#%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

#

rm(list=ls())

#

#library('Rmpi')

library('MASS')

library('gtools');

library('npmlreg')

library('rootSolve')

#library('locfit')

#library('KernSmooth')

library('sm')

library(sandwich)

#

#%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

#

#

continuous\_trait<-function(l){

 #

 set.seed(l)

 #

 nca<-500

 nco<-500

 n<-10000

 #

 b0<-c(0.5,-log(2),log(1.5))

 px1<-0.3

 se0<-1

 sw0<-1

 dft<-6

 dfc<-4

 vt<-dft/(dft-2)

 vc<-2\*dfc

 c0<-c(0,0.5)

 gams<-cbind(-2.8,permutations(3,2,c(0,log(1.5),log(2)),repeats.allowed=T),-0.5)

 #

 #

 #\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

 #

 k<-9

 g0<-gams[k,]

 sumd<-0

 while(sumd<nca){

 e0<-rnorm(n,0,sqrt(se0))

 e1<-sqrt(se0/vc)\*(rchisq(n,dfc,ncp=0)-dfc)

 e2<-sqrt(se0/vt)\*(rt(n,dft))

 xx<-rbinom(n,2,px1)

 ww<-c0[1]+c0[2]\*xx+rnorm(n,0,sqrt(sw0))

 yy<-b0[1]+b0[2]\*xx+b0[3]\*ww+e0

 prob\_xywc<-(1+exp(-g0[1]-g0[2]\*yy-g0[3]\*xx-g0[4]\*ww))^-1

 prob\_xywm<-(1+exp(-g0[1]-g0[2]\*yy-g0[3]\*xx-g0[4]\*ww+log(1.5)\*xx\*yy))^-1

 dd<-rbinom(n,1,prob\_xywc)

 sumd<-sum(dd)

 }

 #mean(dd);sum(dd)

 #

 #

 #\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

 #

 #

 #\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

 #

 #

 id<-1:n

 data\_pop<-cbind(id,yy,xx,ww,dd)

 case\_das<-data\_pop[which(dd==1),]

ncase<-length(case\_das[,1])

 cont\_das<-data\_pop[which(dd==0),]

ncont<-length(cont\_das[,1])

 case\_sel<-case\_das[sample(1:ncase,nca,replace=FALSE,prob=NULL),]

 cont\_sel<-cont\_das[sample(1:ncont,nco,replace=FALSE,prob=NULL),]

 stage2\_das<-rbind(case\_sel,cont\_sel)

 o<-order(stage2\_das[,1])

 stage2\_data<-stage2\_das[o,]

 stage2\_sel<-rep(0,n)

for(i in stage2\_data[,1]){stage2\_sel[i]<-1}

 #

 N1<-sum(dd==1)

 N0<-sum(dd==0)

 sel<-rep(0,n)

 sel[dd==1]<-1

 sel[dd==0]<-sample(c(rep(1,N1),rep(0,N0-N1)))

 #

 #data<-cbind(yy,xx,ww,dd,sel)

 data<-cbind(data\_pop[,2:5],stage2\_sel)

 od<-order(data[,4],decreasing=TRUE)

 data<-data[od,]

 #

 #\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

 #

 y<-data[,1]

 x<-data[,2]

 w<-data[,3]

 d<-data[,4]

 s<-data[,5]

 #

 #

 #\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

 #

 #

 #\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

 #

 n1<-sum(s)

 n<-length(s)

 dcat<-unique(d)

 ld<-length(dcat)

 #

 y1<-y[s==1]

 x1<-x[s==1]

 w1<-w[s==1]

 #

 h00<-rep(0,ld);for(k in 1:ld){h00[k]<-h.select(y[d==dcat[k]],s[d==dcat[k]],method="cv")}

 h01<-rep(0,ld);for(k in 1:ld){h01[k]<-4\*sd(y[d==dcat[k]])\*(length(y[d==dcat[k]])^(-1/3))}

