel sac sxvanairad "Tu nawilsac" uwodeben, Seicavs pirobas, da marjvena nawilisagan (**RHS**), romel sac "maSin nawilsac" uwodeben da Siecavs moqmedebas.

Tu marcxena nawilis piroba kmayofildeba, maSin amoqmeddeba marjvena nawilSi gansazRvruli procedurebi. marcxena nawilis pirobis dakmayofileba _ ar dakmayofileba ganisazRvreba: faqtebis siaSi faqtis arsebobiT an ararsebobiT, an egzemplarebis arseboba _ ararsebobiT egzemplarTa siaSi. erT-erTi pirobis tipi aris "paterni" [30]. paterni Sedgeba SezRudvaTa simravlisgan, romlebic gansazRvraven Tu romeli faqtebi an obieqtebi akmayofileben paterns. process, romelic Seusabamebs faqtebs an obieqtebs, "paternTan SeTanxmeba" ewodeba. CLIPS-Si realizebulia meqanizmi, romelic avtomaturad axorcielebs paternTan SeTanxmebas faqtebis siis da obieqtTa siis mimdinare mdgomareobaze dayrdnobiT da gansazRvravs romeli wesia gamoyenebadi. wesis marjvena nawilSi gansazRvrulia moqmedebebi, romlebic unda ganxorcieldes maSin, roca wesi aris gamoyenebadi. CLIPS-is daskvnebis birTvi Seasrulebs gamoyenebad wesebs rogorc ki miiRebs instruqcias amis Sesaxeb.

CLIPS agreTve uzrunvelyofs codnis warmodgenis procedurul meqanizms. funqciebi abruneben saWiro mniSvnelo-bebs an asruleben sxvadasxva saWiro moqmedebebs. funqciebi SeiZleba gansazRvruli iqnas momxmareblis mier. aseT

SemTxvevaSi isini gamoiZaxeba iseve, rogorc sistemuri funqciebi. funqciebi SeiZleba gansazvruli iyos TviTon **CLIPS**-is garemoSi (deffunction) konstruqciis gamoyenebiT, an realizebuli iyos programirebis sxva garemoSi (C, pascal da a.S.) da daskvnebis birTvi maT iyenebdes gare funqciebis gamoZaxebis meqanizmiT.

moviyvanoT wesebis aRweris enaze Caweril i wesis magal iTi. vTqvaT aris Semdegi wesi: "Tu mavTulis zogadi klasi aris "antena" da manZili antenidan mavTul amde naklebia 10-ze, maSin gamoitane Setyobineba, rom mavTuli axlosaa antenasTan". igi **CLIPS**-is enaze Semdegnairad gamoisaxeba:

```
(defrule sample_rule
    (wire (id ?w_id) (general_class ?gen_class))
    (antenna (id ?a_id))
    (test (eq ?gen_class "antenna") )
=>
    (if (< (get_wire_antenna_distance ?w_id ?a_id) 10) then
            (report_warning "Wire" ?w_id "is close to antenna")
    )
)
```

wesis nawili "=>" simbolomde aris marcxena nawili, simbolos Semdeg _ marjvena nawili. marcxena nawilSi gansazRvrulia paterni freimebis saxiT da piroba, rom mavTulis zogadi klasi unda iyos "antena". aiReba yvela mavTuli da yvela antena wyvil-wyvilad. Tu piroba srul deba (mavTulis zogadi klasi aris "antena"), maSin amoqmeddeba wesis marjvena nawili. marjvena nawilSi gamoiZaxeba gare funqcia (get_wire_anten-na_distance), romelic gamoiTvlis manZils mavTulsa da antenas Soris. xdeba am funqciis amoqmedebis Sedegis Sedareba 10-Tan da Tu igi masze naklebia, gamoiZaxeba meore gare funqcia (report_warning), romelic momxmarebels gamoutans Setyobinebas, rom mavTuli axlosaa antenasTan.

wesebis aRweris enis ZiriTad komponentebs warmoadgens faqtebis baza da wesebis baza. faqtebis baza aRwers problemis

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sawyis mdgomareobas, xolo wesebis baza Seicavs operatorebs, romlebic gardaqmnian problemis mdgomareobas da mihyavT igi amoxsnamde [6]. aqedan gamomdinare, erTis mxriv, saproblemo aris modelis mixedviT unda daformirdes faqtebi, romlebic Caweril iqneba wesebis aRweris enaze da meores mxriv, codnis bazaSi ganTavsebuli wesebic amave enaze unda iqnes Sedgenili.

ase rom, eqspertuli sistemis logikuri gadawyvetilebebis birTvis Sesaqmnelad saWiroa gadawyvetil iqnas Semdegi amocanebi:

1. saproblemo aris modelis safuZvelze daformirdes faqtebi **CLIPS**-is sintaqsis gamoyenebiT.
2. eqspertuli codna daformirdes wesebis saxiT **CLIPS**-is sintaqsis gamoyenebiT.
3. damuSavdes gare funqciebi, romlebsac gamoiZaxebs logikuri gadawyvetilebebis birTvi.
4. damuSavdes Sedegebis warmodgenis da gadamuSavebis saSualebebi.

faqtebi unda warmovadginoT freimebis saxiT [13]. freimi aris informaciuli struqtura, romelic Seicavs iseT informaciul erTeuls, rogoricaa sloti. sloti aris sicariele, xvreli, romelic Seivseba informaciiT. slotebis mniSvnelobebiT Sevsebis SemTxvevaSi, freimi aRwers konkretul obieqts an situacias. Tu freimis slotebi ar aris Sevsebuli mniSvnelobebiT, maSin aseT freims uwodeben prototips.

Cvens SemTxvevaSi TiToeul obieqts, romelic gamoiyeneba saproblemo aris (satransporto saSualebis eleqtruli sistemis) aRsawerad, Sevusabamot calkeul freimi. obieqtis TiToeul parametrs ki Sevusabamot sloti.

freimebi unda Caiweros iseTi formatiT, romelic gasagebia **CLIPS_is** interpretatorisTvis. es formatia:

(freimis saxeli

(sloti 1)

(sloti 2)

```
...
(sloti N)
)
```

magaliTisaTvis moviyvanoT freimis prototipi, romelic
Seesabameba koneqtors:

```
(deftemplate MAIN::connector
(slot id (type STRING))
(slot name (type STRING))
(slot part_number (type STRING))
(slot usage (type STRING))
(slot description (type STRING))
(slot number_of_slots (type NUMBER))
(slot number_of_cavities (type NUMBER))
(slot housing_code (type STRING))
(slot housing_type (type STRING))
(slot add_on_text (type STRING))
(slot comment1 (type STRING))
(slot eqt_part_number (type STRING))
(slot eqt_reference_id (type STRING))
(multislot cavity_terminals )
(slot assembly (type STRING))
 (slot general_class)
(slot length_to_ground (type NUMBER))
(slot level (type NUMBER))
(slot infotainment)
(slot most)
(slot base_node (type STRING))
(multislot processing_information_type )
(multislot processing_information_text )
(multislot installation_information_type )
(multislot installation_information_text )
(multislot alias_part_number )
(multislot alias_part_company_name )
(multislot alias_ids )
```

(slot abbreviation (type STRING))

(slot version (type STRING))

(slot degree_of_maturity (type STRING))

(slot predecessor (type STRING))

(slot copyright_notes (type STRING))

(slot mass_information (type NUMBER))

(slot material_key (type STRING))

(slot material_reference_system (type STRING))

 (multislot associated_cavities)

(multislot associated_wires)

)

mxolod freimebis saxiT warmodgenili faqtebi sakmarisi ar aris saproblemo aris Sesaxeb sruli informaciis misaRebad. garda amisa, saWiroa sxvadasxva eleqtromagnituri Tu geometriuli gaTvlebis ganxorcieleba, wesebSi aRwerili logikis mixedviT eleqtrogayvanilobis modelSi cvlilebebis Setana, Sedegebis warmodgena momxmareblisTvis cxrilebis, grafikebis da a.S. saxiT. yovelive amisaTvis gamoiyeneba gare funqciebi, romlebic realizebulia eqspertul sistemaSi **CLIPS**-is garemos gareT, daregistrirebulia **CLIPS**-is garemoSi da romlebsac gamoiZaxebs logikuri daskvnebis birTvi.

damuSavebuli funqciebi SeiZleba davyoT ramdenime jgufad:

1. funqciebi saproblemo aris Sesaxeb damatebiTi informaciis mosapoveblad.

2. funqciebi satransporto saSualebis eleqtrogayvani-lobis modelSi cvlilebebis Sesatanad.

3. funqciebi logikuri gadawyvetilebebis birTvis muSa-obis Sedegebis warmosadgenad.

4. gamoTvliTi funqciebi.

ganvixiloT TiToeul jgufSi Semavali funqciebi da maTi daniSnuleba:

funqciebi saproblemo aris Sesaxeb damatebiTi informaciis mosapoveblad: am funqciaTa jgufSi Sedis funqciebi, romlebic eleqtrogayvanilobis Semadgeneli komponentisaTvis abrunebs mis Sesabamis sxva komponentebs. magaliTad, mavTulisaTvis im koneqtorebs, romlebTanacaa dakavSirebuli; koneqtorisTvis im mavTulebs, romlebic masTan aris dakavSirebuli; modulisTvis masSi Semaval mavTulebs, koneqtorebs, terminalebs da a.S. es funqciebi realizebulia **CLIPS**-is garemos gareT da iyenebs relaciur bazebSi informaciis Zebnis algoriTmebs. sul realizebulia aseTi tipis 144 funqcia, romelic faqtebTan erTad saSualebas iZleva miRebul iqnas saproblemo aris Sesaxeb amomwuravi da yovel mxrivi informacia.

funqciebi satransporto saSualebis eleqtrogayvanilobis modelSi cvlilebebis Sesatanad: eqspertuli sistema aramarto aRmoaCens problemebs, aramed wesebSi Cadebuli logikis mixedviT SeuZlia aRmofxvras kidec isini. amisaTvis mas esaWiroeba funqciebi, romlebic saSualebas miscemen cvlilebebi Seitanos satransporto saSualebis eleqtrogayvanilobis modelSi. aseTi funqciebic realizebulia **CLIPS**-is garemos gareT. sinamdvileSi es funqciebi gamoZaxebisTanave ar cvlian models. isini qmnian fails, romelSic garkveuli formatiT Cawerilia Sesatani cvlilebebi. rogorc ki logikuri daskvnebis birTvi amTavrebs muSaobas, eqspertuli sistemis post-procesori kiTxulobs am fails da axorcielebs Sesabamis cvlilebebs modelSi. aseTi tipis funqciebis magaliTebia: mavTulis sawyisi da saboloo koneqtorebis Secvla, mavTulis tipis Secvla, sxvadasxva eleqtruli parametrebis miniWeba da a.S. sul damuSavebulia aseTi tipis 175 funqcia.

