**tipebisa da klasebis gamocxadeba**

es Tavi aRwers axali tipebisa da klasebis gamocxadebis meqanizmebs haskelSi. viwyebT ori midgomis gaSuqebiT tipTa gamocxadebis sakiTxisadmi, xolo Semdeg vixilavT rekursiul tips, tavtologiis Semowmebis saSualebaTa Seqmnas da abstraqtul manqanas. masalis gadmocemas vamTavrebT klasebisa da maTi egzemplarebis gamocxadebis CvenebiT.

**10.1 tipebis gamocxadeba**

axali tipis gamocxadebis yvelaze martivi xerxi mdgomareobs axali saxelis SemotanaSi ukve arsebuli tipisaTvis haskelis **type** meqanizmis gamoyenebiT. magaliTad, Semdegi gamocxadeba standartuli biblioTekidan gveubneba, rom *String* tipi aris mxolod sinonimi simboluri siebis [*Char*] tipisaTvis da meti araferi:

**type** *String* = [*Char*]

am magaliTis msgavsad, axali tipis saxeli unda iwyebodes mTavruli asoTi. tipebis gamocxadeba SeiZleba iyos erTmaneTSi Calagebuli im TvalsazrisiT, rom dasaSvebia erTi aseTi tipis gamocxadeba sxva tipis farglebSi. magaliTad, wina TavSi tipi dafebisaTvis cxaddeboda poziciaTa tipis safuZvelze:

**type** *Board* = [*Pos*]

**type** *Pos* = (*Int , Int*)

magram, teqnikuri mizezebis gamo tipis gamocxadebebi ar SeiZleba rekursiuli iyos. magaliTad, ganvixiloT Semdegi mcdari gamocxadeba:

**type** *Tree* = (*Int,* [*Tree*])

maSasadame, xe warmoadgens wyvils, romelic Seicavs mTel ricxvsa da qvexeebis sias. miuxedavad imisa, rom es gamocxadeba savsebiT gonivrulia qvexeebis ca­ri­e­li siiT, rac sabazo (sayrden) SemTxvevas warmoadgens rekursiisaTvis, igi ikr­Za­­leba haskelSi swored imis gamo, rom rekursiulia. aucileblobis SemTxvevaSi re­kursiuli tipebis gamocxadeba SesaZlebelia ufro mZlavri **data** meqanizmis ga­mo­yenebiT, romelic qvemoT iqneba aRwerili.

tipis gamocxadebebi SeiZleba agreTve iyos parametrizebuli sxva tipebiT. maga­li­Tad, wina or TavSi Cven vacxadebdiT Semdeg tipebs parserebisa da inter­aq­ti­u­ri programebisaTvis tipis parametris safuZvelze:

**type** *Parser a* = *String →* [(*a, String*)]

**type** *IO a* = *World →* (*a,World*)

dasaSvebia aseve gamocxadebebi, romlebSic tipis erTze meti parametria war­mo­dge­nili. magaliTad, Sesabamisobis (Zebnis, gardaqmnis) cxrilebis tipi, rom­le­bic akavSirebs erTi tipis gasaRebebs sxva tipis mniSvnelobebTan, SeiZleba gamo­cxad­des (gasaRebi, mniSvneloba) wyvilTa siad:

**type** *Assoc k v* = [(*k, v*)]

am tipis gamoyenebisas, funqcia, romelic gvibrunebs cxrilSi mocemul gasaReb­Tan dakavSirebul (asocirebul) pirvel mniSvnelobas, SeiZleba mere aseTi saxiT ga­ni­sazRvros:

*find* :: *Eq k* ⇒ *k → Assoc k v → v*

*find k t* = *head* [*v |* (*k', v*) *← t, k ==* *k'* ]

**10.2 monacemTa gamocxadeba**

arsebuli tipisaTvis, sinonimis SemoRebis nacvlad, sruliad axali tipi SeiZleba gamocxaddes misi mniSvnelobebis miTiTebiT haskelis **data** meqanizmis gamoyenebis pirobebSi. magaliTad, Semdegi gamocxadeba standartuli biblioTe­kidan gveubneba, rom *Bool* tipi Seicavs or axal mniSvnelobas *False* da *True* saxelebiT:

