University of Zagreb

Faculty of Graphic Arts

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TWIN DYES FOR SECURITY PRINTING IN INFRARED MAPPING

DOCTORAL DISSERTATION

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Supervisor(s):
Vilko Žiljak, PhD, emeritus professor
Zvonimir Sabati, PhD, assistant professor

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Sveučilište u Zagrebu

Grafički fakultet

Maja Matas

BLIZANCI BOJILA ZA SIGURNOSNI TISAK U INFRACRVENOJ KARTOGRAFIJI

DOKTORSKI RAD

Mentor(i):
Prof.dr.sc. Vilko Žiljak
Doc.dr.sc. Zvonimir Sabati

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Povjerenstvo za ocjenu doktorskoga rada:

1. prof. dr. sc. Klaudio Pap, Sveučilište u Zagrebu Grafički fakultet, predsjednik
2. prof. dr. sc. Anayath Rajendrakumar, The Techological Institute of Textile & Sciences Birla Colony, Bhiwani, Haryana State-127021, India, vanjski član
3. izv. prof. dr. sc. Damir Modrić, Sveučilište u Zagrebu Grafički fakultet, član

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3. izv. prof. dr. sc. Damir Modrić, Sveučilište u Zagrebu Grafički fakultet, član
4. prof. dr. sc. Marin Milković, Sveučilište Sjever, Koprivnica, zamjenski vanjski član
5. prof. dr. sc. Nikola Mrvac, Sveučilište u Zagrebu Grafički fakultet, zamjenski član

Mentori:

1. emeritus prof. dr. sc. Vilko Žiljak, Sveučilište u Zagrebu Grafički fakultet
2. doc. dr. sc. Zvonimir Sabati, Sveučilište u Zagrebu Fakultet organizacije i informatike

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„Obranila s ocjenom summa cum laude (s najvećom pohvalom) jednoglasnom odlukom Povjerenstva“

Information on mentors

Vilko Žiljak, PhD, emeritus professor at the University of Zagreb Faculty of Graphic Arts, Zagreb, Croatia. Born in 1946 in Sveti Ivan Zelina, from 1959 he lives in Zagreb. He graduated in experimental physics and became a PhD at the Faculty of Electrical Engineering in 1981. He researched, developed and applied computer graphic techniques in the wider field of science. His biography lists 510 titles and over a hundred published scientific papers. He has produced several textbooks and has organized 18 new subjects for undergraduate and 12 courses in postgraduate studies and is the co-founder of 3 new studies.

Zvonimir Sabati, PhD, assistant professor at University of Zagreb Faculty of Organization and Informatics in Varaždin, Croatia. Born on January 25, 1957 in Varaždin. Graduated from the Faculty of Electrical Engineering in Zagreb. He has been elected on several occasions for a member of the Croatian Parliament.

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Abstract

The aim of this research is an extension of the printing technology with the purpose of concealing security graphics within documents and securities. A new way of making twin dyes is developed which allows targeted setting of double information for the visual and infrared spectrum. The dissertation brings new security solutions for multicolor prints by introducing twin dyes to test digital printing and offset printing of large editions. New standards for print models created through the development of duality printing reproduction of visual and infrared spectrum with spot dyes and their simulation with process dyes are set. Two sets of twin dyes have the same color tone and identical L*a*b* (lightness color-opponent dimensions / brightness, chromaticity coordinates) values, but are made from different recipes. Defined are twin dyes through process dyes CMYK (cyan, magenta, yellow, key) for the visual and infrared spectrum, minimizing ΔE (numerical value of the difference of color tones) for the digital and offset print. Infrared features are set for dyes for authentication and the possibility of marking graphic elements in extended visual space. The method of mixing twin spot dyes with process offset ink is presented, for printing large editions. For digital test printing experimental methods are defined with twin dyes at X_0 and X_{25} through the $CMYKIR^{DT}$ (CMYK infrared / digital printing) separation, for the set L*a*b* values for each color tone and the default ΔE value of the digital print. Graphics using the newly created scale of twin dyes are designed. The reproductions carry two pieces of information, one visible to the naked eye, and the other with ZRGB cameras at 1000nm. The desired target level of participation of the Z security infrared components of twin dyes is set. In this paper, standardization of the process of graphic reproduction of protected documents in the infrared region is determinated. The method of the design of graphic products with the introduction of security printing through infrared twin dyes is extended. It has been shown that the use of dyes in multicolor twin spot printing and experimental digital printing can prove the validity of the document and ensure authors' rights. The process of developing and applying twin dyes sets protection through all phases of prepress, print and further usage is presented.

Keywords:
twin dyes, infrared design, security print, hiding, spot dyes, digital print

Prošireni sažetak

Cilj ovog istraživanja je proširenje tiskarske tehnologije u svrhu skrivanja sigurnosnih grafičkih elemenata unutar vrijednosnica. Inovacija je nastala iz potrebe za novim metodama zaštite protiv krivotvorenja.

Prostor boja je u radu ograđen na 400 - 700nm za V (vizualni) spektar a za Z (bliski infracrveni) između 750 - 1000nm. Za sve boje vode se numeričke vrijednosti RGB (red blue green; crvena zelena plava) i L*a*b* (lightness color-opponent dimensions / svjetlina, koordinate kromatičnosti). Tisak planova i karata se odvija u većem broju boja koje su pripremljene kao spot bojila. Veliki dio reprodukcija se izvodi sa procesnim CMYK bojilima (cyan, magenta, yellow, key / cijan, magenta, žuta, crna). Boje se realiziraju sa procesnim bojama za probni digitalni tisak i spot bojilima za ofsetni tisak velikih naklada. Sastav bojila pokazuje apsorpciju svjetlosti valnih duljina u vizualnom i infracrvenom spektru ovisno o sastavu bojila.

Rad je posvećen sigurnosnom tisku kroz zaštitna bojila za tiskovine koje imaju specifičnu grafičku pripremu u slojevima. Postojeći tijek grafičke pripreme kartografskih dokumenata koristi 15 boja za prikaz različitih grafičkih elemenata, a čije su vizualne vrijednosti zadane standardom tiska: crna, dvije nijanse sive, dvije nijanse plave, dvije nijanse smeđe, četiri nijanse zelene, dvije nijanse žute, narančasta i crvena. Uređivanje grafičkih oblika odvija se za svaku boju u njenom zasebnom sloju, sa zasebnom oznakom. Smeđe boje koje označuju visine terena čine čisti zapis u zasebnom sloju, i ne miješaju se sa plavim bojama koje označuju vode. Svi slojevi boja u pripremi su crno bijeli. Informacija o boji dolazi tek nakon spajanja svih slojeva u jedinstven dokument. Spajanjem svih slojeva različitih boja tek nakon tiska postaje vidljivo da su jedna informacija o visinama a druga o vodama jedna preko druge. Sloj crne boje je jedini koji uvjetuje redoslijed spajanja slojeva zbog ne transparentnosti. Uređivanje se čini samo unutar jednog, određenog sloja. U radu se koristi analiza postojećeg tijeka grafičke pripreme kartografskih dokumenata koja je pokazala da dosadašnjom metodom višebojnog tiska vlasnik originala ostaje oštećen, a informacije ostaju podložne neautoriziranim preinakama. Zbog toga se višebojna priprema tiska izvodi za vizualno aktualno stanje s proširenjem infracrvene zaštite.

Doktorski rad donosi nova rješenja sigurnosnog višebojnog tiska uvođenjem blizanaca bojila (jednak ton boje izrađen u dva bojila koja vizualno izgledaju jednako, a u bliskom infracrvenom području imaju različit odaziv) za probni digitalni tisak i ofsetni tisak velikih naklada. Novost su standardi za modele tiska nastalih kroz razvoj dvojnosti tiskarske reprodukcije za vizualni i infracrveni spektar sa spot bojilima i njihovoj simulaciji sa procesnim bojilima.

U prvom dijelu rada napravljen je presjek uporabe infracrvene tehnologije u svrhu zaštite vrijednosnica. Oblikovanje unutar infracrvenog spektra prikazano je u primjeni u tisku na: odjevne predmete, uniforme, ambalažu. Na primjeru poštanske marke koje su malih dimenzija a moraju sadržavati velik broj informacija., prikazan je proces separacije RGB fotografije i kreiranje dvostruke slike unutar fotografije crkve koja je motiv na poštanskoj marki. Kroz IRD (INFRAREDESIGN®) prostor za informacije se proširuje i na bliski infracrveni spektar. Prikazana je konvencionalna separacija fotografije koristeći GCR (Gray Component Replacement) metodu separacije. Postavljanje ulazne fotografije unutar K kanala odvijalo se u novoj CMYKIR (cyan, magenta, yellow, key, infrared / cijan, magenta, žuta, crna, infracrvena) separaciji upravljanja bojilima u dva spektra. Svakom tonu boje pridružen je kontinuirani prostor zamjene CMY i K poštujući RGB postavke. Kontinuirani prostor zamjene omogućio je separaciju s informacijama koje donosi vanjska slika. U K kanal postavljen je planirano portret koautora znanstvenog rada. Spajaju se dvije informacije, kao dvije nezavisne slike stvorene algoritmom računalne grafike. Skriven portret postaje vidljiv tek promatranjem u infracrvenom spektru. Široki spektar primjene na različite grafičke proizvode imala je za cilj zaštitu izvornosti djela, osiguravanju kvalitete, zaštiti informacija na dokumentima i zaštiti autorskih prava.

U radu je sadržan pregled razvoja umjetnosti i dizajna unutar infracrvenog područja.
U umjetnosti je kroz manipulaciju u dva spektra postignut novi doživljaj promatranja umjetničkog djela kroz aktivno sudjelovanje u umjetnika u dualnom oblikovanju. Radovi unutar InfraredArt-a (infracrvene umjetnosti) bave se propitivanjem pigmenata u odnosu na njihovu Z vrijednost. Dvije slike imaju suprotan način čitanja , koloritnu sliku promatranu golim okom, i tehnološki promatranu crno bijelu. U dualnoj slici jedna se čita kao koloristička, dok je druga crno bijela skrivena. Prošireni prostor određen je dvjema razinama promatranja.