funqciebi logikuri gadawyvetilebebis birTvis muSaobis Sedegebis warmosadgenad: logikuri daskvnebis birTvis muSaobis Sedegebi unda gadamuSavdes da moxerxebuli saxiT miewodos momxmarebels. am funqcias asrulebs eqspertuli sistemis post-procesori. saWiroa garkveuli kavSiris damyareba logikuri

daskvnebis birTvsa da post-procesors Soris. amisaTvis damuSavebul iqna specialuri gare funqciebi. es funqciebi, Tavis mxriv, SeiZleba daiyos ramndenime nawilad: funqciebi angariSebis formirebisaTvis, funqciebi grafikebis dasaxazad, funqciebi cxrilebis Sesadgenad, funqciebi Setyobinebebis momxmareblisaTvis warmosadgenad.

angariSebis formirebis funqciebis saSualebiT pirdapir wesidan SesaZlebelia moxdes angariSebis formireba eleqtrogayvanilobis komponentebis Sesaxeb **Excel**-is cxrilebis saxiT. damuSavebulia aseTi tipis 19 funqcia.

grafikebis dasaxazi funqciebis saSualebiT SesaZlebelia sxvadasxva saxis grafikebis daxazva da momxmareblisaTvis warmodgena pirdapir wesebidan. SesaZlebelia mieTiTos garfikis saxe, warwerebi da a.S. damuSavebulia aseTi tipis 15 funqcia.

cxrilebis Sesadgeni funqciebis saSualebiT SesaZlebelia nebismieri Sinaarsis cxrilis formireba. Seqmnilia aseTi tipis 8 funqcia.

funqciebi momxmareblisaTvis Setyobinebebis warsadgenad, modelis Semcveli funqciebis msgavsad, Setyobinebebs weren specialuri formatis mqone failSi. logikuri gadawyvetile-bebis birTvis muSaobis damTavrebis Semdeg es faili ikiTxeba post-procesoris mier da xdeba Sesabamisi Setyobinebebis momxmareblisTvis wardgena. Setyobineba SeiZleba iyos zogadi xasiaTis an Seexebodes konkretulad romelime obieqts. SemuSavbulia am daniSnulebis mqone 3 funqcia.

gamoTvliTi funqciebi: gamoTvliTi funqciebi aris ori tipis: geometriuli da eleqtromagnituri. geometriuli funqciebi gamoiyeneba eleqtrogayvanilobis sxvadasxva komponen-tebs Soris manZilebis dasadgenad, agreTve mavTulebis saerTo da paraleluri monakveTebis sigrZis saangariSod. magliTad, manZili koneqtorebs Soris, manZili mavTulsa da antenas Soris da a.S. damuSavebulia 14 geometriuli funqcia.

eleqtromagnituri gaTvlebis funqciebi gamoiyeneba sxvadasxva tipis gaTvlebis gansaxorcieleblad. esenia eleqtrostatikuri da eleqtrodinamikuri gaTvlebi. magaliTad, mavTulebis urTierTtevadobebis da induqciurobebis gansazRvra, mavTulsa da antenas Soris $S11$, $S12$, $S21$, $S22$ parametrebis gansazRvra da a.S. SemuSavebulia aseTi tipis 26 funqcia.

logikuri daskvnebis birTvis Sedegebi aris ori tipis: daskvnebi da Setyobinebebi, romelic unda waredginos momxmarebels da cvlilebebi, romlebic avtomaturad unda ganxorcieldes eleqtrogayvanilobis modelSi da amis Semdeg Setyobineba miewodos momxmarebels. orive SemTxvevaSi saWiroa logikuri daskvnebis birTvis muSaobis Sedegebi gadamuSavdes garkveuli saxiT. amas axorcielebs eqspertuli sistemis post-procesori. logikuri daskvnebis birTvis muSaobis Sedegebi post-procesors gadaecema failis saxiT, romelsac igi kiTxulobs da gadaamuSavebs.

eqspertuli sistemis pre-procesori aformirebs faqtebs eleqtrogayvanilobis bazaSi arsebuli informaciis safuZvelze, rac imas niSnavs, rom stransporto saSaulebis Sesaxeb yvela monacemi Caiwereba freimebis saxiT. Semdeg codnis bazidan aiReba arCeuli wesebi da iwereba failis saxiT. faqtebi da wesebi gadaecema logikuri daskvnebis birTvs. logikuri daskvnebis birTvi interpretacias ukeTebs faqtebs da wesebSi aRweril logikis mixedviT axorcielebs sxvadasxva moqmedebebs. muSaobis procesSi logikuri daskvnebis birTvi iyenebs eqspertuli sistemebis sxva modulebis daxmarebas gare funqciebis saSualebiT (sxvadasxva gaTvlebi da a.S.). logikuri daskvnebis birTvi wesebSi gamoyenebuli muSaobis Sedegebis warsadgeni da modelis Sesacvleli funqciebis saSualebiT aformirebs specialuri formatis fails, sadac iwereba Setyobinebebi, romlebic waredgineba momxmarebels da brZanebebi, romelTa mixedviT unda moxdes eleqtrogayvanilobis modelSi

cvlil ebebis ganxorcieleba. am fails kiTxulobs post-procesori da axorcielebs Sesabamis instruqciebs.

Sedegebis fails aqvs Semdegi formati:

$obieqtis tipi $obieqtis identifikatori $Setyobineba $wesi, romlis Sedegicaa

SET: $obieqtis tipi $obieqtis identifikatori $parametri$ mniSvneloba $Setyobineba $wesi, romlis Sedegicaa

. . .

failis TiToeuli striqoni Seesabameba moqmedebas an Setyobinebas. moqmedebis SemTxvevaSi striqoni iwyeba gasaReburi sityviT "SET:", romel sac mosdevs im obieqtis tipi da identifikatori, romelic unda Seicvalos, Semdeg modis parametri, romelic unda Seicvalos da misi mniSvneloba, bolos Caweril ia Setyobineba, romelic unda miewodos momxmarebels. Setyobinebis SemTxvevaSi gansazRvrul ia obieqti, romel sac Seexeba Setyobineba da TviT Setyobineba. igive formati gamoiyeneba Sedegebis dasamaxsovrebl ad maTi Semdgomi gamoyenebis mizniT.

post-procesori kiTxulobs TiToeul striqons, aanalizebs mas da asrulebs masSi Caweril moqmedebebs.

amrigad, eqspertul i sistemis gadawyvetil ebebis birTvi Seqmnil ia codnis warmodgenis ena **CLIPS**−ze dayrdnobiT, romel sac gaaCnia rigi upiratesobebi sxva enebTan SedarebiT. damuSavebul ia el eqtrogayvanil obis modelis Sesabamisi warmodgena faqtebis saxiT, xol o eqspertul i codna warmodgenil ia wesebis meSveobiT. wesebi dafuZnebul ia produqciebze, xol o faqtebi ki _ freimebze. garda amisa, SemuSavebul ia gare funqciebi, roml ebsac iyenebs l ogikuri daskvnebis birTvi muSaobis procesSi. l ogikuri daskvnebis birTvis Sedegebis gadasamuSaveblad da adeqvaturi moqmedebebis gansaxorcieleblad SemuSavebul ia post-procesori, romel ic urTierTqmedebs l ogikuri daskvnebis birTvTTan special uri formatis mqone failis saSualebiT.

3.4 momxmareblis grafikuli interfeisis damuSaveba

eqspertuli sistemis, iseve rogorc nebismieri programuli produqtis, Seqmnisas umniSvnelovanesi adgili ukavia momxmareb-lis interfeisis damuSavebas [32][33]. interfeisi aris programis swored is nawili, romel Tanac urTierTobs uwevs momxmarebels. radganac sistemis daniSnulebaa swored momxmarebels gauwios rekomendaciebi da daxmareba samuSaos SesrulebbaSi, mniSvnelo-vania momxmareblis interfeisi rac SeiZleba mosaxerxebeli da sasiamovno iyos momxmareblisTvis. erTis mxriv, igi unda iyos martivi da advilod gamosayenebeli, xolo, meores mxriv, farTo SesaZleblobebs unda aZlevdes momxmarebals.

damuSavebuli eqspertuli sistemis momxmareblis interfe-isi SeiZleba daiyos ramdenime nawilad:

1. programis mTavari fanjara, romelic moicavs yvela sxva interfeisul obieqts
2. saSualebebi proeqtTan, wesebis biblioTekasTan da proeqtis istoriasTan samuSaod
3. monacemTa cxriluri vizualizatori
4. monacemTa samganzomilebiani vizualizatori
5. monacemTa sqematuri vizualizatori
6. komponentTa Tvisebebis dialoguri fanjrebi
7. wesebis redaqtori
8. Sedegebis post-procesori.

ganvixiloT TiToeuli maTgani da momxmareblis maTTan muSaobis scenari.

programis mTavari fanjara mocemulia nax. 25.-ze.

programis mTavari fanjara Sedgeba ramdenime nawilisagan. fanjris zeda mxares ganTavsebulia mTavari meniu. misi saSualebiT momxmarebeli iZaxebs programis sxvadasxva funqcias. menius qvemoT moTavsebulia instrumentTa paneli, romelic dublirebas ukeTebs menius ZiriTad punqtebs da saSualebas aZlevs momxmarebels swrafad gamoiZaxos saWiro funqciebi.

nax. 25. eqspertuli sistemis mTavari fanjara

instrumentTa panelis qvemoT ganTavsebulia monacemTa
cxriluri vizualizatori. masSi xdeba monacemTa bazaSi
arsebuli eleqtrogayvanilobis komponentebis parametrebis
vizualizacia cxrilebis saxiT.

fanjris marjvena mxares moTavsebulia interfeisuli
komponenti, romelic Sedgeba sami gverdisagan. pirvel gverdze
ganTavsebulia xe, romelic gamoiyeneba proeqtTan samuSaod.
meore gverdze ganTavsebulia xe, romelic gamoiyeneba wesebis
biblioTekasTan samuSaod, xolo mesame gverdze _ xe proeqtis
istoriasTan samuSaod.

fanjris udidesi centraluri nawili uWiravs ares, sadac
muSaobis procesSi xdeba sxvadasxva Svilobili fanjrebis
gaxsna. esenia: samganzomilebiani vizualizatori, sqematuri
vizualizatori, wesebis redaqtori da grafikebis vizuali-
zatori.

fanjris qveda nawilSi moTavsebulia Setyobinebebis dafa.
igi Sedgeba sami gverdisagan. pirvel gverdze gamodis zogadi

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Setyobinebebi (romeli faili CaitvirTa da a.S.), meore gverdze mimdinareobs Setyobinebebis gamotana proeqtSi ganxorcielebuli cvlilebebis Sesaxeb. mesame gverdze gamodis Setyobinebebi, romel Tac gzavnian eleqtrodinamikuri da eleqtrostatikuri gaTvlebis birTvebi.

rodesac momxmarebeli iwyebs eqspertul sistemasTan muSaobas, igi qmnis proeqts. proeqti Sedgeba CatvirTuli satransporto saSualebis eleqtrogayvanilobebisagan, satran- sporto saSualebis Zaris triangulirebuli badeebisagan, antenebisagan, proeqtSi mimdinare wesebis amoqmedebis sesiebi- sagan, eqspertuli sistemis muSaobis Sedegad formirebuli cxrilebisagan da grafikebisagan.