 #

 dgr<-1

 h0<-h01

 probs<-rep(0,n);probd<-rep(0,n);for(k in 1:ld){ydk<-y[d==dcat[k]];sdk<-s[d==dcat[k]]

 probs[d==dcat[k]]<-sm.regression(ydk,sdk,h=h0[k],eval.points=ydk,poly.index=dgr)$estimate

 probd[d==dcat[k]]<-rep(sum(sdk)/length(sdk),length(sdk))}

 #

 #

 #\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

 #

 wgts<-s/probs

 wgtd<-s/probd

 wgts1<-wgts[s==1]

 wgtd1<-wgtd[s==1]

 exclude<-which((probs<=0.01)|(probs>=0.99)|(as.numeric(is.na(probs))==1))

 #length(exclude)

 #

 #\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

 #

 # Ideal Case Approach

 #

 fid<-function(b){apply(cbind(1,x,w)\*(y-b[1]-b[2]\*x-b[3]\*w),2,sum)}

 bid<-multiroot(fid,b0,maxiter=200,rtol=1e-6,atol= 1e-8,ctol =1e-8)$root

 sid<-sqrt(diag(-solve((gradient(fid,bid,centered =FALSE,pert=1e-8)))))

 #

 #

 #\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

 #

 # Complete Case Approach

 #

 ffc<-function(b){cbind(1,x1,w1)\*(y1-b[1]-b[2]\*x1-b[3]\*w1)}

 fcc<-function(b){apply(ffc(b),2,sum)}

 bcc<-multiroot(fcc,b0,maxiter=200,rtol=1e-6,atol= 1e-8,ctol =1e-8)$root

 GGcc<-solve((gradient(fcc,bcc,centered =FALSE,pert=1e-8)))

 BBcc<-(n1-1)\*var(ffc(bcc))

 scc<-sqrt(diag(GGcc%\*%BBcc%\*%t(GGcc)))

 #

 npar<-length(bcc)

 #

 #\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

 #

 # SIPW Approaches

 #

 #\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

 #

 #

 # Simple weights

 #

 fipws<-function(b){wgtd1\*cbind(1,x1,w1)\*(y1-b[1]-b[2]\*x1-b[3]\*w1)}

 ipws<-function(b){apply(fipws(b),2,sum)}

 bipws<-multiroot(ipws,b0,maxiter=200,rtol=1e-6,atol= 1e-8,ctol =1e-8)$root

 Gipws<-solve((gradient(ipws,bipws,centered =FALSE,pert=1e-8)))

 Bipws<-(n1-1)\*var(fipws(bipws))

 sipws<-sqrt(diag(Gipws%\*%Bipws%\*%t(Gipws)))

 #

 #

 #\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

 #

 # Kernel-assisted weights

 #

 #

 if(length(exclude)>0){

 #

 cexps<-matrix(0,ncol=npar,nrow=n)

 fipwk<-function(b){(wgts\*cbind(1,x,w)\*(y-b[1]-b[2]\*x-b[3]\*w))[-exclude,]}

 ipwk<-function(b){apply(fipwk(b),2,sum)}

 bipwk<-multiroot(ipwk,b0,maxiter=200,rtol=1e-6,atol= 1e-8,ctol =1e-8)$root

 Gipwk<-solve((gradient(ipwk,bipwk,centered =FALSE,pert=1e-8)))

 dmat<-cbind(1,x,w)\*(y-bipwk[1]-bipwk[2]\*x-bipwk[3]\*w)

 dmas<-s\*dmat;for(k in 1:ld){

 cexps[d==dcat[k],]<-sapply(1:ncol(dmat),function(j){

 ydk<-y[d==dcat[k]];dmak<-dmas[d==dcat[k],j]

 (sm.regression(ydk,dmak,h=h0[k],eval.points=ydk,poly.index=dgr)$estimate)/probs[d==dcat[k]]})}

 messipw<-wgts\*dmat+(1-wgts)\*cexps;msipwk<-matrix(0,ncol=npar^2,nrow=n)

 for(i in 1:n){msipwk[i,]<-as.vector(messipw[i,]%\*%t(messipw[i,]))}

 Bipwk<-matrix(apply(msipwk[-exclude,],2,sum),ncol=npar,nrow=npar)

 sipwk<-sqrt(diag(Gipwk%\*%Bipwk%\*%t(Gipwk)))