Današnja tehnologija zahtjeva nove tehnike sakrivanja koje mogu pratiti promjene u digitalnom svijetu. Različite metode steganografije, discipline sakrivanja informacija unutar određenog medija, razvijaju se u svrhu sigurnosti podataka i zaštite od neovlaštenih preinaka. U tisku se proširenjem informacija u bliski infracrveni spektar koristi svojstvo materije i bojila u svrhu zaštite. Otvara se mogućnost umetanja sadržaja koji nije vidljiv golim okom. Steganografija se kroz IRD proširuje na spektar od 400 do 1000nm u tiskarskim procesima.

U kartografskim dokumentima, sve se informacije pohranjuju digitalno. Karte sadržavaju važne prostorne informacije. Moderne metode skeniranja i digitalnog tiska omogućavaju stvaranje krivotvorina, koje otežavaju razlikovanje krivotvorenog od originalnog dokumenta sa ispravnim informacijama. Lako uređivanje digitalno pohranjenih dokumenata otvara potrebu za zaštitom dokumenta. Manipulacija otisnutih informacija je jednostavna, a nije postojala do sada mogućnost provjere autentičnosti reprodukcija. Metoda izrade karata ne pruža kvalitetne mogućnosti utvrđivanja i dokazivanja autorstva kojim bi se potvrdila izvornost prikazanih informacija.

Prikazani su zadani profili boja za tisak sa motivima planova i karata koji imaju specifičnu grafičku pripremu u slojevima. Zaključeno je da određivanje profila boja samo u jednom prostoru, u ovom slučaju RGB, nedovoljno definira ton boje koji za sve reprodukcije i tiskarske strojeve treba imati jednak vizualni standard. RGB prostor boje označava trenutni doživljaj boje na računalnom zaslonu sa njegovim postavkama i kalibracijom. To otvara prostor stvaranja sustava koji precizno definira tonove boja za vrijednosnice, te koji će dati jednaka rješenja na svim reprodukcijama. Boje osim što nisu ispravno definirane, nemaju kontroliranu vidljivost u infracrvenom spektru unutar kojeg se može uspješno postaviti zaštita.

Uočena je potreba za propitivanjem sigurnosnog obilježavanja u grafičkoj pripremi i tisku dokumenata kartografskog sadržaja. Provedena je anketa u svrhu utvrđivanja znanja, potrebe i važnosti zaštite izvornosti grafika koje se izvode procesom izrade planova i karata, a u sadašnjem stanju imaju potrebu za proširenjem metode sigurnosti. Anketiranje je provedeno na izdavačima, korisnicima karata i planova i dizajnerima. Njihov doprinos vrednovan je kroz odgovore na anketni upitnik koji postavlja pitanja o sigurnosti i ispravnosti informacija na grafičkom otisku, kvaliteti zapisa, načinima uporabe dokumenata i korištenja tiskanih informacija. Postavljena su glavna poglavlja za pitanja koja se odnose na sigurnost dokumenata i krivotvorenje dizajnerskih proizvoda.

Anketa je omogućila postavljanje novih zahtjeva za zaštitu svih vrsta tiskovina. Provedeno istraživanje dokazalo je važnost uvođenja novog sigurnosnog sistema koji štiti dokumente, karte i planove i dizajnerske proizvode kroz sve faze izrade. Kroz razgovor sa javnim bilježnicima otkriven je čest problem pri otkrivanju identiteta osoba osobito kada fotografija na osobnom dokumentu ne sliči osobi koja stoji pred javnim bilježnikom. Provedeno istraživanje dokazalo je važnost uvođenja novog sigurnosnog sistema koji štiti dokumente, karte i planove i dizajnerske proizvode kroz sve faze izrade. Kroz razgovor sa javnim bilježnicima otkriven je čest problem pri otkrivanju identiteta osoba osobito kada fotografija na osobnom dokumentu ne sliči osobi koja stoji pred javnim bilježnikom.

Znanstveni doprinos ovog istraživanja odnosi se na postavljanje metodologije izrade zaštitnih bojila blizanaca sa odazivom u vizualnom i infracrvenom spektru. U eksperimentalnom radu daju se recepture za blizance bojila za ofsetna bojila i procesna bojila digitalnog tiska te se unaprjeđuje metoda sigurnosnog tiska. Faze eksperimentalnog rada dijele na:

- Ručno miješanje spot bojila blizanaca za ofsetni tisak
- Mjerenje Z udjela i odaziva u vizualnom i infracrvenom spektru
- Proračun i mjerenje odstupanja u tonovima blizanaca bojila ΔE
- Miješanje bojila blizanaca kroz $CMYKIR^{DT}$ (CMYK infrared / digitalni tisak) separaciju za digitalni tisak
- Mjerenje Z udjela bojila
- Testiranje otisaka na različitim podlogama
- Proračun i mjerenje odstupanja u tonovima blizanaca bojila ΔE
- Planiranje i dizajn grafičkih elemenata za sakrivanje
- Apliciranje i izrada tiskovina sa dvostrukim vizualnim stanjem

Razvijen je novi način izrade višerazinskih blizanaca bojila koja dozvoljava ciljano postavljanje dvostrukih informacija za vizualni i infracrveni spektar. Dvije grupe blizanaca bojila istih su tonova boje i jednake L*a*b* vrijednosti, a iz različitih receptura. Blizanci su ugođeni na prostor boja od 400 do 700nm. Različitom materijom je postignut i različit odaziv u vizualnom i bliskom infracrvenom spektru.

U prvom dijelu eksperimenta ručno su miješani tonovi V i Z bojila blizanaca željenih tonova boja. Procesnim ofsetnim bojilima je prikazan princip miješanja spot bojila blizanaca za tisak velik naklada. Bojilima je postavljeno infracrveno svojstvo za utvrđivanje autentičnosti i mogućnosti obilježavanja grafičkih elemenata u proširenom vizualnom prostor.

Nakon utvrđivanja principa izrade ručnog miješanja tonova V i Z bojila ciljano su miješani željeni tonovi boja i postavljene recepture za nove parove blizanaca bojila. Kolorimetrijskim mjerenjem za recepture C, M, Y, K ofsetnih procesnih bojila izmjerene u vizualne L*a*b* vrijednosti boja nanošenih na papir. Testirane su recepture snimljene IR kamerom a na prikazima je dokazana podjela apsorpcije svjetlosti V i Z blizanaca bojila. Otisak izložen valnoj duljini od 1000 nm pokazuje uspješnost eksperimenta gdje V par blizanaca bojila nema odaziv.

Barijerno skeniranje pokazalo je odsutnost pojedinih dijelova vizualnog spektra kod bojila. Prvi barijerni rez napravljen je blokiranjem žute komponente na 570 nm. Drugi rez na 695 nm blokira magenta boju. Treći barijerni rez je na granici vizualnog spektra na 715 nm za cijan. Posljednje skeniranje izvedeno je na 850 nm u bliskom infracrvenom spektru. Na 850 nm žuta, magenta i cijan potpuno reflektiraju infracrveno svjetlo a apsorpcija se odvija isključivo na crnom K bojilu. U posljednjem barijernom rezu ostaje samo apsorpcija svjetla na 1000 nm. Barijernim skeniranjem utvrđene su razlike u apsorpciji svjetla između V i Z otiska blizanca bojila. Prikazani su otisci 7 izabranih parova blizanaca bojila od kojih samo Z parovi blizanaca bojila ostaju vidljivi iznad 1000 nm što dokazuje uspješnost receptura. Barijerno skeniranje je provedeno u svrhu kontrole planirane apsorpcije svjetla u vizualnom i infracrvenom spektru. Na taj način se provjerava oduzimanje svake od komponenata procesnih bojila u tisku. Nakon što se izdvoje žuta, magenta i cijan, u posljednjem skenu ostaje samo infracrvena apsorpcija svjetla na 850 nm. Na otiscima uočavamo da apsorpcija infracrvenog svjetla ostaje samo na bojilu Z blizanca koje u sebi sadrži K.

Za kontroliranje odstupanja u tonovima blizanaca bojila izračunate su numeričke vrijednosti izjednačavanja doživljaja tona boje ΔE (numerička vrijednost razlike u tonu boje). U ovom radu uvaženi su samo tonovi boja koji imaju izmjerenu razliku ΔE <6 jer su u ofsetnom tisku dopuštene veće tolerancije razlike u tonovima boja originala i reprodukcije. Ručno miješanje spot bojila ima puno manju preciznost od izrade procesnih bojila za digitalni tisak stoga se uvažava ΔE <6 kao dobra vrijednost pri izjednačavanju blizanaca bojila. Prikazano je sedam parova blizanaca sivih, zelenih, smeđih i crvenkastih tonova. Zaključak je da je nakon kolorimetrijskih izmjera moguće učiniti precizne promjene receptura za izradu bojila blizanaca sa manjim vizualnim odstupanjima u tonovima boja.

Drugi dio eksperimenta se odnosi na probni digitalni tisak. Za probni tisak eksperimentalnim metodama definirani su blizanci bojila X_0 i X_{25} kroz separaciju $CMYKIR^{DT}$ za zadanu L*a*b vrijednost za svaki ton boje i zadanu ΔE vrijednost digitalnog tiska. Među kreiranim parovima blizanaca V blizanac bojilo ima vrijednost Z=0, a Z blizanac bojilo ima vrijednost Z=25%.

U digitalnom tisku otisnuti su uzorci parova boja različitih profila. Grafički programi imaju definirane opcije postavka boja, no u izradi novih profila bojila blizanaca isključen je zadani color management. Upravljanje bojama je definiran vlastitim postavkama prostora boja. U sljedećem eksperimentu su provedena mjerenja i optimiziranje jednakosti parova bojila blizanca za zadane tonova boje. Svrha eksperimenta je postizanje dva tona boje koji vizualno izgledaju što sličnije, a imaju različitu apsorpciju svjetlosti u infracrvenom spektru. Postavljeni su recepti za parove bojila sa jednakim vizualnim doživljajem, a drugačijim odazivom u infracrvenom spektru. Za sve tonove boja vode se numeričke vrijednosti CMYK i L*a*b*.