proeqtTan muSaoba mimdinareobs xis saSualebiT (nax. 26.), romelic programis mTavari fanjris marjvena nawil Sia ganTav- sebuli.
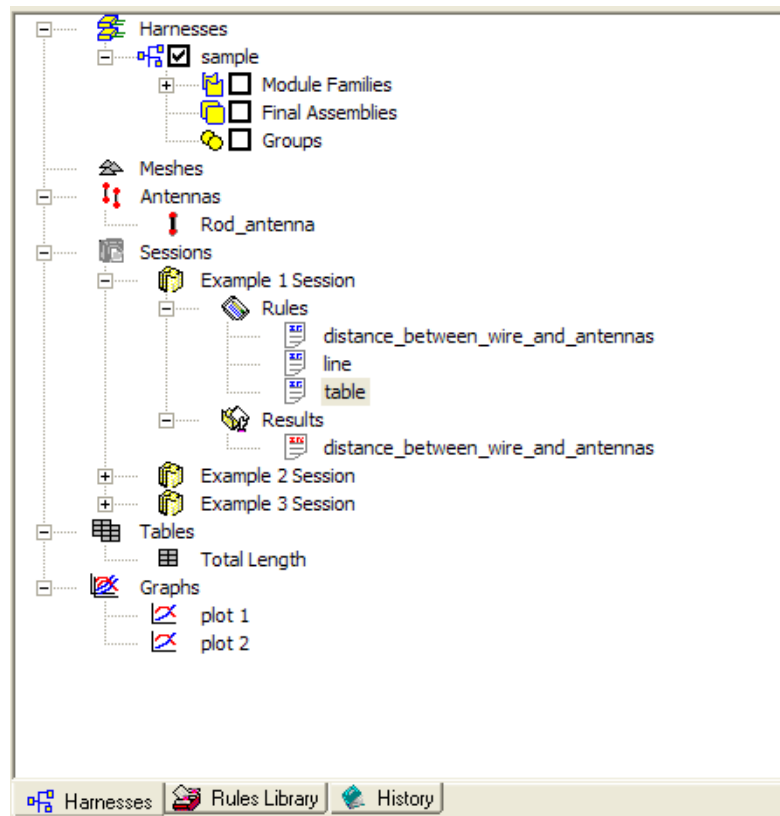
nax. 26. proeqtis marTvis xe

proeqtis marTvis xis saSualebiT xorciel deba eqspertul i sistemis proeqtis Semadgenel i kopmonentebiT manipul ireba. igi Sedgeba xuTi ZiriTadi kvanZisagan. esenia:

1. satransporto saSualebis el eqtrogayvanil obebi
2. meSebi
3. antenebi
4. sesiebi
5. cxrilebi
6. grafikebi

el eqtrogayvanil obebis kvanZis qveS moTavsebul ia proeqtSi CatvirTul i el eqtrogayvanil obebi. erTdroul ad proeqtSi SesaZl ebel ia CatvirTul i iyos ramdenime el eqtrogayvanil oba, magram drois garkveul momentSi mxol od erT-erT aqtiurTan mimdinareobs muSaoba. xis saSualebiT SesaZl ebel ia aqtiuri gayvanil obis arCeva, misi vizual izacia cxril urad an sivrcul ad sam ganzomil ebaSi, agreTve ramdenime gayvanil obis gaerTianeba, erTmaneTTan Sedareba, proeqtidan waSl a, eqsporti da a.S.

meSebis kvanZis qvemoT ganTavsebul ia proeqtSi CatvirTul i triangul irebul i badeebi, romel Ta saSualebiTac xorciel deba satransporto saSualebis Zaris model ireba. SesaZl ebel ia meSebis parametrebis naxva, maTi waSl a proeqtidan da a.S.

antenebis kvanZis qveS moTavsebul ia proeqtSi CatvirTul i antenebi. SesaZl ebel ia antenebis parametrebis naxva, maTi waSl a proeqtidan da a.S.

sesiebis kvanZis qveS moTavsebul ia wesebis amoqmedebis sesiebi. TiToeul i sesia Sedgeba wesebisagan da maTi amoqmedebis Sedegebisagan. rodesac momxmarebel s surs aamoqmedos raime wesebi da miiRos Sedegebi, igi qmnis sesias. Semdeg sesiaSi aformirebs wesebs. wesebi SesaZl ebel ia gadmotanil i iqnes codnis bazidan, an Seiqmnas TviT sesiaSi. SesaZl ebel ia wesebis daj gufeba garkveul i jgufebis saxiT. mas Semdeg, rac sesiaSi ganisazRvreba wesebi, momxmarebel s SeuZl ia amuSaos isini cal -

cal ke an erTdroul ad. miRebul i Sedegebic ganTavsdeba sesiis kvanZis qvemoT igive jgufSi, ra jgufis wesic iyo amuSavebul i. momxmarebel s xis meSveobiT aqvs saSual eba Seqmnas, waSal os da aamuSaos sesia, Seqmnas wesebis jgufebi, Seqmnas, redaqtire-bisTvis gaxsnas da waSal os wesebi, aamuSaos wesebi da wesebis jgufebi, naxos wesebis amoqmedebis Sedegebi.

cxril ebis kvanZis qveS moTavsebul ia cxril ebi, roml Ta formirebac SeiZl eba moxdes wesebis amuSavebis Sedegad. xis saSual ebiT momxmarebel s SesaZl ebl oba aqvs naxos isini an waSal os.

grafikebis kvanZis qveS moTavsebul ia grafikebi, roml Ta formirebac SeiZl eba moxdes wesebis amuSavebis Sedegad. xis saSual ebiT momxmarebel s SesaZl ebl oba aqvs naxos isini an waSal os.

xis saSual ebiT operaciebi xorciel deba mis kvanZebze mausis marjvena Ril akis daWeriT da konteqsturi menius punqtebis arCeviT.

codnis bazaSi arsebul i wesebis marTva xorciel deba agreTve xis saSual ebiT, romel ic meore gverdzea ganTavsebul i (nax. 27.).

xe Sedgeba kvanZebisagan, romel Tagan TiToeul i Seesabameba an wess an wesebis jgufs. wesebi SesaZl ebel ia dajgufebul i iqnes nebismerad. SesaZl ebel ia rogorc cal keul i wesebis, aseve mTl iani jgufebis gadatana proeqtis sesiebSi. momxmarebel s saSual eba aqvs Seqmnas axal i wesebi, moaxdinos maTi importi da eqsporti, waSal os an gaxsnas redaqtirebisTvis. obieqtebze moqmedebebis ganxorciel eba am xeSic xdeba kvanZze mausis marjvena Ril akis daWeriT da Sesabamisi konteqsturi menius punqtis arCeviT.

```
Examples
    set_general_class_for_actuator_connectors
    set_general_class_for_wires_with_name_31
    signal_class_of_wires_with_net_30_must_be_power
    loudspeaker_wires_must_be_twisted
    sensor_connectors_should_have_length_to_ground_less_than_0.8
    CAN_to_antenna_wires_distance_should_be_more_than_5_cm
FUNCTIONS RULES
    Set Functions
        set_antenna_functions
        set_cavities_functions
        set_connector_functions
        set_wire_functions
        set_net_class_functions
    Get Corresponding Elements Functions
        get_families_corr_elements
        get_assemblies_corr_elements
        get_fixings_corr_elements
        get_cavity_seals_corr_elements
        get_terminals_corr_elements
        get_cavity_terminals_corr_elements
        get_segments_corr_elements
        get_nodes_corr_elements
        get_wires_corr_elements
        get_connectors_corr_elements
        get_net_classes_corr_elements
        get_wire_protections_corr_elements
        get_accessories_corr_elements
        get_cavity_plugs_corr_elements
    Calculation Functions
    Plot Functions
    Reporting Functions
    Geometry Functions
    Table Functions
Demo

Harnesses    Rules Library    History
```

nax. 27. wesebis bibl ioTekis xe
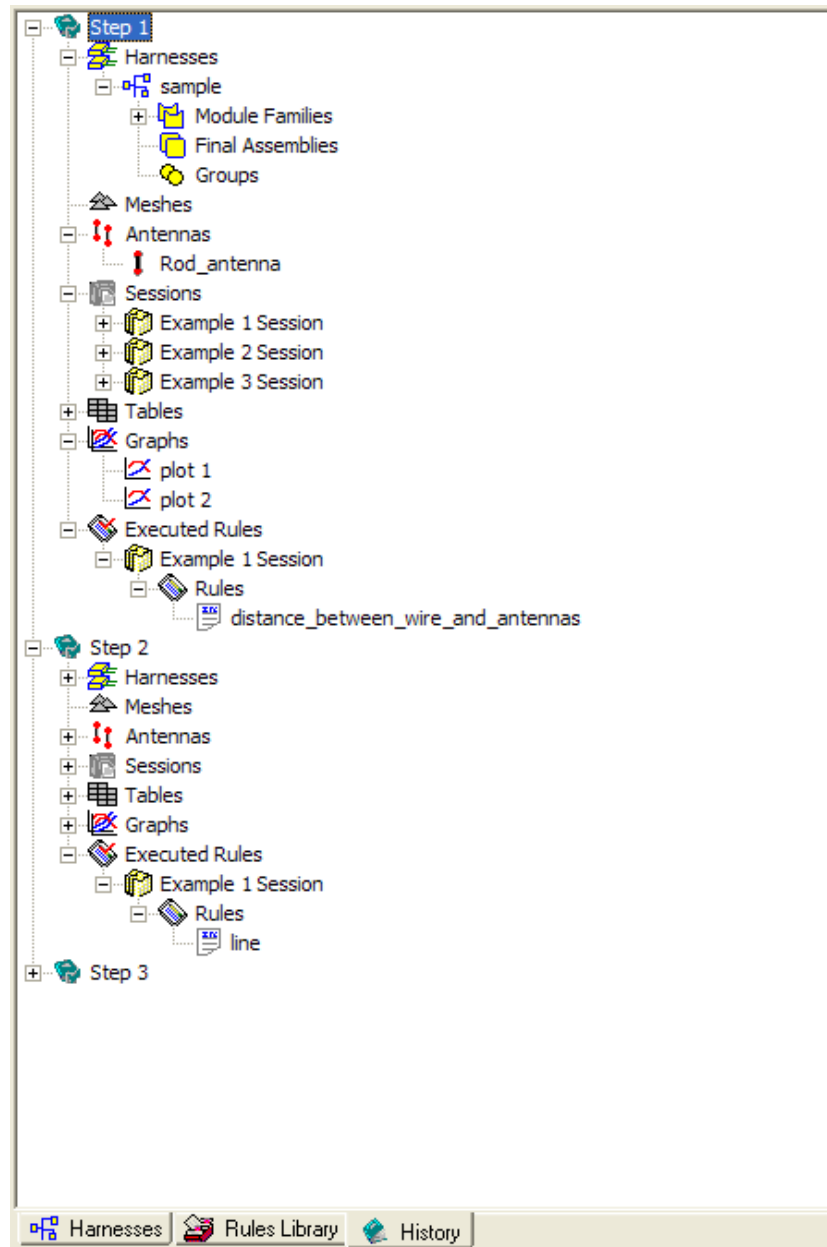
nax. 28. istoriis xe

programas SeuZlia daimaxsovros proeqtis mdgomareoba wesebis yoveli amoqmedebis win da ganaTavsos istoriaSi. momxmarebels saWiroebis SemTxvevaSi saSual eba eZleva aRadgi-nos proeqtis mdgomareoba nebismier bijze. amis ganxorciel eba xdeba istoriis xis meSveobiT (nax. 28.).