**data** *Bool* = *False | True*

aseT gamocxadebebSi ( | ) simbolo ikiTxeba rogorc «an», xolo tipis axal mniS­vne­­lobebs am tipis *konstruqtorebad* miiCneven. axali tipebis SemTxvevis msgav­sad, axali konstruqtorebis saxelebi mTavruli asoebiT unda iwyebodes. garda ami­sa, konstruqtoris igive saxeli ar SeiZleba gamoiyenebodes erTze meti ti­pi­saTvis.

yuradReba miaqcieT, rom saxelebs, axal tipebsa da konstruqtorebs ar aqvs Hugs sistemisaTvis raime mniSvneloba. magaliTad, zemoT mocemuli gamocxadeba SeiZleba **data** *A* = *B | C* saxiTac Caiweros, vinaidan zusti monacemebi saxelebis Sesaxeb araarsebiTia, im faqtis garda, rom aqamde isini ar gamouyenebiaT. vTqvaT, saxelebs, rogoricaa *Bool*, *False* da *True*, azrs programisti aniWebs iseTi funqciebis saSualebiT, romlebic gansazRvravs am saxelebs axali tipebis konteqstSi.

axali tipis mniSvnelobebi CaSenebuli tipis mniSvnelobaTa msgavsad gamoyeneba. ker­Zod, isini Tavisuflad gadaicema funqciaTa argumentebis saxiT, gvibrundeba funq­ciaTa muSaobis saboloo Sedegebad, inaxeba monacemTa struqturebSi, rogo­ri­caa, vTqvaT, siebi, ixmareba SablonebSi. magaliTad,

**data** *Move* = *Left | Right | Up | Down*

gamocxadebiT mocemuli funqcia, romelic axorcielebs erTi poziciidan meore­Si gadaadgilebas (gavixsenoT, rom poziciebi moicema ekranis zeda marcxena kuT­xis mimarT), risTvisac iyenebs poziciebSi gadaadgilebis sias da cvlis gada­adgi­le­bis mimarTulebas sawinaaRmdegoze, SeiZleba ase ganisazRvros:

*move* :: *Move → Pos → Pos*

*move Left* (*x , y*) = (*x −* 1*, y*)

*move Right* (*x , y*) = (*x* + 1*, y*)

*move Up* (*x , y*) = (*x , y −* 1)

*move Down* (*x , y*) = (*x , y* + 1)

*moves* :: [*Move*] *→ Pos → Pos*

*moves* [] *p* = *p*

*moves* (*m* : *ms*) *p* = *moves ms* (*move m p*)

*flip* :: *Move → Move*

*flip Left* = *Right*

*flip Right* = *Left*

*flip Up* = *Down*

*flip Down* = *Up*

monacemTa gamocxadebebSi konstruqtorebs aseve SeiZleba hqondes argumentebi. magaliTad, im figuris tipi, romelic Seicavs mocemuli radiusebis wreebsa da mocemuli zomebis marTkuTxedebs, aseTi gziT gamocxaddeba:

**data** *Shape* = *Circle Float | Rect Float Float*

amrigad, *Shape* tips ori saxis mniSvnelobebi aqvs, esenia: *Circle r*, sadac *r* aris ricxvi mcuravi wertiliT, da *Rect x y*, sadac *x* da *y* warmoadgens ricxvebs aseve mcu­ravi wertiliT. Semdeg SesaZlebelia am konstruqtorebis gamoyeneba fi­gu­reb­Tan Tanamoqmedi funqciebis gansazRvrisaTvis. saxeldobr, aseTi funqcia Sei­Zle­ba agebdes garkveuli zomis kvadrats, aseve angariSobdes wris an marT­kuT­xe­­dis farTobs:

*square* :: *Float → Shape*

*square n* = *Rect n n*

*area* :: *Shape → Float*

*area* (*Circle r*) = *pi* ∗ *r ↑* 2

*area* (*Rect x y*) = *x* ∗ *y*

argumentebis gamoyenebis gamo, *Circle* da *Rect* konstruqtorebi sinamdvileSi war­mo­adgens funqciaTa konstruqtorebs, romlebic iZleva *Shape* tipis Sedegebs *Float* tipis argumentebis safuZvelze. amis demonstrireba TvalnaTliv SeiZleba gan­va­xorcieloT Hugs sistemis saSualebiT:

*>* :**type** *Circle*

*Circle* :: *Float → Shape*

*>* :**type** *Rect*

*Rect* :: *Float → Float → Shape*

gansxvaveba Cveulebriv funqciebsa da funqciaTa konstruqtorebs Soris isaa, rom konstruqtorebs ar gaaCnia ganmsazRvreli gantolebebi da isini arsebobs, umTav­resad, monacemTa komponentebis asagebad. magaliTad, maSin roca *negate* 1*.*0 gamo­saxuleba SeiZleba iyos Sefasebuli (*−*1*.*0) mniSvnelobiT *negate*-is gan­saz­Rvre­bis gamoyenebiT, *Circle* 1*.*0 gamosaxuleba ukve mTlianad Sefasebulia da, amrigad, ar SeiZleba damatebiT iyos gamartivebuli, vinaidan *Circle*-saTvis ar ar­sebobs ganmsazRvreli gantolebebi. albaT, *Circle* 1*.*0 gamosaxuleba ufro mona­cem­Ta elementia, iseve, rogorc ricxvi 1*.*0 Tavad aris mxolod monacemi da me­ti araferi.

sakvirveli ar aris, rom SesaZlebelia sakuTriv monacemTa gamocxadebebis para­me­­trizeba. magaliTad, standartuli biblioTeka Semdegi tipis gamocxadebas axor­ci­elebs:

**data** *Maybe a* = *Nothing | Just a*

maSasadame, *Maybe a* tipis mniSvnelobebia an *Nothing*, an *Just x* forma *a* tipis gar­kveuli *x* mniSvnelobisaTvis. *Maybe a* tipis mniSvnelobebi SeiZleba iyos in­ter­pretirebuli *a* tipis mniSvnelobebad. es interpretacia SeiZleba niSnavdes an warumateblobas *Nothing* mniSvnelobiT, an warmatebas *Just* mniSvnelobiT. maga­li­Tad, am tipis gamoyenebiT SeiZleba ganisazRvros saimedo, usafrTxo versiebi sa­bib­lioTeko *div* da *head* funqciebisaTvis, romlebic gvibrunebs *Nothing*-s ara­swo­ri argumentebis da ara Secdomis SemTxvevaSi:

*safediv* :: *Int → Int → Maybe Int*

*safediv \_* 0 = *Nothing*

*safediv m n* = *Just* (*m* `*div*` *n*)

*safehead* :: [*a*] *→ Maybe a*

*safehead* [] = *Nothing*

*safehead xs* = *Just* (*head xs*)

**10.3 rekursiuli tipebi**

**data** meqanizmis gamoyenebiT gamocxadebuli tipebi aseve SeiZleba iyos rekursiu­li. pirveli martivi magaliTis saxiT ganvixiloT Semdegi rekursiuli tipi:

**data** *Nat* = *Zero | Succ Nat*

aqedan TvalnaTliv Cans, rom *Nat* tipis mniSvneloba aris an *Zero*, an *Succ n* for­­ma *Nat* ti­pis ra­Rac *n* mniSvnelobisaTvis. amitom es gamocxadeba iZleva mniS­vne­lo­ba­Ta usa­sru­lo mimdevrobas, dawyebuls *Zero* mniSvnelobiT da ga­grZe­le­buls funqciis *Succ* konstruqtoris Tanamimdevrulad gamoyenebiT wina mniS­vne­lo­basTan mimarTebaSi:

*Zero*

*Succ Zero*

*Succ* (*Succ Zero*)

*Succ* (*Succ* (*Succ Zero*))



rogorc es saxelebis arCevanSia gadmocemuli, *Nat* tipis mniSvnelobebi SeiZleba gan­vixiloT naturalur (mTel arauaryofiT) ricxvebad. *Zero* Seesabameba natu­ra­lur ricxvs 0, xolo *Succ* \_ mowesrigebis 1+ funqcias aseT ricxvebze. magali­Tad, *Succ* (*Succ* (*Succ Zero*)) iZleva 1 + (1 + (1 + 0)) = 3 sidides. ufro formalu­rad SesaZlebelia gardasaxvis Semdegi funqciebis gansazRvra:

*nat2int* :: *Nat → Int*

*nat2int Zero* = 0

*nat2int* (*Succ n*) = 1+*nat2int n*

*int2na* :: *Int → Nat*

*int2nat* 0 = *Zero*

*int2nat* (*n* + 1) = *Succ* (*int2nat n*)

magaliTad, am funqciaTa gamoyenebiT SesaZlebelia ori naturaluri ricxvis Se­kre­ba jer maTi konvertirebiT (gardasaxviT) mTel ricxvebad, am mTeli ricxve­bis SekrebiT da Semdeg Sedegis gadaqmniT kvlav naturalur ricxvad:

*add* :: *Nat → Nat → Nat*

*add m n* = *int2nat* (*nat2int m* + *nat2int n*)

magram rekursiis saSualebiT *add* funqcia SeiZleba Tavidan ganisazRvros aseTi gar­da­saxvis gamouyeneblad da, maSasadame, ufro efeqturadac:

*add Zero n* = *n*

*add* (*Succ m*) *n* = *Succ* (*add m n*)

es gansazRvreba axdens im ideis formalizebas, rom ori naturaluri ricxvi Sei­Zleba Seikribos *Succ* konstruqtorTa piris gadaRebiT, dawyebuli pirveli ric­xviT da damTavrebuli xsenebuli ricxvis amowurviT. am momentisaTvis *Zero* bo­loSi Canacvldeba meore ricxviT.

magaliTad, 2 + 1 = 3 procesi Semdegnairad mimdinareobs:

*add* (*Succ* (*Succ Zero*)) (*Succ Zero*)

= { *add-is gamoyeneba* }

*Succ* (*add* (*Succ Zero*) (*Succ Zero*))

= { *add-is gamoyeneba* }

*Succ* (*Succ* (*add Zero* (*Succ Zero*)))

= { *add-is gamoyeneba* }

*Succ* (*Succ* (*Succ Zero*))

meore magaliTis saxiT ganvixiloT **data** meqanizmi, romelic SeiZleba gamovi­ye­noT siaTa CaSenebuli tipis sakuTari variantis gamosacxadeblad, roca igi pa­ra­me­tri­ze­bu­lia nebismieri tipiT:

**data** *List a* = *Nil | Cons a* (*List a*)

maSasadame, *List a* tipis mniSvneloba warmodgenilia an *Nil*-iT, romelic cariel sias Seesabameba, an aracarieli siis Sesatyvisi *Cons x xs* formiT garkveuli *x*:: *a* da *xs*:: *List a* mniSnelobebisaTvis. am tipis gamoyenebiT SesaZlebeli xdeba siebTan Tanamoqmedi sabiblioTeko funqciebis Cveni sakuTari versiebis gan­saz­Rvra. magaliTisaTvis sakmarisia davasaxeloT funqcia, romelic siis sigrZes an­ga­ri­Sobs:

*len* :: *List a → Int*

*len Nil* = 0

*len* (*Cons xs*) = 1 + *len xs*

miuxedavad imisa, rom siebi gamoTvlebSi, albaT, yvelaze xSirad gamoyenebad mo­na­cemTa struqturebs warmoadgens, monacemTa Sesanaxad aranakleb sasargebloa or­gverda ganStoebuli struqtura, anu *binaruli* (*orobiTi*) *xe*, romlis erT-er­Ti SesaZlo magaliTi naCvenebia qvemoT.



am magaliTSi ricxvebi 1*,* 4*,* 6*,* 9 Cndeba xis gare *foTlebze* (ingl. *leaves*), xo­lo ric­xve­bi 5*,* 3*,* 7 \_ Sida *kvanZebSi* (ingl. *nodes*). aseTi xeebis war­mo­sadgenad re­kur­si­is gamoyenebiT Sesaferisi tipi SeiZleba Semdegnairad ga­mo­cxaddes:

**data** *Tree* = *Leaf Int | Node Tree Int Tree*

simartivisaTvis mniSvnelobaTa tipi aq gansazRvrulia mxolod mTeli ric­xve­bi­sa­­Tvis, magram gamocxadebis parametrizaciiT advilia am SemTxvevis ganzo­ga­deba. ase­Ti tipis gamoyenebiT xe zemoT mocemul naxazze SeiZleba Se­mde­gi saxiT war­mo­va­­d­gi­­­noT:

*t* :: *Tree*

*t* = *Node* (*Node* (*Leaf* 1) 3 (*Leaf* 4)) 5 (*Node* (*Leaf* 6) 7 (*Leaf* 9))

axla ganvixiloT ramdenime funqcia aseT xeebze. upirveles yovlisa, ganvsazR­vroT funqcia, romelic adgens mocemuli mTeli ricxvis arsebobas xeze:

*occurs* :: *Int → Tree → Bool*

*occurs m* (*Leaf n*) = *m ==* *n*

*occurs m* (*Node l n r*) = *m ==* *n* ∨ *occurs m l* ∨ *occurs m r*

amrigad, mTeli ricxvi gvxvdeba foTolze, Tu igi emTxveva mniSvnelobas fo­Tol­ze, da gvxvdeba kvanZSi, Tu igi emTxveva mniSvnelobas kvanZSi, gvxvdeba mar­cxe­na qvexeze an gvxvdeba marjvena qvexeze. yuradReba miaqcieT, rom gadadebuli (zar­maci) gamoTvlebis gamo, Tu nebismier pirobas pirveli ori pirobidan kvan­Zis SemTxvevaSi aqvs *True* mniSvneloba, maSin *True* Sedegi gvibrundeba darCenil pi­ro­baTa Sefasebis aucileblobis gareSe.

magram uares SemTxvevaSi *occurs* funqcias SeiZleba mouxdes mTeli xis Semovla, ker­Zod, maSin, roca mocemuli ricxvebi xeze ar gvxvdeba. axla ganvixiloT fun­q­cia, romelic axorcielebs siasTan Tanamoqmedi xis gawonasworebas:

*flatten* :: *Tree →* [*Int*]

*flatten* (*Leaf n*) = [*n*]

*flatten* (*Node l n r*) = *flatten l* ++ [*n*] ++ *flatten r*

Tu am funqciis gamoyeneba iZleva Sedegs daxarisxebuli siis saxiT, maSin Tavad xes *Zebnis xe* ewodeba. vTqvaT, xis Cveni magaliTi, rogorc es TvalnaTliv Cans, Ze­bnis xes warmoadgens, radgan:

*flatten t* = [1*,* 3*,* 4*,* 5*,* 6*,* 7*,* 9]

Zebnis xes mniSvnelovani Tviseba gaaCnia: saxeldobr, roca arkveven gvxvdeba Tu ara xeze mocemuli ricxvi, yovelTvis SesaZlebelia kvanZis ori qvexidan im qve­xis gansazRvra, romelsac es ricxvi miekuTvneba. kerZod, Tu mTeli ricxvi na­kle­bia, vidre mniSvneloba kvanZSi, maSin misi povna mxolod marcxena qvexeSi Se­i­Zleba, xolo, Tu ricxvi aRemateba mniSvnelobas kvanZSi, igi mxolod marjvena qve­xeSi SeiZleba imyofebodes. amrigad, Zebnis xeebisaTvis *occurs* funqcia Se­i­Zle­ba Semdegi saxiT gadaiweros:

*occurs m* (*Leaf n*) = *m ==* *n*

*occurs m* (*Node l n r*)

*| m ==* *n* = *True*

*| m < n* = *occurs m l*

*| otherwise* = *occurs m r*

es gansazRvreba wina versiaze ufro efeqturia, vinaidan mas uxdeba mxolod er-Ti gzis gavla \_ qveviT xis gaswvriv, potenciurad mTeli xis Semovlis nac­vlad.

am paragrafis dasasrul unda aRiniSnos, rom xe gamoTvliT teqnikaSi, iseve, ro­gorc bunebaSi, sxvadasxva formiT iCens Tavs. magaliTad, SesaZlebelia ti­pe­bis gamocxadeba xeebisaTvis, romlebsac aqvs monacemebi mxolod TavianT foT­leb­Si, monacemebi mxolod TavianT kvanZebSi, monacemebi rogorc TavianT foT­leb­Si, aseve kvanZebSi (ix. zemoT), an romlebic Seicavs qvexeTa sias:

**data** *Tree a* = *Leaf a | Node* (*Tree a*) (*Tree a*)

**data** *Tree a* = *Leaf | Node* (*Tree a*) *a* (*Tree a*)

**data** *Tree a b* = *Leaf a | Node* (*Tree a b*) *b* (*Tree a b*)

**data** *Tree a* = *Node a* [*Tree a*]

xis ama Tu im formis Sesaferisobas gansazRvravs situacia. yuradReba miaqcieT, rom ukanasknel magaliTSi ar arsebobs konstruqtori foTlebisaTvis, vinaidan kvanZs qvexeTa carieli siiT SeuZlia foTlis rolis Sesruleba.