Eksperiment u kojem se na otisnutim uzorcima blizanaca bojila mjere parovi služi kako bi se utvrdio stupanj podudaranja u vizualnom tonu. U tu svrhu korišten je spektrofotometar X-Rite SpectroEye u svrhu mjerenja ΔE parametara. Mjerene su vrijednosti boja sa točnošću od najmanje tri mjerenja za svaki referenti ton. Rezultati mjerenja utvrdili su odstupanje ΔE.

Rasterski sustav je postavljen na 25% pokrivenosti. Dobivene relacije se ne koriste za pokrivenost iznad 25%. Opsežni eksperimenti mjerenja u bliskom infracrvenom spektru su pokazali da je sakrivena slika dovoljno prepoznatljiva kao zadana grafika sa 25% vrijednosti Z. Zbog toga, vrijednost pokrivenosti grafike Z se kontinuirano smanjuju na maksimalno zacrnjenje od 25% prije početka CMYKIR separacije. Tamnije i svjetlije površine su dobivene kao stanje između X_0 i X_{25}.

Digitalno određivanje tonova blizanaca bojila ima veći stupanj preciznosti i mogućnosti lakših i bržih iteracija od ručnog miješanja spot bojila. U svrhu provjere profila boja i njihove prihvatljivosti za skrivanje Z slike, rađeno je instrumentalno mjerenje njihovih razlika u tonu boje. Odstupanja u tonovima postavljeni ΔE numeričkom vrijednosti manja su kod blizanaca bojila digitalnog tiska. Dobivene ΔE vrijednosti variraju za isti ton boje ako je tiskan drugačijim tiskarskim strojem ili na drugačijem papiru. Vrijednosti variraju i za isti ton boje tiskan na drugim pozicijama. To dokazuje neravnomjerni nanosa bojila u procesu tiska i ne savršenost tiskarskog stroja.

Spektrogram Projectina Docubox precizno opisuje kako postići najbolje rezultati pri izjednačavanju vrijednosti dvaju bojila. Svojstva apsorpcije svjetla miješanih V i Z bojila blizanaca za ofsetni i digitalni tisak prikazana su spektralnom analizom. Novi tonovi boja sa vrijednošću čija vrijednost iznosi $\Delta E < 3$ služe za projektiranje i izradu dvostrukih zaštitnih grafika u digitalnom tisku. Digitalno određivanje tonova blizanaca bojila ima veći stupanj preciznosti i mogućnosti bržih iteracija od ručnog miješanja bojila blizanaca. Ručno miješanje spot bojila ima puno manju preciznost od izrade procesnih bojila za digitalni tisak stoga se prihvaća vrijednost $\Delta E < 6$ kao za izjednačavanje tonova dvaju blizanaca bojila. Za svaku tehniku tiska izrađuju se novi parovi bojila blizanaca. U radu su definirani blizanci boja preko procesnih bojila CMYK za vizualni i infracrveni spektar, uz minimalizaciju ΔE za probni digitalni tisak i ofsetni tisak velikih naklada.

Nakon definiranja metode izrade bojila blizanaca infracrvene kartografije, projektirana je grafika pomoću novo stvorene skale blizanaca bojila. Reprodukcije u sebi nose dvije informacije, jednu vidljivom golim okom, a drugu ZRGB (IR kamera) kamerama na 1000 nm.

U radu su karte preinačene u svrhu eksperimenta. Originalan dokument sadrži bijele površine koje ne sadrže informacije u boji te u njih nije moguće dodati skrivena grafička obilježja. Eksperimentalno su na originalnom dokumentu karte izvedene tri različite razine podizanja boja bijelih površina, a ujedno i svih ostalih tonova boja u svrhu sakrivanja informacija. Ciljano je postavljena željena razina učešća sigurnosne infracrvene komponente za Z (infracrveni udio) blizance bojila na 20%, 30% i 40%. Povećanjem tamnoće tonova gubi se čistoća svjetlijih tonova boja. Potamnjenje ujedno djeluje i na jasnoću i intenzitet IR prikaza koji se otkriva NIR kamerom. Na karti sa podizanjem tonova na 20% čistoća svjetlijih tonova boja nije znatno komprimirana, a otvorena je mogućnost skrivanja IR slike i na svjetlije tonove. Granica vidljivosti skrivenih informacija testirana je u tri razine, postavljajući različite skrivene tekstove za karte na 20%, 30% i 40% podizanja tonova. Dvostruke slike izrađene su za SWOP (Specifications for Web Offset Publications) postavke boja.

Dizajner je nositelj zadatka koji ima mogućnost oblikovanja vizualnih informacija koji zadovoljavaju zadane zahtjeve i u skrivenoj razini dati svoj doprinos. Novi zadatak u dizajnu dvostrukih grafika je postavljen kao sakrivanje tipografija unutar vidljive slike koja ima dovoljnu čitljivost u IR spektru. Infracrvena obilježja stvaraju informacijski sustav unutar proširene stvarnosti. Informacije se označavaju, ističu i sakrivaju unutar infracrvenog spektra, a vidljiva slika se čuva. Pojedini kanali dvostruke slike prikazuju oduzimanje i izostanak Z informacije iz K kanala kroz preostale C, M, Y kanale.

Oblikovanje dvostrukih slika stvara ovisnost motiva u vizualnom V spektru i u bliskom infracrvenom Z spektru. Kartografski motivi se kroz bojila blizance oblikuju u oba spektra, ovisno o željenom efektu i vrsti uporabe. Planovi i karte se koriste za obilježavanje puta i određivanje lokacija što dizajneru postavlja razloge zaštite kroz dva spektra. Infracrveni sigurnosni tisak područje je širokih primjena, a prikazani dizajn koristi mogućnosti planiranja kroz svojstva bojila blizanaca. Razlozi sakrivanja prikazani su u radu kroz nekoliko prijedloga: dizajn odjevnog predmeta i tisak na tekstilu, te integracija prirodno snimljenih fotografija i planova sa kartografskim motivima.

Dok karta u NIR spektru nestaje, tipografski se promatraju stihovi dječje pjesme Zeko i potočić. Ne samo što je pjesma sjećanje na djetinjstvo u Osijeku same dizajnerice dvostruke slike, već je i autor stihova iz Osijeka. Mogućnost višeslojne povezanosti informacija koje zajedno funkcioniraju ne narušavajući međusobno likovnost otvara novo područje za dizajnere.

Na sljedećem primjeru je prirodno snimljena fotografija vidljiva u V spektru a prostorni plan skriven u bliskom infracrvenom spektru. Nova metoda dozvoljava integraciju skrivene informacije o karti unutar naizgled bezazlenog i ugodnog vizuala koji sadržajno nije povezan sa kartom. Plan grada je skriven iza prirodno snimljene grafike, a otkriva ga uporaba IR kamere.

Bojila blizanci omogućavaju izradu IRD rješenja na različitim materijalima kao što je u radu dokazano na papiru i pamučnoj tkanini. Za svaki materijal potrebno je izraditi nove recepture blizanaca bojila sa pripadnim bojama. Tkanina se neće bojati sa bojilima za tisak na papiru, već će se raditi novi proračun. Kod sakrivanja teksta u dvostrukoj slici cilj je da je on jednolično izveden na cijelom području za infracrveni spektar. Zadatak jednoličnosti iziskuje da svi spektri završavaju u Z točki na jednakoj zadanoj pokrivenosti. U ovom radu to je Z=40%. Prvi stupanj individualizacije infrared grafike je određivanje Z vrijednosti za korištenje dualnih bojila. Predlaže se da se taj broj maksimalizira, određujući maksimum Z svakoj boji, za što jači infracrveni efekt. Takav pristup poželjan je posebno u ofsetnom tisku gdje se uvode parametri redoslijeda tiska bojila i transparentnosti boje. Crno bojilo ograničava slobodni redoslijed tiska kao jedino bojilo koje u pravilu nije transparentno. U digitalnom tisku su provedene transformacije boja u $CMYKIR^{DT}$ proces bojila. Spajanje dviju slika prikazan je kroz kartografsku grafiku koja pomoću malog broja boja mora označiti velik broj informacija.

U posljednjem dijelu disertacije provodi se diskusija o ulozi dizajnera i mogućnostima dizajna kroz sigurnosnu infracrvenu grafiku.

U radu je postavljena standardizacija procesa grafičke reprodukcije zaštićenih dokumenata u infracrvenom području. Proširena je metoda oblikovanja grafičkih proizvoda sa uvođenjem sigurnosnog infracrvenog tiska kroz blizance bojila. Dokazano je da se korištenjem bojila blizanaca u multicolor (višebojnom) spot tisku i pokusnom digitalnom tisku može dokazati ispravnost dokumenta i osigurati prava autora. Proces izrade i primjene bojila blizanaca postavlja zaštitu kroz sve faze grafičke pripreme, tiska i daljnjeg korištenja.

Ključne riječi:
bojila blizanci, infrared dizajn, sigurnosni tisak, sakrivanje, spot bojila, digitalni tisak

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1 INTRODUCTION

The content of the work describes the study of double images and planned hiding of visual information through the infrared spectrum and cartography-based graphics. Graphic products featuring spaceal plans require specific forms of prepress in layers. Special layers are placed for all colors while designing graphic elements that determine the position of an object in space, an action or intent. For all the colors exist numeric values RGB (red, green, blue) and L*a*b* (lightness color-opponent dimensions / brightness, chromaticity coordinates). Color is caused by the experience of different visual stimuli and the color space is defined in the light spectrum [1]. The RGB values are within the spectral range of 380-750nm [2]. In this dissertation, the color space which creates the sensation of color in our eyes, is limited to the range 400 – 700nm.