xis TiToeuli mTavari kvanZi Seesabameba TiToeul damaxsovrebul mdgomaroebas. kvanZebi emateba qronol ogiurad yoveli wesebis amoqmedebis win. mTavari kvanZis qvemoT moTavse-

buli a proeqtis xe im mdgomareobaSi, ra mdgomareobaSic iqna damaxsovrebul i da agreTve im wesebis sia, romel Ta amoqmedebamdec damaxsovrebul iqna proeqtis mdgomaroba. momxmarebel s SeuZl ia aRadginos nebismeri mdgomareoba, Tu igi mausis marj vena Ril aks daaWers kvanZze da airCevs konteqsturi menius punqts "aRdgena".

proeqtSi CatvirTul i satransporto saSual ebis el eqtro- gayvanil obis, meSebisa da antenebis Sesaxeb informacia momxmare- bel s waredgineba cxril ebis saxiT. amisaTvis SemuSavebul iqna cxril uri vizual izatori (nax. 29.). is, Tu romel i gayvanil oba an misi nawil i iqneba vizual izebul i cxril ebis saxiT, momxmarebel s SeuZl ia gansazRvros proeqtis xis meSveobiT.

nax. 29. cxril uri vizual izatori

cxril uri vizual izatori Sedgeba ramdenime gverdisagan. TiTo gverdze moTavsebul ia TiTo cxril i, romel ic Seesabameba erTi tipis komponents. es cxril ebia: modul ebis oj axebi, modul ebi, mavTul ebi, mraval gul iani mavTul ebi, koneqtorebi, terminal ebi, kontaqtis SemamWidrovebl ebi, kontaqtis sarqvel ebi, kontaqtis terminal ebi, damxmare komponentebi, damatabiTi

komponentebi, anakrebi komponentebi, fiqsatorebi, kvanZebi, segmentebi, kontaqtebi, qselis klasebi, meSebi, antenebi.

momxmarebels saSualeba aqvs Secvalos cxrilebis mimdevroba, TviT cxrilebSi SesaZlebelia svetebis mimdevrobis gadaadgileba. cxrilSi informaciis sortireba xdeba svetebis mixedviT. Tu momxmarebeli mausis marcxena Rilaks daaWers svetis dasaTaurebas, cxrilSi arsebuli informacia dalagdeba am svetis mixedviT zrdadobiT, meored daWeris SemTxvevaSi dalageba moxdeba klebadobiT. SesaZlebelia cxrilSi informaciis moZebna. Zebnis kriteriumebis gansazRvra xorcieldeba specialuri fanjris meSveobiT (nax. 30.).
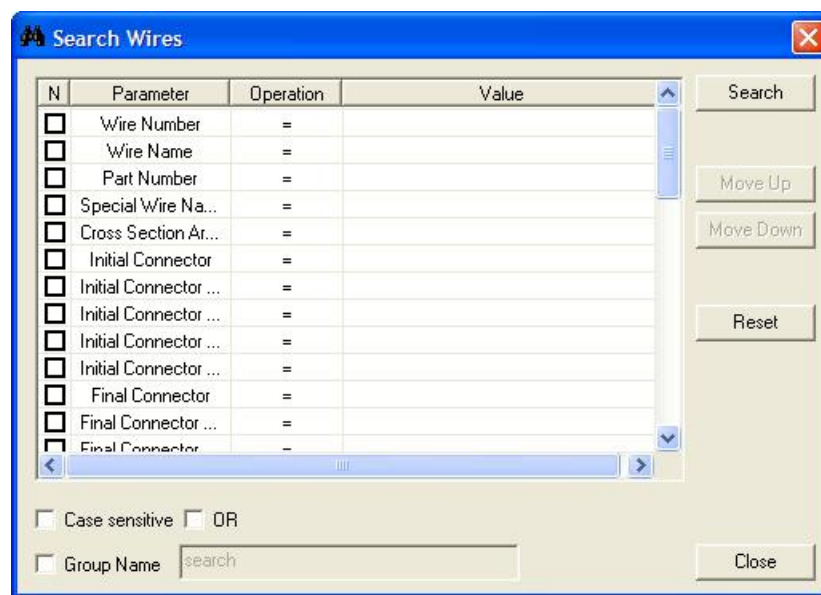
nax. 30. Zebnis fanjara

Zebnis fanjaraSi SesaZlebelia im parametrebis arCeva, romliTac mimdinareobs Zebna, maTi mniSvnelobebis da sxva kriteriumebis gansazRvra. moZebnili komponentebi SesaZlebelia avtomaturad gaerTiandnen jgufSi.

SesaZlebelia cxrilSi gamoCndes yvela komponenti an mxolod moniSnulebi. cxrilebis safuZvelze SesaZlebelia Excel-is angariSebis formireba.

cxril Si komponentis moniSvnisa da masze mausis marjvena Rilakis daWeris SemTxvevaSi gamoiZaxeba konteqsturi meniu, romlis saSualebiTac SesaZlebelia komponentze operaciebis ganxorcieleba. es meniu sxvadasxva komponentisTvis sxvadasxvaa, magram maTSi aris iseTi saerTo punqtebi, rogoricaa "dakavSirebuli komponentebis naxva", "komponentis redaqtirebis fanjaraSi gaxsna", "komponentis jgufisaTvis miniWeba", "komponentis sxva gayvanilobaSi gadatana" da a.S.

yvelive zemoT aRwerili funqcionaluroba cxrilur vizualizators xdis Zalze Zlier da mosaxerxebel saSualebas satransporto saSualebis eleqtruli sistemebis kvlevisaTvis.

gayvanilobis kvlevis kidev erT mZlavr saSualebas warmoadgens samganzomilebiani vizualizatori, romelic momxmarebels warmoudgens gayvanilobis realur models (nax. 31.).
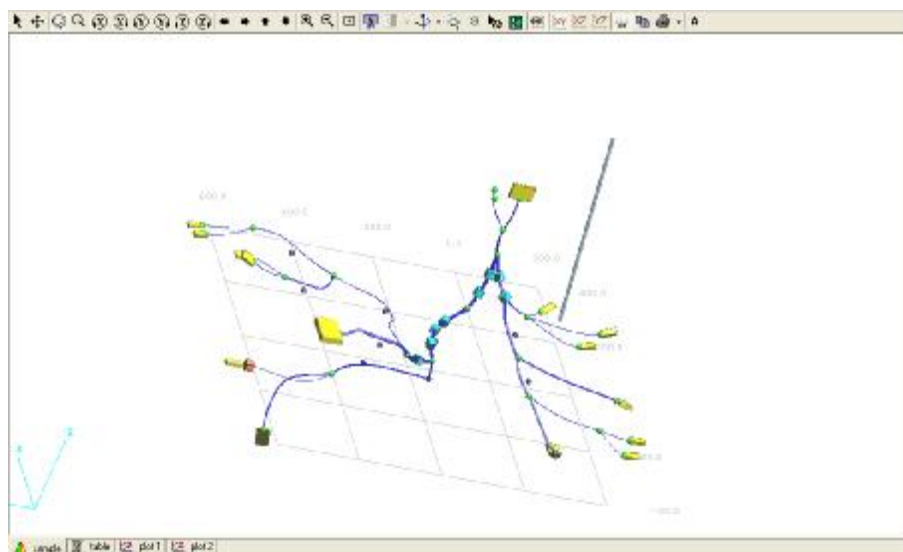
nax. 31. samganzomilebiani vizaulizatori

momxmarebels saSualeba aqvs vizualizacia gaukeTos rogorc mTlian gayvanilobas, aseve mis nawils. SesaZlebelia modelis mobruneba nebismieri kuTxiT, gadatana, masStabireba, kveTis sibrtyeebis dayeneba, ganaTebiT da gamWvirvalobiT

manipulireba da a.S. garda amisa, momxmarebels saSualeba aqvs moniSnos obieqtebi mausis marcxena Rilakis meSveobiT da ganaxorcielos maTze operaciebi. unda aRiniSnos, rom obieqtis moniSvna cxril ur vizualizatorSi, samganzomilebian vizualizatorSi da sqematur vizualizatorSi xdeba paralelurad. erTdroulad SesaZlebelia gamoZaxebul iqnas ramdenime vizualizatori.

gayvanilobis kvlevis kidev erT saSualebas warmoadgens sqematuri vizualizatori (nax. 32.). masSi gayvaniloba warmodgenilia eleqtruli sqemis saxiT.
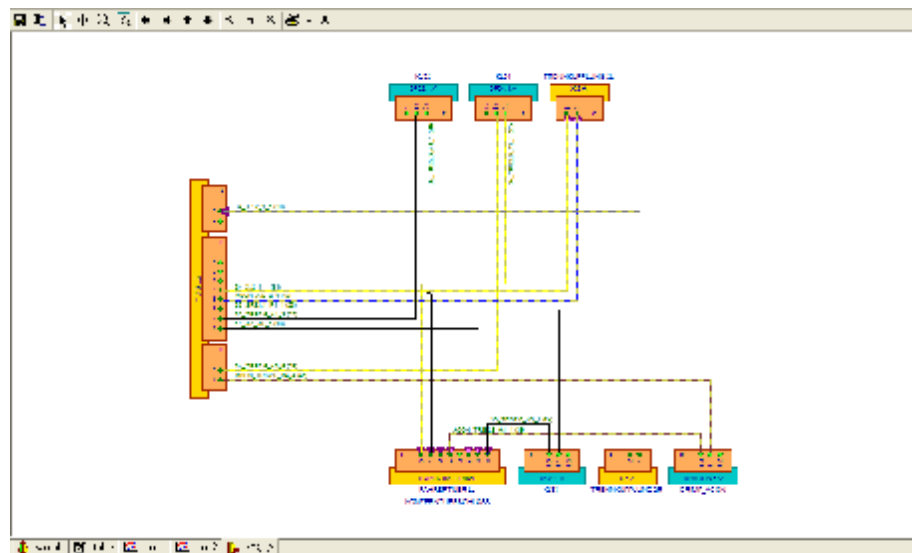
nax. 32. sqematuri vizualizatori

momxmarebels SesaZlebloba aqvs masSi moniSnos obieqtebi, agreTve gaakeTos gamosaxulebis gadatana da masStabireba.

satransporto saSualebis eleqtruli sistemis TiToeuli komponentis parametrebis naxvisa da redaqtirebisaTvis SemuSavebulia dialoguri fanjrebi. maTi aqtivacia xdeba komponentis moniSvniT da konteqsturi menius Sesabamisi punqtis gamoZaxebiT. nax. 33.-ze da nax. 34.-ze gamosaxulia mavTulisa da koneqtoris Sesabamisi dialoguri fanjrebi.