 #

 #

 #\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

 #

 # AIPW Approach

 #

 aipw\_f<-function(wgta){

 #

 cexps<-matrix(0,ncol=npar,nrow=n)

 faipw<-function(b){

 dmat<-cbind(1,x,w)\*(y-b[1]-b[2]\*x-b[3]\*w)

 dmas<-s\*dmat

 for(k in 1:ld){

 cexps[d==dcat[k],]<-sapply(1:npar,function(j){

 ydk<-y[d==dcat[k]]

 dmak<-dmas[d==dcat[k],j]

 (sm.regression(ydk,dmak,h=h0[k],eval.points=ydk,poly.index=dgr)$estimate)/probs[d==dcat[k]]})}

 (wgta\*dmat+(1-wgta)\*cexps)[-exclude,]}

 aipw<-function(b){apply(faipw(b),2,sum)}

 baipw<-multiroot(aipw,b0,maxiter=200,rtol=1e-6,atol= 1e-8,ctol =1e-8)$root

 #

 GGaipw<-solve((gradient(aipw,baipw,centered =FALSE,pert=1e-8)))

 BBaipw<-(n-length(exclude)-1)\*var(faipw(baipw))

 saipw<-as.vector(sqrt(diag(GGaipw%\*%BBaipw%\*%t(GGaipw))))

 rbind(baipw,saipw)

 }

 #

 aipw1<-aipw\_f(wgtd)

 aipw2<-aipw\_f(wgts)

 sipw1<-rbind(bipws,sipws)

 sipw2<-rbind(bipwk,sipwk)

 } else{

 #

 #\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

 #

 #\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

 #

 #

 cexps<-matrix(0,ncol=npar,nrow=n)

 fipwk<-function(b){wgts\*cbind(1,x,w)\*(y-b[1]-b[2]\*x-b[3]\*w)}

 ipwk<-function(b){apply(fipwk(b),2,sum)}

 bipwk<-multiroot(ipwk,b0,maxiter=200,rtol=1e-6,atol= 1e-8,ctol =1e-8)$root

 Gipwk<-solve((gradient(ipwk,bipwk,centered =FALSE,pert=1e-8)))

 dmat<-cbind(1,x,w)\*(y-bipwk[1]-bipwk[2]\*x-bipwk[3]\*w)

 dmas<-s\*dmat;for(k in 1:ld){

 cexps[d==dcat[k],]<-sapply(1:npar,function(j){

 ydk<-y[d==dcat[k]];dmak<-dmas[d==dcat[k],j]

 (sm.regression(ydk,dmak,h=h0[k],eval.points=ydk,poly.index=dgr)$estimate)/probs[d==dcat[k]]})}

 messipw<-wgts\*dmat+(1-wgts)\*cexps;msipwk<-matrix(0,ncol=npar^2,nrow=n)

 for(i in 1:n){

 msipwk[i,]<-as.vector(messipw[i,]%\*%t(messipw[i,]))}

 Bipwk<-matrix(apply(msipwk,2,sum),ncol=npar,nrow=npar)

 sipwk<-sqrt(diag(Gipwk%\*%Bipwk%\*%t(Gipwk)))

 #

 #

 #\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

 #

 # AIPW Approach

 #

 aipw\_f<-function(wgta){

 #

 cexps<-matrix(0,ncol=npar,nrow=n)

 faipw<-function(b){

 dmat<-cbind(1,x,w)\*(y-b[1]-b[2]\*x-b[3]\*w)

 dmas<-s\*dmat;for(k in 1:ld){

 cexps[d==dcat[k],]<-sapply(1:npar,function(j){

 ydk<-y[d==dcat[k]];dmak<-dmas[d==dcat[k],j]

 (sm.regression(ydk,dmak,h=h0[k],eval.points=ydk,poly.index=dgr)$estimate)/probs[d==dcat[k]]})}

 wgta\*dmat+(1-wgta)\*cexps}

 aipw<-function(b){apply(faipw(b),2,sum)}

 baipw<-multiroot(aipw,b0,maxiter=200,rtol=1e-6,atol= 1e-8,ctol =1e-8)$root

 #

 GGaipw<-solve((gradient(aipw,baipw,centered =FALSE,pert=1e-8)))