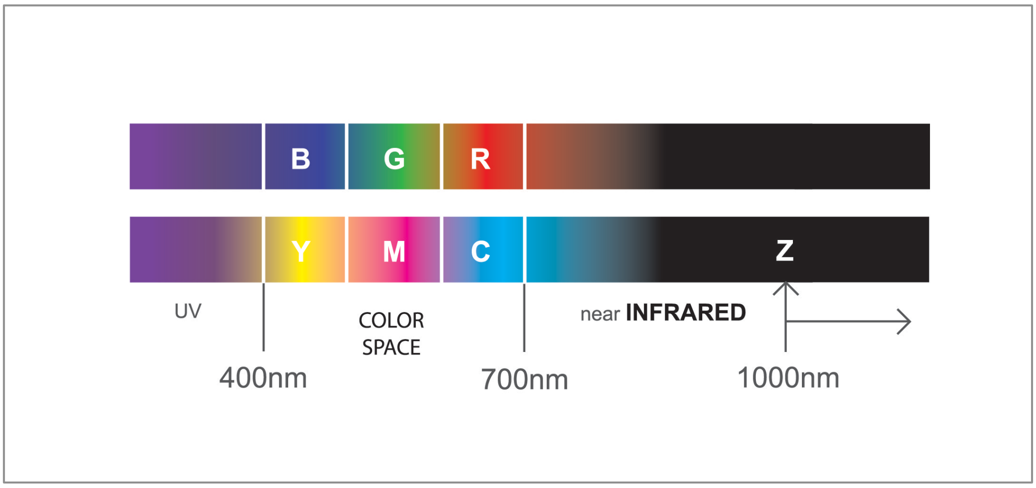


Figure 1. The visual range (V) of 400 to 700nm RGB and CMYK color space visible to the naked eye and near infrared (NIR) range from 750 to 1000nm not visible to the naked eye.

The mentioned colors are realized as colorants, paint matter for different printing techniques. In the printing industry, spot colors are used, with corresponding spot dyes. Visual dyes found within the color space at 400 - 700nm are called V (visual) dyes. Infrared dyes are called Z (infrared) and have a width extending beyond the visual part.

Infrared Z colors and dyes give response in both visual and infrared spectrums. V dyes have visibility only in the visual spectrum. The response in the Z spectrum is defined by measuring absorption of infrared light at 1000nm. Light absorbs in matter in the whole sun spectrum, while we see the reflection of all colors from 400 to 700nm. Instrumental measurement of each color possesses a specific curve of spectral reflection. Different printing colors have different properties in the area of infrared radiation. In this dissertation, the key is the near infrared spectrum (NIR) which is instrumentally measured and is positioned between 750 and 1000nm.

The printing of plans and maps is conventionally carried out in a number of colors that are prepared as spot colorants. Much of the reproduction is performed with process CMYK (cyan, magenta, yellow, key) dyes. The colors are produced with process colors for digital test printing and spot dyes for offset printing of large editions.

In the first section, several reviews of previous research are given on the topic of making protective dyes, protection of securities and copyright, art and design in the infrared region and the concept of steganography in prepress. A cross section of the developement of art and design within the infrared area is made. Color profiles and print featuring plans and maps which have a specific prepress in layers are explained. A survey on the quality of record, security and accuracy of maps and plans is conducted. This dissertation presents the method of creating twin dyes (pairs of dyes with the same V visual value, but different Z value) of spot dyes for the offset print. The twin dyes are set to the color space from 400 to 700nm. The properties of the light absorption of hand-mixed V and Z twin dyes are shown by spectral analysis. Sets of dyes of the same color tone, but in different composition, are presented. Different matter composition achieved different responses in the visual and near infrared spectrum. The experimental work is divided into process color for digital test printing and spot dyes print for large editions. The twin dyes are defined through the new $CMYKIR^{DT}$(CMYK infrared / digital press) infrared separation by maximizing the Z share and the optimization of the ΔE (numerical value of difference in color tones) between the V and Z dyes.

New color tones with a $\Delta E < 3$ value are used in designing double graphics on a variety of materials. For each material and each printing technique, new twin dye pairs are produced. The printing technology is expanded by setting standards for print models for double graphics. The fourth chapter discusses the role of designers and design possibilities through security graphics.

1.1 Overview of past Research

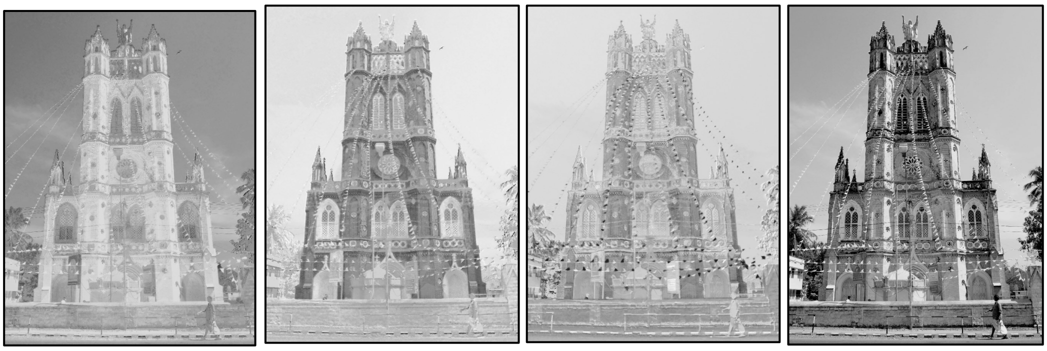
Designing security graphics has emerged as a necessity to protect securities that have experienced numerous changes and falsification in history. In search of a new security method, the protection of the dyes within the visual and infrared spectrum developed. Through infrared IRD (INFRAREDESIGN®) theory [3] the management is set of dyes within the near infrared spectrum (NIR) [4]. The IRD theory introduces an innovative solution of placing two graphics in the same place, one in the visual spectrum visible to the naked eye, and the other in the near infrared spectrum. The detection of graphics hidden in the IR spectrum was enabled with the development of an apparatus called the ZRGB camera [5]. Standard security cameras and cameras with night vision (used at night) setting are also characteristic for observation of the environment within the infrared spectrum, but the new ZRGB apparatus [6] allows the simultaneous detection of infrared and visual images, and serves as a tool in detecting hidden information and determining the originality of a document. The prevalence of infrared cameras is grand because of their easy accessibility, therefore today they can be found in almost all public areas, and more and more private properties.

In this dissertation the IRD theory serves as a base, and through experimental work comes the expansion of the IRD theory. In 2009 a new concept of separation of transition from CMYK named CMYKIR (cyan magenta yellow key color infrared) [7] and [8] was introduced. The CMYK separation is based on current color settings. IRD relies on an algorithm that uses the transformation from RGB to CMYKIR. IRD algorithms respect the color settings to produce reproductions with a given combination of paper and CMYK dyes. The separation system is applicable to the standard printing technology [9]. A different approach to separation is intended for the set K value to enable the hiding of graphics within the reproduction before the separation of C, M, Y, so that it is detected only by observing in the infrared spectrum. In 2012, a new mathematical model of Z-regression [10] as a special form of the CMYKIR separation was set. More precise placement of dual hidden image is enabled by setting the desired value of the K channel prior to the separation.

Application of the IRD theory found a broad used in the printing technology: in the press on textile [11], [12], in newspaper press [13] and print on leather [14]. Since 2013, the applications have expanded to print of postage stamps [15]. In the example on a post stamp design [16] is shown the process of separating RGB images and creating a double image within the image of a church as a motive on a small postage stamp. Post stamps are in small dimensions, but contain a lot of information. Through the IRD space, the information expand also to the NIR spectrum.

R G B

Figure 2. A photograph of a church in India – a motive of the postage stamp, RGB separation



C M Y K

Figure 3. A photograph of the same church in India – a motive of the postage stamp, GCR (Grey Component Replacement) separation

C M Y K

Figure 4. A photograph of a church in India – a motive of the postage stamp, CMYKIR separation with a set double image

The postage stamp contains a photograph of a church in Kerala, India. The conventional separation of photograph by using the GCR (Gray Component Replacement) method of separation is shown. The placement of the entry photography within the K channel took place in the new CMYKIR separation of managing dyes in two spectrums.

Each color tone is associated with a continuous color space of replacement for C, M, Y and K respecting the RGB settings. The continuous replacement of space has enabled the separation of information which the outside photograph brings. In the K channel, the planned portrait of the coauthor of the scientific paper is placed. Two photographs as two independent images created with the algorithm of computer graphics are connected. The hidden portrait is only shown by vieweing in the infrared spectrum.

V image Z image

Figure 5. Postage stamp motive – a photograph of the church viewed with the naked eye (V) and viewed with a IR camera (Z) at 1000nm

The application of IRD theory broadens after post stamps to transparent polymeric materials [17], packaging of pharmaceutical drugs and textile for camouflage uniforms [18]. The wide range of applications to different graphical products with an aim of protecting the originality of works, assuring quality, protecting information on documents and copyright protection. Visual reality is expanded with space for additional graphical marking. Dual integrated information are placed in the printing prepress, prior to the press. All print media can be printed by conventional method, without increasing the costs in the press.

The concept of twin dyes (dyes with equal visual value L*a*b* / RGB, and different Z value) [19] was defined to extend the IR information technology in 2013. Twin dyes [20] are defined by the equality in the visual spectrum and diversity in the infrared spectrum. For the same color tone two dyes that visually look the same are made, but have a different response [21] in the infrared area. The visual V dye has a value of Z=0 and Z twin infrared dye has a Z value previously set on the target Z>0.

In 2013, at the conference in Toronto [22] were given recipes for twin dyes for color mixing process with SWOP (Specifications for Web Offset Publications) color values in the print of two photographies. They were printed and placed in the same place, but visible in different spectrums, one in visual, and the other in the infrared. In the presented research paper twin dyes were developed for achieving double photographies.