101

Wire Properties

Wire Number 43

Wire Name | ACON_X.2_2_1
Part Number | N_037_004_5
Bend Radius | 4.8
Outside Diameter | 1.6
Cross Section Area | 0.5
Signal Name | ACON
Start Connector | X.2.A
End Connector | *CSL2
Start Cavity | A:2
End Cavity | B:5

Advanced <<

OK   Apply   Cancel

General | EMC Parameters | User-defined Parameters | Em

General Class | Supply
Subclass | none
Signal Class | Ground
Susceptibility Class | none
Radiation Class | none
Initial Connector | none
Final Connector | none
Utilization | none
Max Frequency | 0
Min Transition Time | 0
Resistance | 0
Inductance | 0

Voltage
Typ 0   Min 0   Max 0

Current
Typ 0   Min 0   Max 0

nax. 33. mavTulis redaqtirebis dialogi

Connector Properties

Name *CSL2

34_X.12_1_1 (30)

Base Node | *BSJ1_2934635
Part Number | 1A0_973_100
Usage |
Description | MEHRFACHSTECKERAUFN

Advanced <<

OK   Apply   Cancel

General | EMC Parameters | User-defined Parameters | C

Abbreviation | nv
Version | 1.0
Degree of Maturity |
Predecessor |
Copyright Notes |
Mass Information | 0
Material Information |
Housing Code | CSL
Housing Type |
Housing Color |

Placement
Position X 232   Y 39   Z 338
U   X 0.996   Y 0   Z 0.087
V   X 0   Y 1   Z 0

nax. 34. koneqtoris redaqtirebis dialogi

msgavsi dialogebia damuSavebuli sxva danarCeni komponentebisTvisac. maTi saSualebiT momxmarebels SesaZlebloba aqvs mosaxerxebeli formiT ganixilos komponentis parametrebi da Secvalos zogierTi maTganis mniSvnelobebi.

eqspertuli sistemis umniSvnelovanes nawils warmoadgens wesebis redaqtori, romlis saSualebiTac SesaZlebelia sistemas gadavceT eqspertuli codna. wesebis redaqtori warmoadgens teqstur redaqtors, romelic samganzomilebiani vizualizatorisa da sqematuri vizualizatoris msgavsad ixsneba Svilobili fanjris saxiT (nax. 35.).

wesebis redaqtori Sedgeba ori nawilisagan: TviT redaqtorisa da asistantis xisgan. redaqtorSi xdeba gasaReburi sityvebis sxva ferad gamoyofa, friCxilebis da blokebis gamoyofa, rac Zalze mosaxerxebelia momxmareblisTvis wesebis daweris dros. agreTve SesaZlebelia redaqtorSi sityvebis Zebna da avtomaturi Secvla.

nax. 35. wesebis redaqtori

marcxniv ganTavsebuli asistantis xis daniSnulebaa gauadvilos momxmarebels gare funqciebisa da gayvanilobis komponentebis gamoyeneba wesebSi. masSi CamoTvlilia yvela komponenti Tavisi yvela parametriT da agreTve yvela gare funqcia. komponentis parametrze an funqciaze mausis orjer dawkapunebiT Sesabamisi parametri an funqcia avtomaturad jdeba teqstSi kursoris adgilze. agreTve SesaZlebelia xeSi funqciis moniSvna da masze daxmarebis gamoZaxeba (nax. 36.).

eqspertuli sistemis muSaobis Sedegebis wardgena momxma- reblisTvis xdeba post-procesoris saSualebiT. Sedegebi momxma- rebels waredgineba cxriluri da grafikuli saxiT. post- procesoris fanjara Sedgeba ori gverdisagan (nax. 37.).

nax. 36. daxmarebis fanjara

nax. 37. post-procesoris fnjara (pirvel i gverdi)

pirvel gverdze mocemulia detaluri informacia. igi Sedgeba ori cxrilisagan. zeda cxrilSi mocemulia wesebi, romlebic amoqmedda, xolo qveda cxrilSi maTi amoqmedebis Sedegad miRebuli Setyobinebebi. qveda cxrili Sedgeba ramdenime svetisagan. esenia: obieqtis tipi, romel mac ar daakmayofila raime kriteriumi, misi dasaxeleba, Setyobineba, romelic aRwers problemas, eleqtromagnituri Tavsebadobis riski da momxma-reblis komentari. rodesac obieqti iniSneba cxrilSi, misi paralelurad moniSvna xdeba cxrilur, samganzomilebian da sqematur vizualizatorebSi. SesaZlebelia Sedegebis angariSis formireba.

meore gverdze warmodgenilia ukve komponentebis mixedviT dajgufebuli jamuri informacia (nax. 38.).

pirvel svetSi mocemulia komponentis tipi, meoreSi misi dasaxeleba, mesameSi im wesebis raodenoba, romelmac aRmoaCina komponentis problematuroba, Semdeg jamuri eleqtromagnituri Tavsebadobis riski, xolo Semdeg modis svetebi, romlebic aRwers TiToeuli wesis mixedviT Tu ra riski hqonda komponents.

nax. 38. post-procesoris fanjara (meore gverdi)

cxril ebSi SesaZlebelia riskebis gansazRvra, komentarebis gakeTeba, Zebna, dalageba da a.S.

wesebis amoqmedebis Sedegad formirebuli grafikebi waredgineba momxmarebels calke Svilobili fanjris saxiT. SesaZlebelia grafikebis eqsportireba da redaqtireba (nax. 39.).
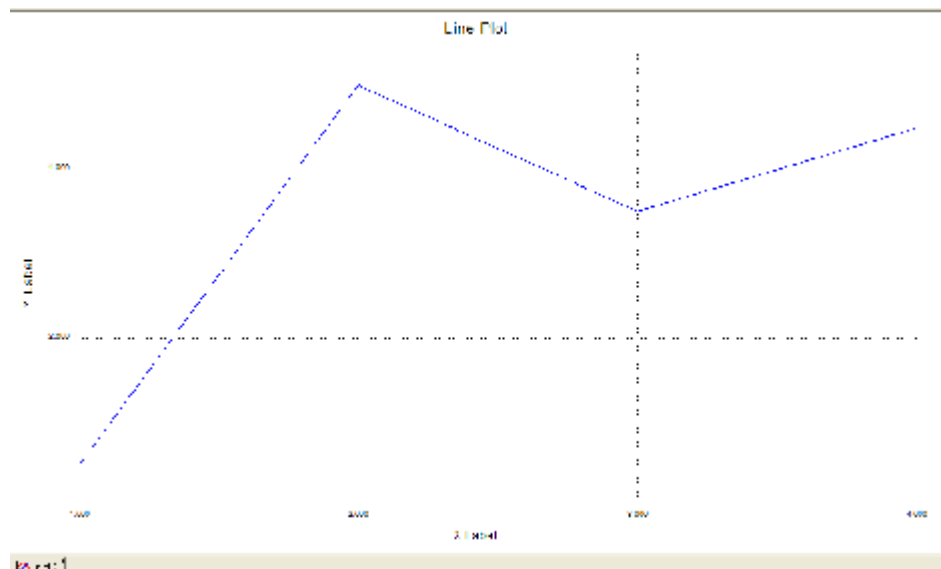
nax. 39. Sedegebis grafikuli vizualizatori

amrigad, eqspertuli sistemisTvis SemuSavebuli iqna mosaxerxebeli grafikuli momxmareblis interfeisi. igi moicavs saproblemo aresTan da codnis bazasTan muSaobis mZlavr saSualebebs. informacia momxmarebels waredgineba sxvadasxava saxiT (cxrilurad, vizualurad, sqematurad, grafikulad). SemuSavebulia eqspertuli codnis sistemisTvis gadacemis da muSaobis Sedegebis momxmareblisTvis wardgenis mosaxerxebeli saSualebebi. yovelive es satransporto saSualebebis eleqtro-magnituri Tavsebadobis kvlevis eqspertul sistemas xdis mZlavr da advilad gamosayenebel saSualebad.

3.5 daskvna mesame Tavis Sesaxeb

1. Seiqmna satransporto saSual ebebis el eqtrogayvanilobis Semadgeneli komponentebis da maT Soris kavSirebis monacemTa baza.

2. moxda eqspertuli sistemis logikuri daskvnebis birTvis da codnis warmodgenis meTodebis realizacia.

3. Seiqmna satransporto saSual ebebis eql qtrogayvanilobis samganzomilebiani, sqematuri da cxriluri saxiT vizualizaciis saSualebebi, eqspertuli sistemis muSaobis Sedegebis post-procesori.

5. SemuSavda momxmareblis grafikuli interfeisi.

6. moxda mTliani eqspertuli sistemis realizacia obieqtze orientirebuli meTodebis gamoyenebiT.

4 sistemis eqsperimentul i Semowmeba

4.1 el eqtromagni turi Tavsebadobis kvl evis arsebul i meTodebi

satransporto saSual ebebis daproeqtebisas dResdReobiT gamoiyeneba rogorc sacdel i eqsperimentebi real ur model ebze, agreTve kompiuterul i model irebis sxvadasxva meTodebi. unda aRiniSnos, rom real uri eqsperimentebis ganxorciel ebas gaaCnia mTel i rigi uaryofiTi mxareebi. aseTi eqsperimentis CatarebisaTvis aucil ebel ia satransporto saSual ebis mza prototipis arseboba, rac, erTis mxriv, did finansur danaxarj ebTanaa dakavSirebul i, xol o, meores mxriv, SesaZl ebel ia ganxorciel des mxol od daproeqtebis bol o etapze. am dros aRmoCenil i probl emebis aRmofxvra ki gacil ebiT ufro did droiT da finansur danaxarj ebTanaa dakavSirebul i vidre daproeqtebis adreul etapze.

amitom sul ufro xSirad gamoiyeneba stransporto saSual ebis el eqtromagni turi Tavsebadobis kvl evis kompiuterul i meTodebi. proeqtirebadi satransporto saSual ebis kompiuterul i model is Seqmna SesaZl ebel ia daproeqtebis adreul etapze da bevrad nakl eb danaxarj ebTanaa dakavSirebul i vidre real uri prototipis ageba. ZiriTadad kvl evebisaTvis gamoiyeneba kompiuterul i programebi, roml ebic ricxviT meTodebzea damyarebul i maTi didi sizustisa da Sedegebis real ur eqsperimentTan siaxl ovis gamo.

aseTi programul i saSual ebebis ricxvs miekuTvneba **EMC Studio**, **FEKO**, **Microwave Studio**. maTi muSaobis principi damyarebul ia momentebisa da sasrul i el ementebis meTodze, amitom isini muSaobis procesSi moiTxoven did gamoTvl iT da droiT resursebs. Sesabamisad, maTi saSual ebiT SesaZl ebel ia mxol od mcire zomis model ebTan muSaoba. mTl iani satransporto

saSualebis eleqtromagnituri Tavsebadobis kvleva ricxviTi meTodebiT SeuZlebelia, swored amitom Seiqmna eqspertuli sistema, romelsac SesaZlebloba aqvs ganixilos mTliani satransporto saSualeba da aRmoaCinos problematuri areebi, romlebic SemdegSi ufro zusti kvlevis mizniT SesaZlebelia amoRebul iqnes modelidan da gamokvleul iqnes zemoT aRniSnuli saSualebebis gamoyenebiT.

satransporto saSualebebis eleqtromagnituri Tavsebadobis kvlevis eqspertuli sistemis muSaobis sizustis Semowmebis mizniT erTi da igive amocanebi gadawyvetil iqna eqspertuli sistemisa da EMC Studio-s meSveobiT da moxda Sedegebis Sedareba. EMC Studio aris msoflioSi mowinave programuli sistema, romelic gamoiyeneba avtomobilebis eleqtromagnituri Tavseba- dobis kvlevisaTvis. misi muSaobis principi damyarebulia momen- tebis meTodze. Sedarebuli Sedegebi erTmaneTs daemTxva didi sizustiT, rac adasturebs eqspertuli sistemis maRal efeqturobas.

eqspertuli sistema warmatebiT aris danergili msoflios iseTi cnobili avtomwarmoeblebis sawarmoo procesSi, rogo- ricaa folksvageni, audi da reno.