 BBaipw<-(n-1)\*var(faipw(baipw))

 saipw<-as.vector(sqrt(diag(GGaipw%\*%BBaipw%\*%t(GGaipw))))

 rbind(baipw,saipw)

 }

 #

 aipw1<-aipw\_f(wgtd)

 aipw2<-aipw\_f(wgts)

 sipw1<-rbind(bipws,sipws)

 sipw2<-rbind(bipwk,sipwk)

 }

 #

 #round(cbind(bid,bcc,sipw1[1,],sipw2[1,],aipw1[1,],aipw2[1,])-b0,3)

 #round(cbind(sid,scc,sipw1[2,],sipw2[2,],aipw1[2,],aipw2[2,]),3)

 #range(probs);length(exclude)

 #

 #\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

 #

 #

 #\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

 #

 # Full cohort MLE

 #

 xa<-c(0,1,2)

 ngq<-10

 ng2<-t(rep(1,ngq))

 pxa<-dbinom(xa,2,px1,log=FALSE)

 xxs<-gqz(numnodes=ngq,minweight=0.000001)

 wei<-xxs$weight

 loc<-xxs$location

 yo2<-t(y%\*%ng2)

 do2<-t(d%\*%ng2)

 #

 #\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

 #

 #

 #

 mle\_full<-function(a){

 lmis<-apply(sapply(1:3,function(k){

 zloc<-sqrt(sw0)\*loc+0.5\*xa[k]

 py\_xw0<-exp(-0.5\*(yo2-a[1]-a[2]\*xa[k]-a[3]\*zloc)^2/a[4])/sqrt(2\*pi\*a[4])

 hxyw0<-(1+exp(-a[5]-a[6]\*yo2-a[7]\*xa[k]-a[8]\*zloc-a[9]\*xa[k]\*yo2))^-1

 pd\_xyw0<-(hxyw0^do2)\*((1-hxyw0)^(1-do2))

 apply(wei\*pd\_xyw0\*py\_xw0\*pxa[k],2,sum)}),1,sum)

 #

 py\_xw<-exp(-0.5\*(y-a[1]-a[2]\*x-a[3]\*w)^2/a[4])/sqrt(2\*pi\*a[4])

 pdyxw1<-(1+exp(-a[5]-a[6]\*y-a[7]\*x-a[8]\*w-a[9]\*x\*y))^-1

 pd\_yxw<-(pdyxw1^d)\*((1-pdyxw1)^(1-d))

 pw\_x<-exp(-0.5\*(w-0.5\*x)^2/sw0)/sqrt(2\*pi\*sw0)

 p\_x<-dbinom(x,2,px1,log=FALSE)

 lobs<-pd\_yxw\*py\_xw\*pw\_x\*p\_x

 -sum(log(lobs[s==1]))-sum(log(lmis[s==0]))

 }

 #

 mle\_fb<-optim(c(b0,se0,g0,-log(1.5)),mle\_full,hessian=TRUE)

 bmle<-as.vector(mle\_fb$par)[1:3]

 smle<-sqrt(diag(solve(mle\_fb$hessian)))[1:3]

 #

#\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

 #

 #

 #\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

 #

 bhat<-as.vector(cbind(bmle,bcc,sipw1[1,],sipw2[1,],aipw1[1,],aipw2[1,]))

 sder<-as.vector(cbind(smle,scc,sipw1[2,],sipw2[2,],aipw1[2,],aipw2[2,]))

 tval<-rep(b0,6)

clb<-bhat-1.96\*sder

cub<-bhat+1.96\*sder

 cps<-as.numeric(tval-clb>=0)\*as.numeric(cub-tval>=0)

 #

 #round(cbind(bmle,bcc,sipw1[1,],sipw2[1,],aipw1[1,],aipw2[1,])-b0,3)

 #round(cbind(smle,scc,sipw1[2,],sipw2[2,],aipw1[2,],aipw2[2,]),3)

 #cps

 #

 c(as.vector(rbind(bhat,sder,cps)),mean(d),mean(s),sum(s),sum(d[s==1]))

 #

}

#

#

#%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

#

#

#%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%