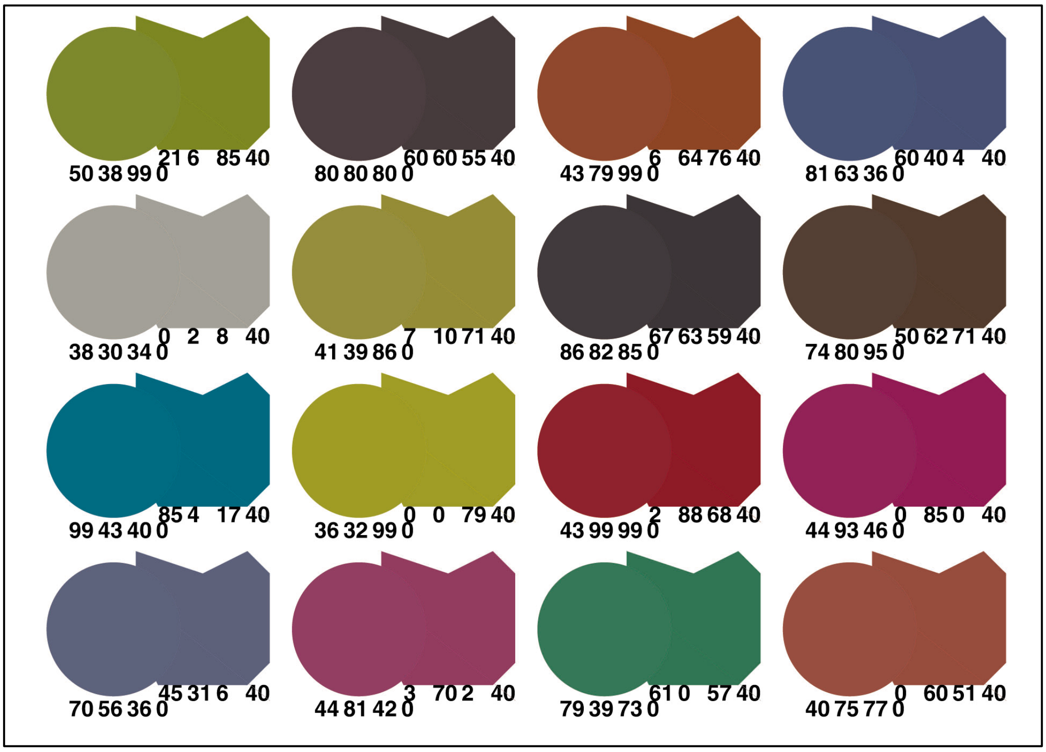


Figure 6. Twin dyes with the same visual experience but different NIR response X_0 and X_{40}

The use of advanced twin dyes for double portraits of the author is shown – a portrait visible to the naked eye and another portrait from the side which is hidden from the visual spectrum. The other portrait is detected in the IR spectrum with the usage of the ZRGB camera.

RGB portrait:Z portrait.:

Figure 7. Two entering photographs fot the CMYKIR separation

C M Y K

Figure 8. C, M, Y, K channels of the CMYKIR separation

CMYKIR separation was used to create double photographs. The hidden portrait is located in the K channel as an information for the NIR spectrum.

1.2 CMYKIR separation for connecting V and Z information

The transition from the RGB color system to the CMY dyes is defined through relations given in Table 1. The absorption of dye properties for creating the infrared response is used. Some of the dyes have a strong response to the Z value which is the basis of the development of the CMYKIR separation.

Table 1. Transition from RGB system to CMY

	Range 0 to 1	8 bit	4 bit	Percentage %
Cyan + Red =	1.0 vector graphic	0 – FF Pixel graphic	0 – F Pixel graphic	0 – 100 % Print CMYK
Magenta + Green =				
Yellow + Blue =				

Mathematical relations which enable the separation from "FSFog39" CMYKIR standard are given according to the dependance C40, M40, Y40 = f (C0, M0, Y0) for K=40%.

$$Z_{40}=A^{Fsfog39} * T \quad ; (1)$$

Z_{40}values of process dye coverage are set at 40% carbon black dye.

$$Z_{40}=\begin{bmatrix} C_{40} \\ M_{40} \\ Y_{40} \end{bmatrix} \quad ; (2)$$

Independent variables of CMYKIR separation are given in vector (3) and further relations (4):

$$T=\begin{bmatrix} G_M \\ E_Y \\ D_C \\ Y_0 \\ M_0 \\ C_0 \\ 1 \end{bmatrix} \; ; \; (3)$$

$$D_C=C_0/M_0 +C_0/Y_0$$
$$E_Y= Y_0/M_0 + Y_0/C_0 \quad ; (4)$$
$$G_M= M_0/C_0 + M_0/Y_0$$

Matrix $A^{Fsfog39}$ indicates the parameters of the linear regression at 40% coverage of black carbon offset dyes for special coated paper. For each combination of dyes and paper, this matrix is specific. For print on coated paper, the regression coefficient relations are as follows:

$$A^{Fsfo39} = \begin{bmatrix} 2.28053 & -0.78802 & -1.47864 & 0.12248 & -0.22929 & 1.63392 & -57.916 \\ -2.59669 & -4.83079 & -0.02830 & 0.08817 & 1.40283 & -0.35638 & -11.576 \\ -3.60028 & -4.85615 & 6.18267 & 1.63614 & 0.01668 & -0.3095 & -32.836 \end{bmatrix}; \quad (5)$$

Matrix A carries the value of linear regression which is calculated on the measurements of twin dyes in a wide range of CMYKIR separation and the merge of the two images. For the proposed relations and parameters (5) for connecting two images through the CMYKIR separation, input and output values of C, M, Y are given in percentages. These relations apply for concealed Z graphics rasterized with spiked raster [23]. In IRD graphics an individualized rasterization comprised of one-tone text is applied. The new raster element [24] is created through a software algorithm that controls the shape and opacity. The IR system of managing process dyes is based on the subtractive synthesis of the properties of the gray color. At the level of a raster field, microscopical observation is done on the marking in the NIR spectrum.

1.3 Steganography in graphic technology

The discipline of hiding information within a specified media is called steganography and it has been used since ancient Greece. The role of steganography is to unnoticeably convey a hidden message in a media in which you do not see that contains hidden information [25], [26]. The process by which the information was distorted is called cryptography and it differs from steganography because the process of steganography involves hiding the visibility of an existing information. While cryptography is changing information in a way that it becomes impossible to be seen by the observer for whom the information is not intended, steganography will make the information completely invisible. Many different steganographic methods have been developed using the characteristics of the media as holders of hidden elements. The information hidden by stego key is often an image or audio, which gives stego medium.

The size of the hidden message is restrained by the amount of bits (memory unit) of the image that are unused and unnecessary sound that can be replaced. Similar to the infrared design method, in steganography double information can be inserted within the media that does not interfere with the media's format. The use of steganography on image files [27] is called the LSB (least significant bit) that replaces the least significant bit of theimage with the bit's hidden messages. The process starts by selecting stego media and files which are hidden. The number of bits in the selected media must match the number of bits of a file that is hidden. After that, every least significant bit is replaced with secret information, until all bits are replaced [28].

Computer programs that hide and detect skriptographic digital information and are available on the market, are: Gifshuttle, Hide4PGP, MP3Stego, Stego, Digital Picture Envelope. The most common use in scriptography are digital watermarks in the images that are used to protect copyright and counterfeiting. Hiding images within the printing process refers to matter and properties of dyes. In the context of concealing the visual elements through infrared characteristics, the concept stegnography in the design and printing of postage stamps is used for the purpose of protecting them in a new way [27].

Today's technology requires new techniques of concealment that can monitor changes in the digital world. Different methods of steganography are being developed for the purpose of data security and protection from unauthorized modification. In the press, the expansion of information in the near infrared spectrum uses the property of matter and dyes in order to secure them. The possibility of inserting content that is not visible to the naked eye is opening. Steganography in the IRD expands the range of 400 to 1000nm in the printing processes.

1.4 **Art and design in the infrared spectrum**

The possibility of applying infrared design to art in the modern age was first questioned by the painter Nada Žiljak 2010 in her solo exhibition of V/Z IRD image. The challenge was to create a work of art using paint, whose response in the visual and infrared spectrum was known. That was a new experience of watching a work of art through the active participation of the artists in the shaping of the two spectra. It introduced the concept of InfraredArt (infrared art) [30]. Works within InfraredArt deal with questioning pigments relative to their Z value. The expanded space is determined by two levels of observation. This made the painting method more dependant on modern technology. Two levels of observation are divided into natural (naked eye) and technologically sophisticated (RGB camera). Through InfraredArt, easel painting takes on the nature of an installation. The static external image is complemented by a virtual hidden picture that must be observed using technological devices. The content of the dual image determines the artist through their mutual function. Creating art dual image used for the establishment of management mode with visible and invisible elements on the canvas using the knowledge of pigments and compositions of individual dyes.

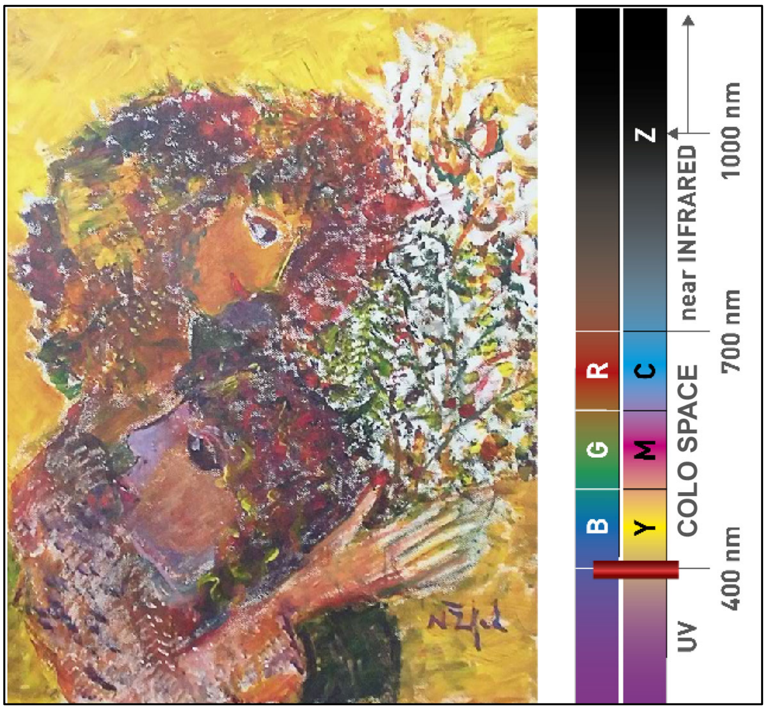


Figure 9. Painting of the artist Nada Žiljak showing dual image in the visual spectrum visible to the naked eye