4.2 eqsperimentuli Semowmebis Sedegebi

eqsperimentis Catarebis mizniT gamokvleul iqna mavTulebs Soris urTierTqmedeba. satransporto saSualebebSi maRali denis matarebeli mavTulebi xSirad ganTavsebulia mgrZnobiare mavTulebis maxlobdad, Sesabamisad, maRali denis gavlena mgrZnobiare mavTulze SesaZlebelia aRmoCndes kritikuli da gamoiwvios aparaturis muSaobis Seferxeba. eqsperimenti Catarda idealur modelze, roca mavTulebi ganTavsebulia erTmaneTis paralelurad da realuri avtomobilidan aRebuli gayvanilobis

model ze. model ebi gamokvl eul iqna eqspertul i sistemisa da
EMC Studios-s saSual ebiT da Sedegebi Sedarda erTmaneTs. agreTve
gamokvl eul iqna gamoTvl ebisaTvis saWiro droc.

pirvel SemTxvevaSi ori mavTul i moTavsebul ia erTmaneTis
gverdiT. erT mavTul Tan mierTebul ia denis wyaro. vikvl evT
meore mavTul Si aRZrul dens (nax. 40.).
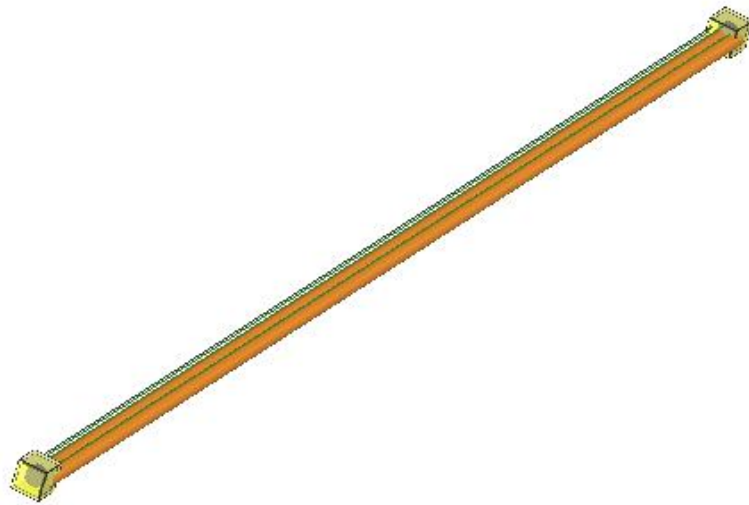
nax. 40. ori erTmaneTis gverdiT ganTavsebul i mavTul i
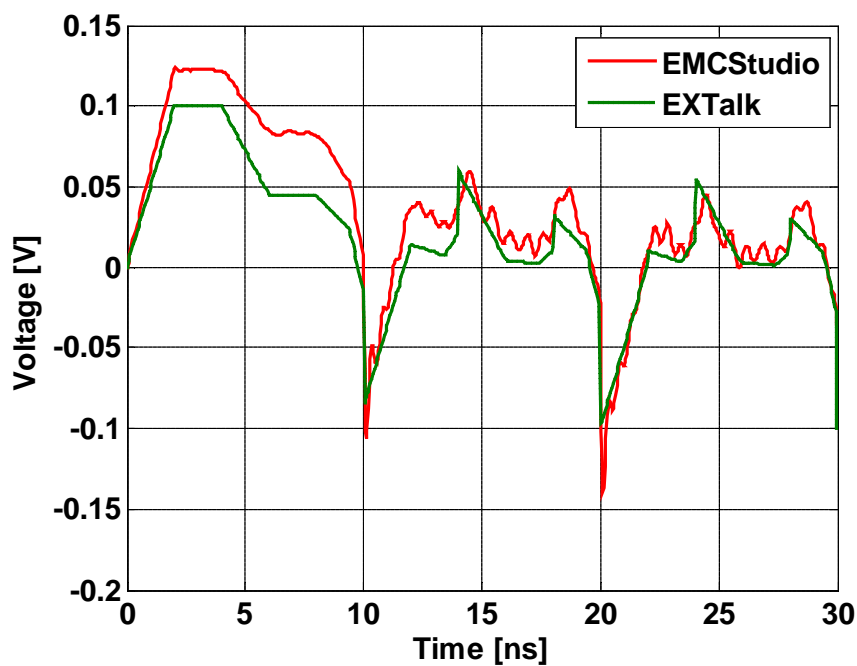
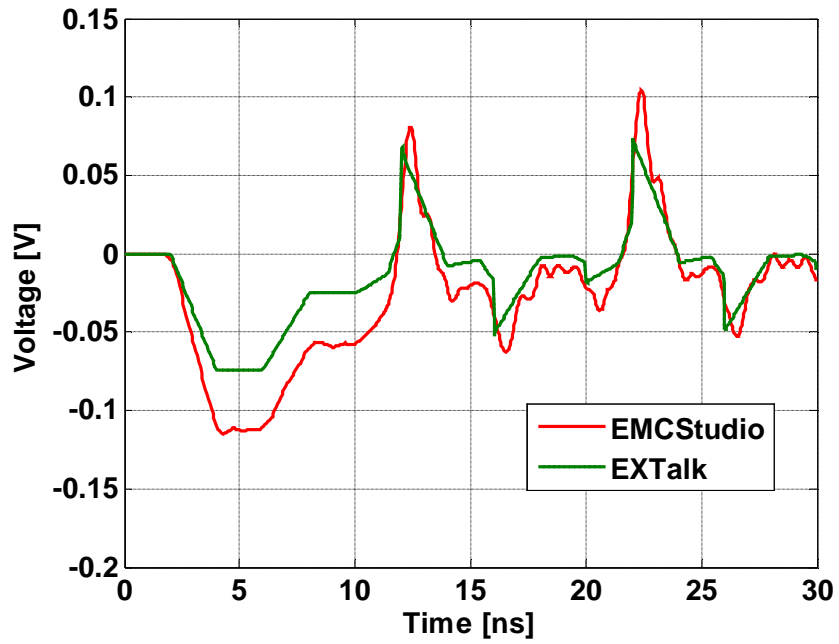Sesabamisi sqema mocemul ia nax. 41.-ze
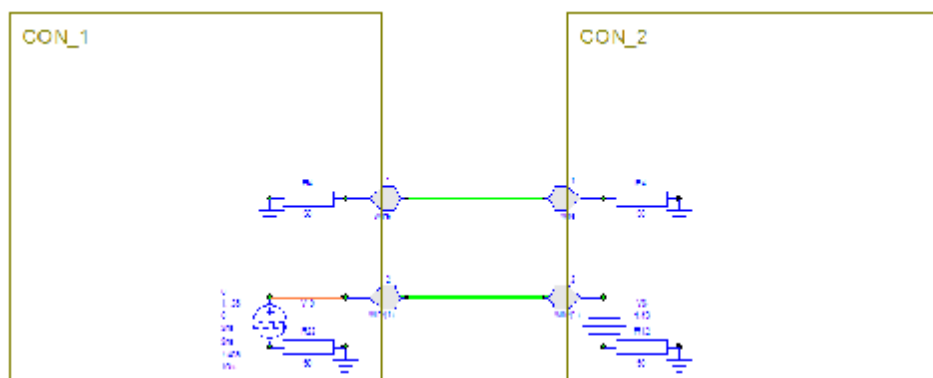
nax. 41. mavTul ebTan mierTebul i mowyobil obebis sqema

programebis muSaobis Sedegebi warmodgenilia Semdeg grafikebiT (wiTel i grafiki aris **EMC Studio**-s gaTvl ebis Sedegi, xol o mwvane _ eqspertul i si stemis):

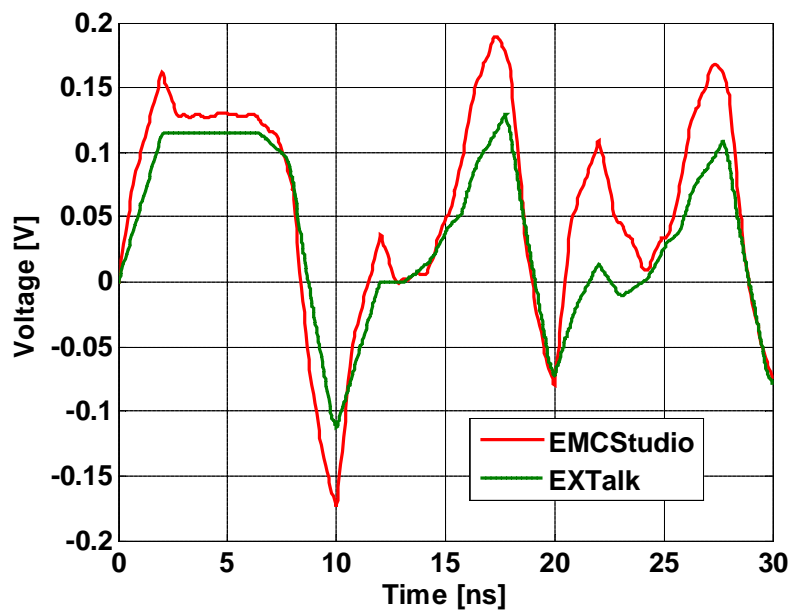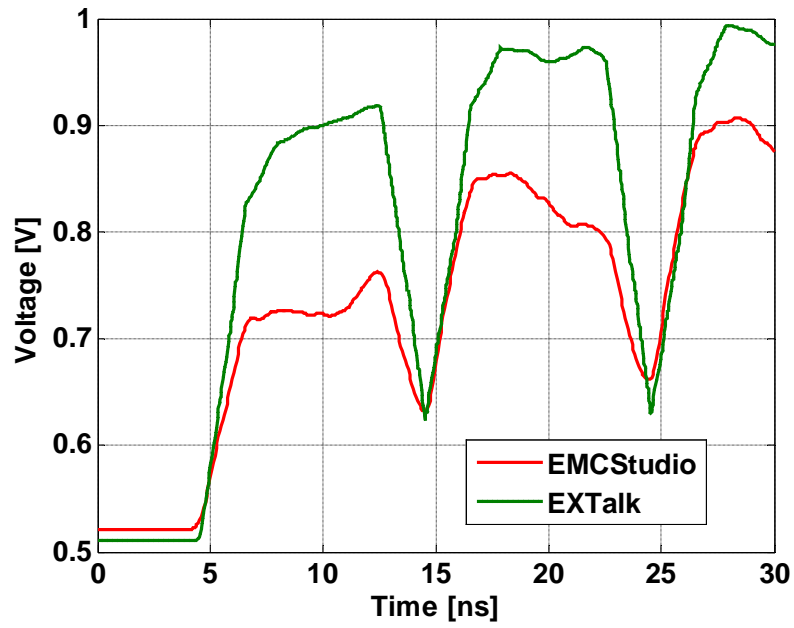nax. 42. Zabva gamomsxivebel i mavTul is pirvel kontaqtze

nax. 43. Zabva mgrZnobiare mavTul is pirvel kontaqtze

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nax. 44. Zabva gamomsxivebel i mavTul is meore kontaqtze
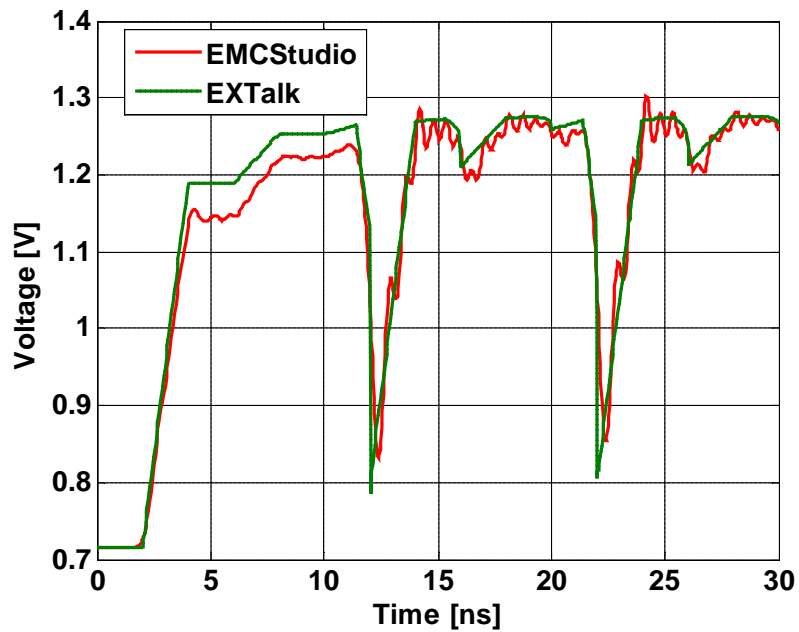
nax. 45. Zabva mgrZnobiare mavTul is meore kontaqtze

rogorc eqsperimentis Sedegebis Sedarebidan Cans ori programis muSaobis Sedegebi sakmaod didi sizustiT daemTxva erTmaneTs.

nax. 46. avtomobilis eleqtrogayvanilobis nawili

meore eqsperimentis dros aRebul iqna namdvili avtomobilis eleqtrogayvanilobis nawili (nax. 46.). ori mavTuli aris gamomsxivebeli, xolo ori _ mgrZnobiare.

Sesabamisi eleqtruli sqema mocemulia nax. 47.-ze.
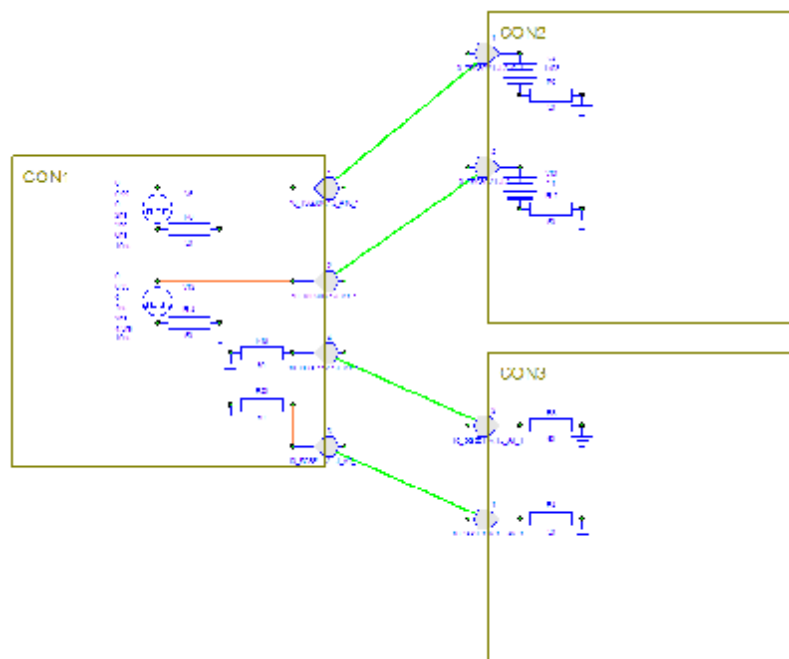
nax. 47. mavTul ebTan mierTebuli mowyobilebebis sqema

eqsperimentis Sedegebi warmodgenilia Semdegi grafikebiT
(wiTel i grafiki aris **EMC Studio**-s gaTvl ebis Sedegi, xol o mwvane
_ eqspertul i sistemis):
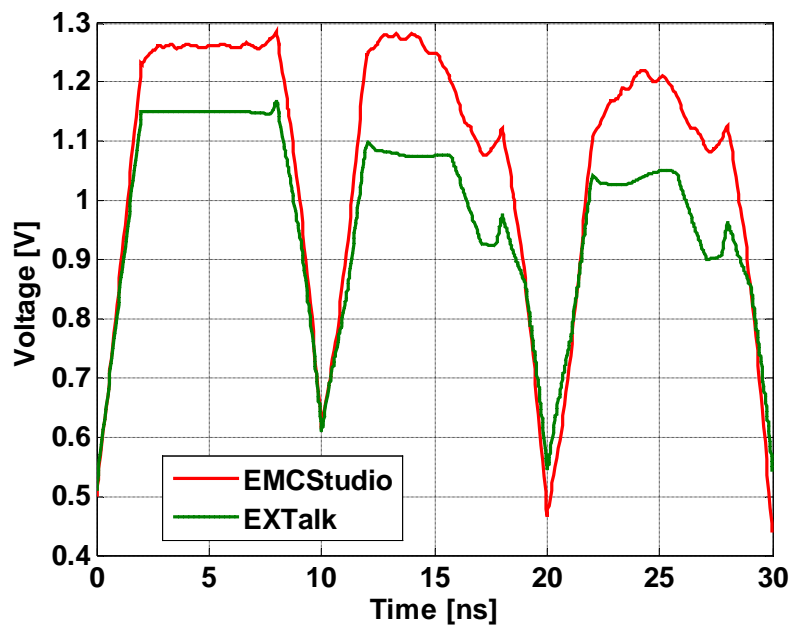
nax. 48. Zabva pirvel i gamomsxivebel i mavTul is pirvel kontaqtze
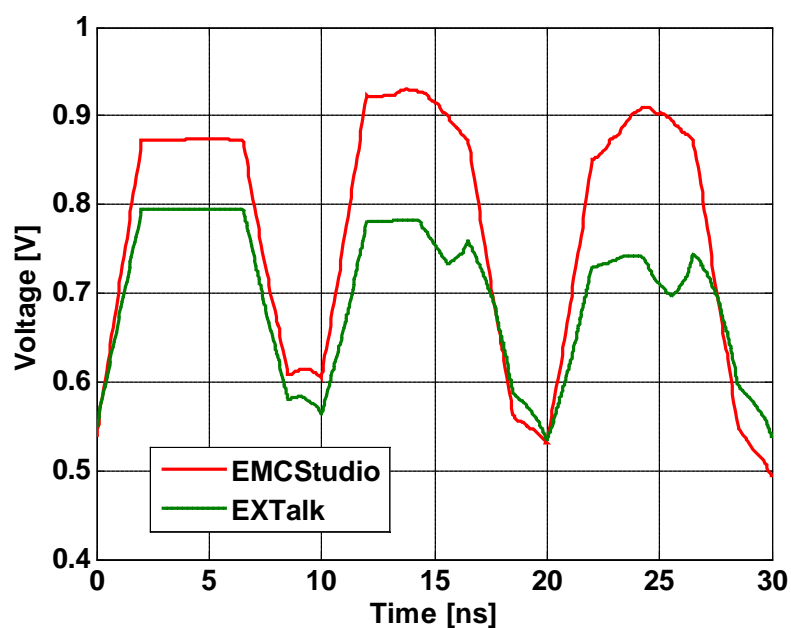
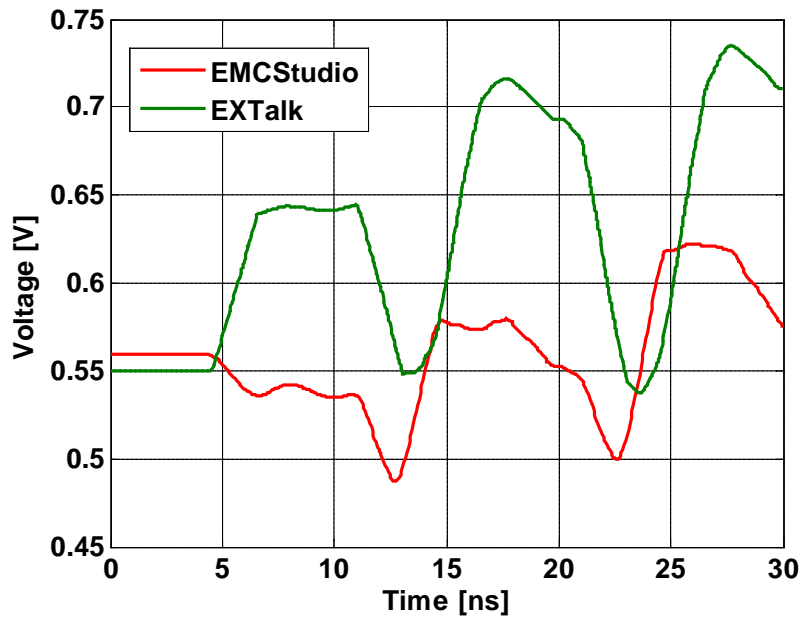nax. 49. Zabva meore gamomsxivebel i mavTul is pirvel kontaqtze
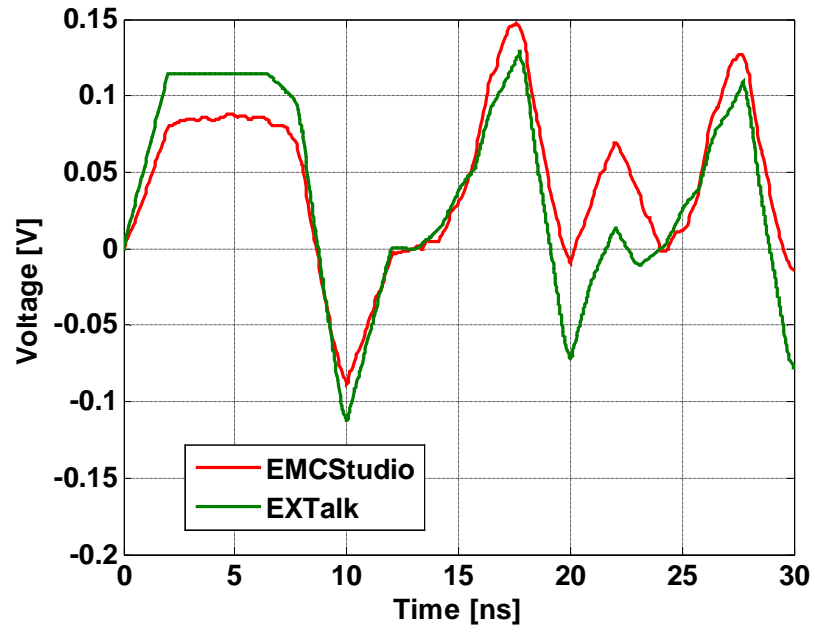
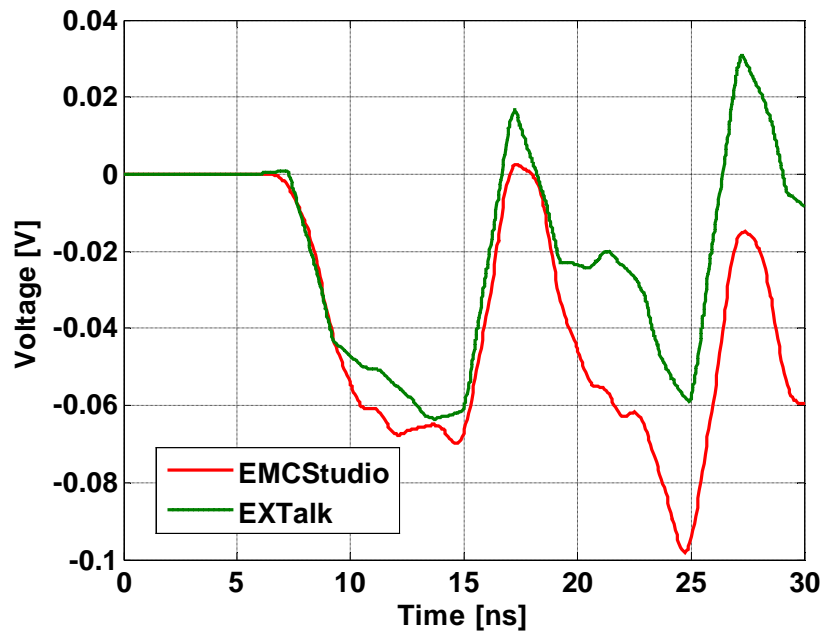nax. 50. Zabva pirvel i mgrZnobiare mavTul is pirvel kontaqtze