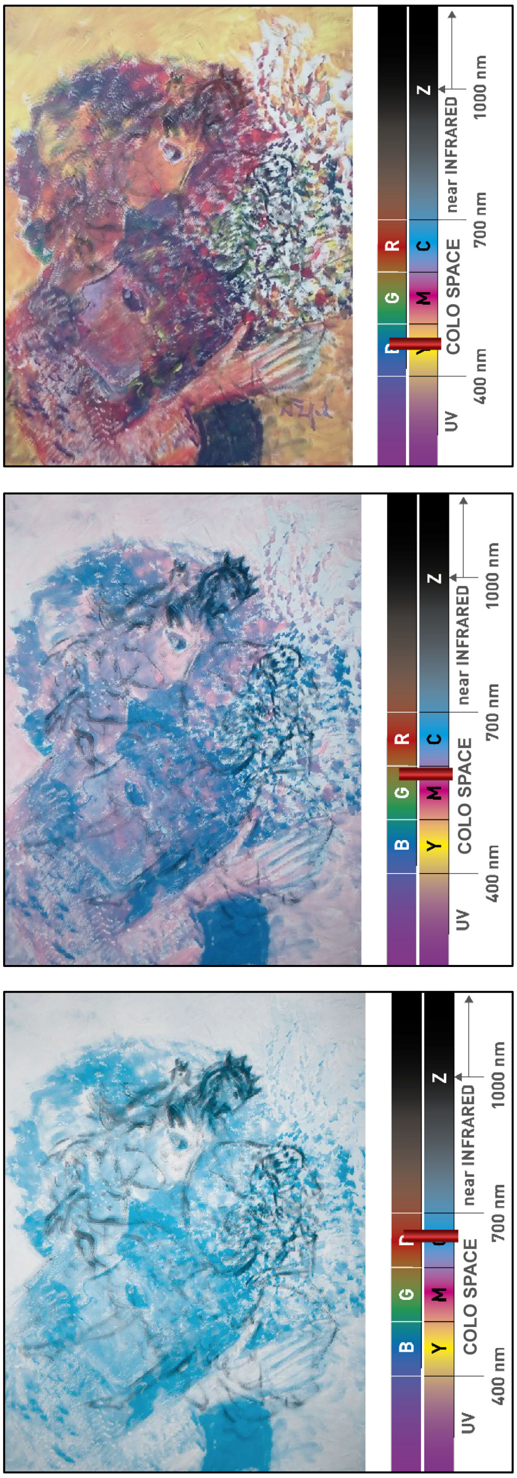


Figure 10. Painting of the artist Nada Žiljak with dual image throught spectrums from 400 to 700nm

Works of art have to be dated upon beeing viewed in the infrared spectrum in order to study the composition of dyes and for authentication. Observation is implied on the subject of questioning the reasons to conceal the image within the media which is intended. New

Dimension offers the artist the possibility of a new avant-garde expression in the spirit of concealment of motives that are socially acceptable, humorous and provocative remarks and expression of the interweaving of modern everyday life with virtual reality. Throughout history, many artists and scholars engaged in the study of invisible elements and information on works of art. Infrared technology has brought a number of innovations in the reproduction of works and the ability to study a part of the old masters [31]. Infrared imaging could be seen under the top paint coats, and so it was possible to discover the layers of paint before the final version and changes during the painting. The works are painted over each other, and both have the same dyes, therefore, in the past there was no controlled painting with dye twins.

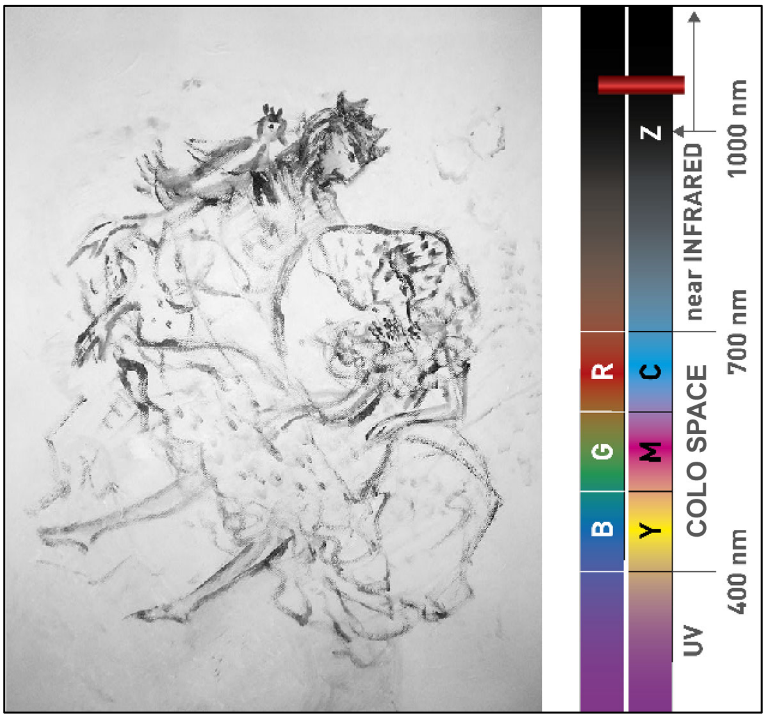


Figure 11. Painting of the artist Nada Žiljak with dual image shown in Near Infrared Spectrum at 1000nm

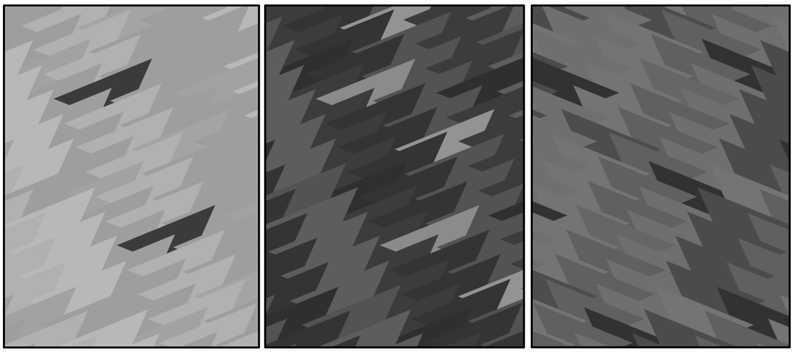
The creation of dual images established management of visible and not visible elements in the painting. An expanded view of the infrared camera becomes an integral part of the design and analysis of a work of art [32]. Recordings can perceive elements that describe the formation of an artistic work and its stages, which helps in understanding the artist. By no means a design within the infrared spectrum is being created deliberately. Artists now have a tool for painting double paintings as a new way of creating art works whose originality and authorship can be protected.

The link between art and technology is design as a combination of two disciplines. There is a clash between the designs and features of technical performance. Conceptual design and implementation solution is therefore often very different. Infrared design method offers the designer to be actively engaged in the new technology in order to develop the design solution. Together with technologists, designers can complete printing and optimize process execution solutions. The content of two graphics, V and Z, can be connected or disconnected. The two images are separated by dyes and are located in different spectrums or associated meaning. Design graphics and a selection of pictures depends on the possibilities of making use of the twins and dyes for desired color tones. The task for the designers is extensive - including knowledge of color theory and separation requirements and further education.

The concept of hiding within poster design is introduced. The question of why the double image is elaborated. The link between the two images - shown and hidden – is a new task for designers. Double infrared graphics allows designers to design a completely new dimension and creates added value in the interpretation of information. Posters are publicly visual information and an important part of the history of the development of graphic technology and graphic design. They are located in the public areas and are seen by many people. Therefore, they are interesting to design. They serve as advertising and for promotion of events, public figures, politicians. Posters usually contain visual information such as illustrations, photographs and typography.

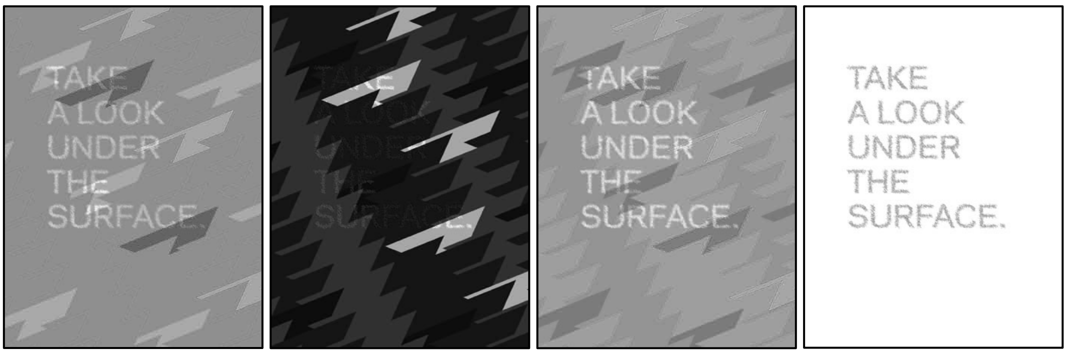
Designed posters show the potential of the new IRD technology. The first shows abstract forms that can be interpreted arbitrarily, ie, everyone sees in them a kind of a different meaning. In the infrared spectrum is the hidden basic message "Take a look under the surface" which suggests the viewer to look beyond the surface.

Figure 12. Dual poster1 observed in V (left) i Z spectrum (right)



R G B

Figure 13. Abstract graphic on poster and the RGB separation



C M Y K

Figure 14. CMYKIR separation with planned image in K channel

The next poster has photographed people and is partly covered with an abstract graphics which conveys the message "I am more than you see". Through IRD technology in an innovative way is presented content through the medium of the poster.

Figure 15. Dual poster2 observed in V (left) i Z spectrum (right)

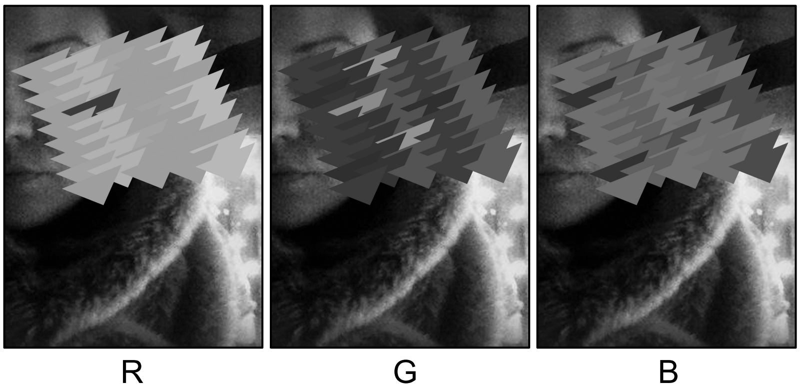


Figure 16. Portrait photography and graphics on poster and the RGB separation

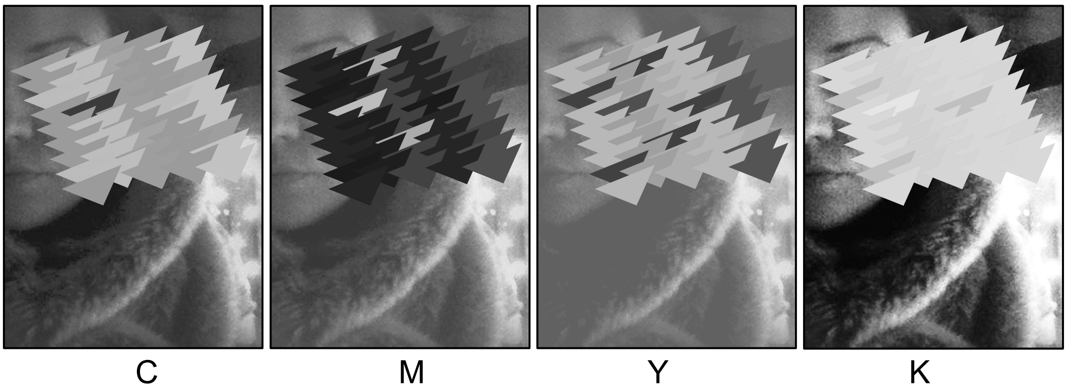


Figure 17. Poster in the conventional GCR method without hidden Z information

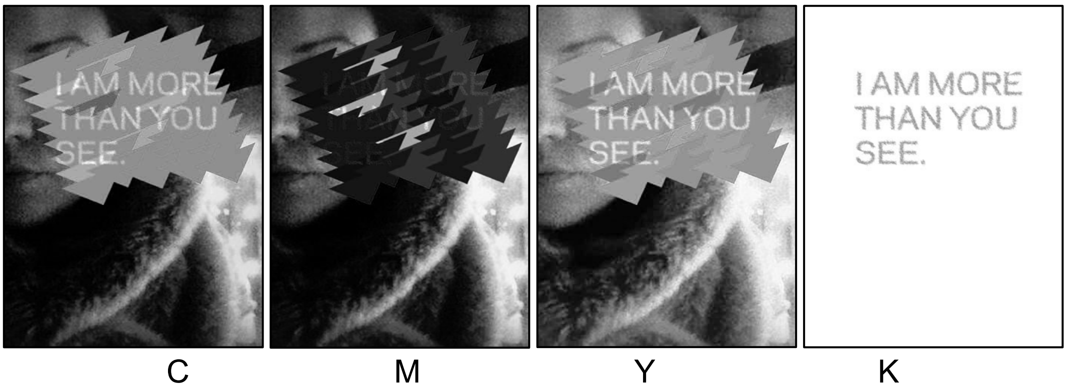


Figure 18. IRD CMYKIR separation with inserted hidden image inside the poster

The last poster is a photography of the scene of the war, also with abstract prints, and hides the message "There is more than they show" with the tag for currency dollar artificially in letters, which would further emphasize that thinks that events in the world have to do with money and power.

Figure 19. Dual poster3 observed in V (left) and Z spectrum (right)

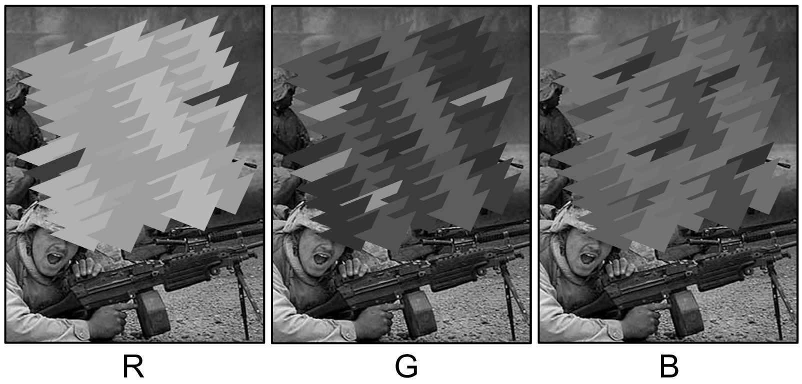


Figure 20. Scene photography and graphic on poster and the RGB separation

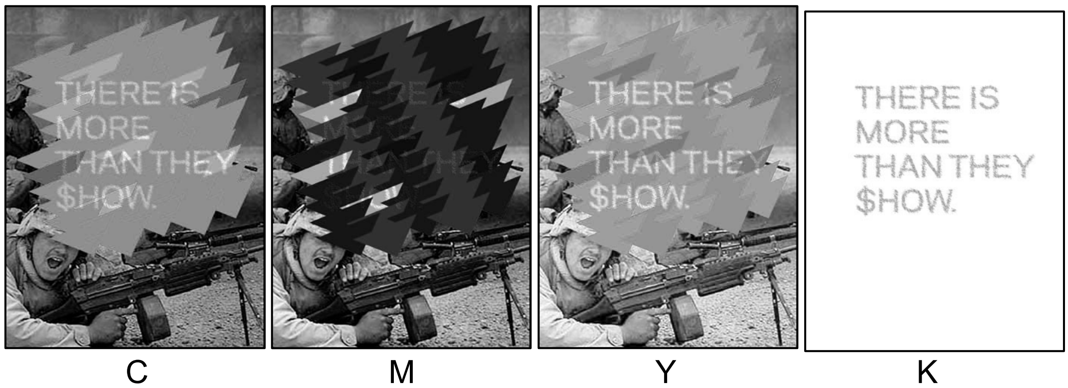


Figure 21. IRD CMYKIR separation with inserted hidden information

The designer controls and chooses the motives and print process. He plans the visual elements in two spectrums, shapes them in two spaces. Other hidden graphics will be detected only by using ZRGB apparatus and infrared cameras. The combination of black and white photographs and multicolor abstract shapes in the visual field hides written phrases in the NIR region.

Figure 22. Usage of infrared camera to detect Z double information to design posters

Previous work has opened the possibility of making identical solutions in test digital printing and offset printing of large editions. Before mass reproduction, it is important to achieve the test print the same results in the press with process colors and those which are mixed before printing. Development of the system of twin dyes for different types of security printing graphic products refers to the possibility of authentication and authenticity of documents and protection of the rights of authors. The aim is to take advantage of new technologies that handle, store and present information in a unique way. Images and text are linked to the content of the IRD technology in a variety of materials in the industry press. Although originating from the area of security printing, IRD innovation opens up new possibilities for the design based on a double image.

The design is a combination of art and technology, and one of the many roles of design is communication, whether it is the industrial, graphic or textile design. It can be direct, but also hidden or multilayer. The advantages of infrared technology in printing and making everyday objects are exploited. The conference Blaz Baromić 2016. [33] presented the innovative use of Infrared design on textiles in promotional - exhibition purposes.

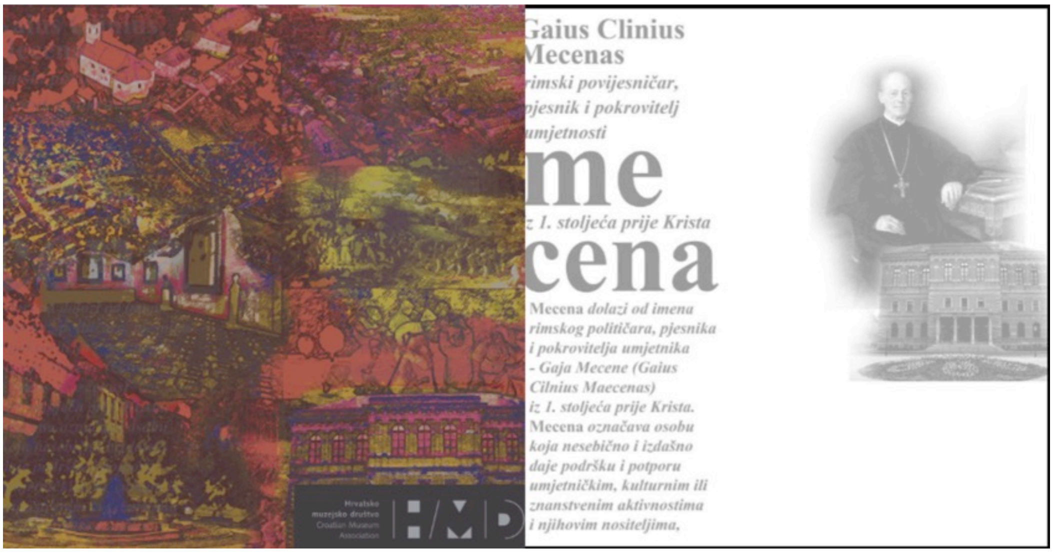


Figure 23. Dual graphic printed on textile in visual spectrum (left) and infrared (right)

Through infrared design print on cotton two images are associated by content. Relation between the two contents is set by the designer. The designs printed on cotton are related to the visual and infrared spectrum. Two pictures, V and Z, may have several mutual links. Something that connects them and something that divides them according to content without compromising visual quality of some graphics. Some letters or a part of an image may appear in the two states. Hiding parts of the picture is specific for visuality, especially in the infrared spectrum. Designer enters a new area, a new width, new design options. The design of the future has been extended to the skill of planning hidden information. Discussion of double imaging occurs in the technology and design sense.

The infrared information, hidden from the naked eye, was printed on cotton and silk with an inkjet printer. Hidding information, planned by designers, that are printed on clothing is a new task. The image is intended to be viewed with ZRGB cameras that recognize the area of the IR spectrum at 1000nm. The work presents the parameters of the regression model for the textile materials and inkjet printer obtained experimental procedure for determining dye twins. Optimized is the difference between the coverage of dyes K = 0 and K = 40%. Mathematical model was applied on the design of clothes. Double IRD files with hidden information are printed all over the whole surface of the material.