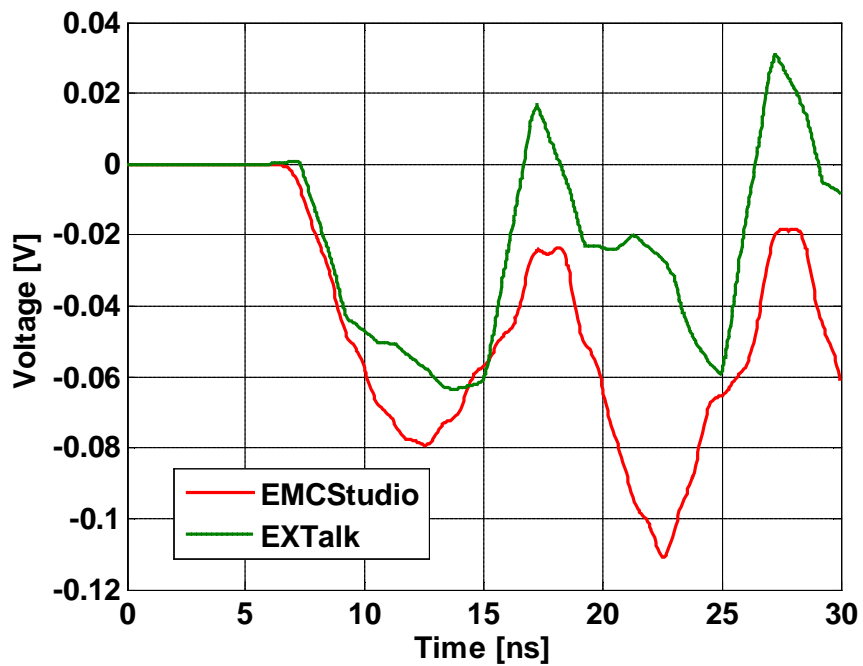nax. 51. Zabva meore mgrZnobiare mavTul is pirvel kontaqtze

nax. 52. Zabva pirvel i gamomsxivebel i mavTul is meore kontaqtze

nax. 53. Zabva meore gamomsxivebel i mavTul is meore kontaqtze

nax. 54. Zabva pirvel i mgrZnobiare mavTul is meore kontaqtze

nax. 55. Zabva meore mgrZnobiare mavTul is meore kontaqtze

rogorc moyvanili grafikebidan Cans, am SemTxvevaSic Sedegebi didi sizustiT emTxveva erTmaneTs. mcire gansxvavebebi

gamowveulia im faqtiT, rom **EMC Studio–sa** da **EMC Expert–Si**
SeuZlebelia zustad identuri modelis Seqmna.

gaTvlebisaTvis saWiro drois dasadgenad aRebul iqna
mavTulebis rTuli sistema 5 gamomsxivebeli da 40 mgrZnobiare
mavTuliT (nax. 56.).
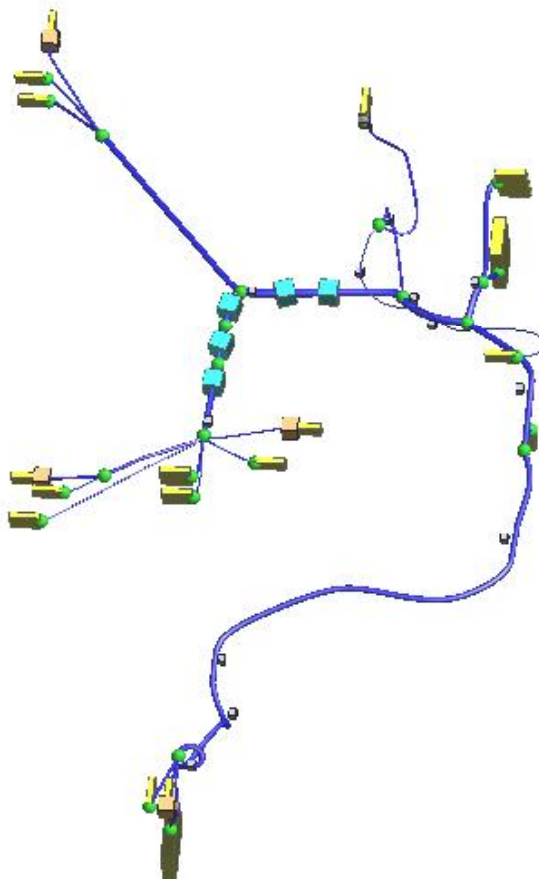
nax. 56. avtomobilis rTuli eleqtrogayvanilobis nawili

gaTvlebis dro arsebul SemTxvevaSi Seadgenda 3 wuTs, rac
sakmaod kargi Sedegia. programebSi, romlebic iyeneben ricxviT
meTodebs msgavsi sistemis gamokvleva praqtikulad SeuZlebelia
Zalian didi droiTi da gamoTvliTi resursebis saWiroebis gamo.

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4.3 daskvna meoTxe Tavis Sesaxeb

1. Catarebulma eqsperimentebma gviCvena, rom **EMC Experts**-s SeuZlia swrafad da didi sizustiT aRmoaCinos eleqtro-magnituri Tavsebadobis potenciuri problemebis mqone areebi satransporto saSualebis rTul eleqtrogayvanilobaSi. aseTi areebi SemdgomSi SesaZlebelia amoRebul iqnas gayvanilobis mTliani modelidan da gamokvelul iqnas zusti meTodebis gamoyenebiT (ricxviTi meTodebi).

2. eqspertuli sistemis warmatebiT danergva iseTi avtomwarmoeblebis sawarmoo procesSi, rogoricaa folksvageni, audi da reno, metyvelebs mis udides praqtikul mniSvnelobasa da mis warmatebiT realizaciaze.

daskvna

sadisertacio naSromSi warmodgenili eleqtromagnituri Tavsebadobis diagnostikisa da analizis eqspertuli sistemis samecniero da praqtikuli Sedegebis ganxilvis safuZvelze SeiZleba gaukeTdes Semdegi daskvnebi:

1. Camoyalibebulia satransporto saSualebebis eleqtruli sistemebis eleqtromagnituri Tavsebadobis kvlevis aqtualu-robis sakiTxebi. ganxilulia eleqtromagnituri Tavsebadobis kvlevis tradiciuli meTodebi Tavisi dadebiTi da uaryofiTi mxareebiT. dasabuTebulia eqspertuli sistemis Seqmnis aucileb-loba.

2. SemuSavebuliqna satransporto saSualebebis eleqtro-gayvanilobis warmodgenis modeli, eqspertuli codnis warmodge-nisa da gadwyvetilebebis miRebis meTodebi, eleqtromagnituri urTierTqmedebis modelirebis meTodebi eleqtrodinamikur da eleqtrostatikuri gaTvlebis birTvebze dayrdnobiT.

3. SemuSavebuliqna kompleqsuri programuli uzrunvel-yofa obiqtze orientirebuli da relaciuri meTodebis gamoyenebiT. SemuSavebuliqna struqturebi monacemTa SenaxvisaTvis, informaciis Zebnis, samganzomilebiani vizuali-zaciis, sqematuri warmodgenis saSualebebi da momxmareblis grafikuli interfeisi.

4. eqspertuli sistemis muSaobis Sedegebis Sedarebam realur eqsperimentebTan da eleqtromagnituri Tavsebadobis sxva meTodebiT kvelevebis SedegebTan gviCvena misi muSaobis sakmaod didi sizuste. sistema warmatebiT iqna danergili evropuli avtomwarmoeblebis sawarmoo procesSi.

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