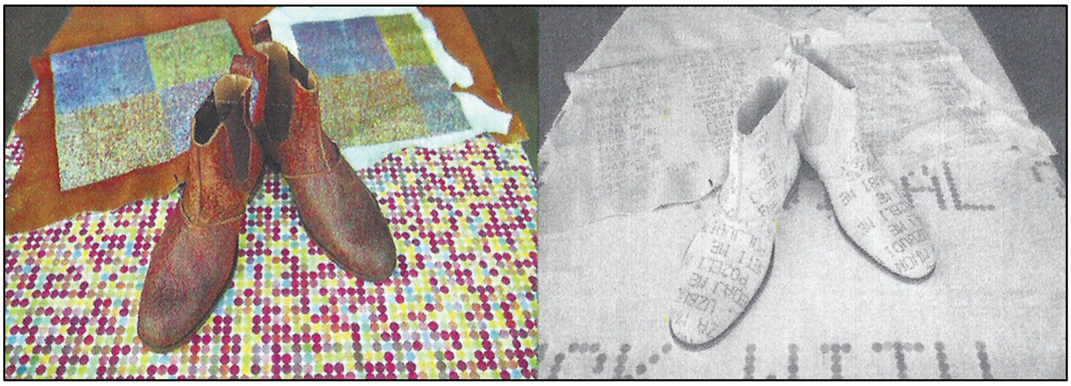


Figure 24. Dual images printed on leather observed in V and Z spectrum; reproduction of designs by Jana Žiljak Vujić, Ivana Žiljak Stanimirović, Kludio Pap, Vilko Žiljak

Figure 25. Dual images printed on leather and cotton, observed in V and Z spectrum; reproduction of designs by Jana Žiljak Vujić, Ivana Žiljak Stanimirović, Kludio Pap, Vilko Žiljak

1.5 Protection of cartographic documents and copyright

Graphic protection for documents appeared in the 19th century. The problem of counterfeit banknotes [35] lead to the development of security features of the securities. Security dyes, papers and several printing technologies are used to make the protection as complex as possible. With the development of printing technology, new methods of separation for better reproduction quality are developed [36], [37]. Security graphics [38], [39], [40] whose research has not been directed towards protecting the securities from the world of cartography, are designed. Mapping and production of topographic maps in the past was reserved for the military administration [41]. As the maps were a military secret, Croatian state administration and Croatian companies were able to order printed copies with reduced content or civilian maps. After the dissolution of the federal state, the only available were printed maps, because all the reproduction originals (films) were kept in Belgrade. To meet the needs of military operations in 1991 and 1992, many maps were copied, scanned and printed, but resulted in poor quality. Much better results were achieved in 1992 by the Ministry of Defence. They scanned all the map sheets, made some minor changes, raster files were divided into CMYK color palette, and were printed in offset procedure. The production of new maps, for civil purposes, started from existing maps by separating scanned maps from the colors used in the original printing.

In the cartographic documents, all information is stored digitally. The cards contain important spatial information. The accuracy of the information on the maps must be guaranteed. Maps are state documents for which the introduction of new protection through infrared technology is essential. Manipulation of printed information is simple, but the possibility of authentication of a reproduction was not possible [42]. Validation ensures the quality and accuracy of customer's map.

Maps and plans belong to the group of protected graphic products because the correctness of the presented information has to be guaranteed. They are state documents for which the introduction of protection in the infrared technology is new. Verification of originality ensures quality and accuracy for map users. Graphic industry creates security area in a new way. Today, more than ever, the progress in printing technology and publishing is expected. The new direction is security graphics that does not increase the price and process of printing.

Geographical information in the printing of maps for the first time was presented 2014 at a conference in Greece [43], a research of twin dyes whose visual values were given in standard press [44]. The separation of the black dye, which is standard in geographical documents, was completed. In the display of a city, the black dye which marks the constructed buildings and roads was separated in two visually identical blacks with a set dual status. Built buildings with names of places are marked with dye and response in the visual and in the infrared region and remain visible at 1000 nm. All other elements marked in black are just visible to the naked eye.

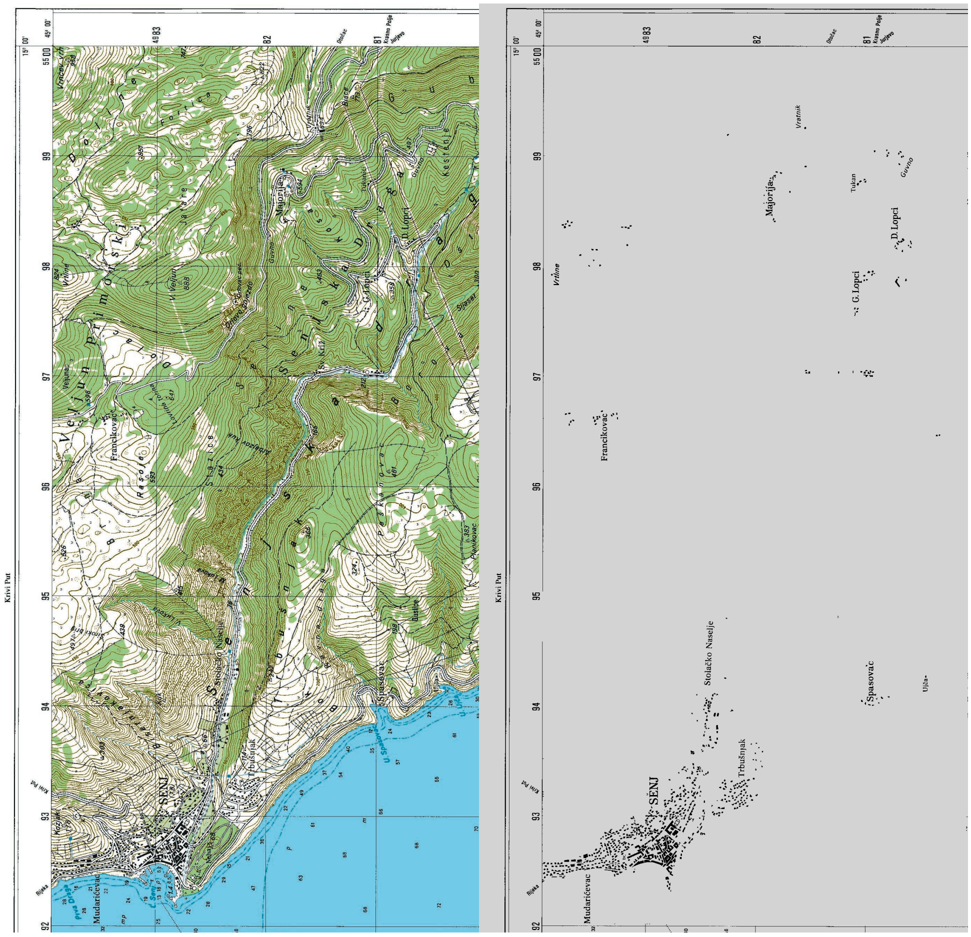
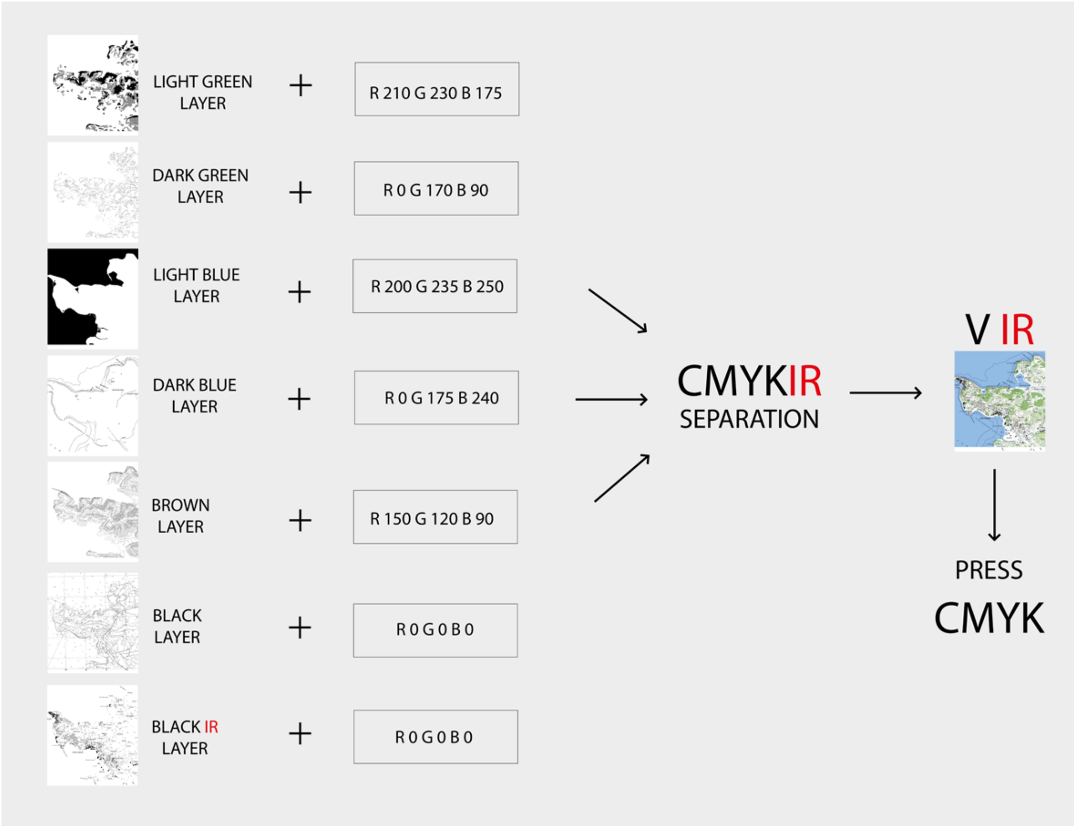


Figure 26. V visual map and K channel with information in IR spectrum

In 2014, a study was carried in which twin dyes black dyes according to IRD procedure for digital printing [45], and in 2015 a double state of black dyes for offset printing for Eurostandard color settings [46].

Table 2. Table shows the process of prepress in six layers in color and one with a double response to V and Z spectrums



In CMYKIR, separation of black and white information comes from the layers, a color is assigned to each layer through their default RGB value and determines the color after printing. Constructed buildings and names of places are marked with Z (infrared) black dye, and V (visual) dye was used to mark roads and paths. Thus, the two highlighted colors in the same tone are completely isolated in the infrared spectrum.

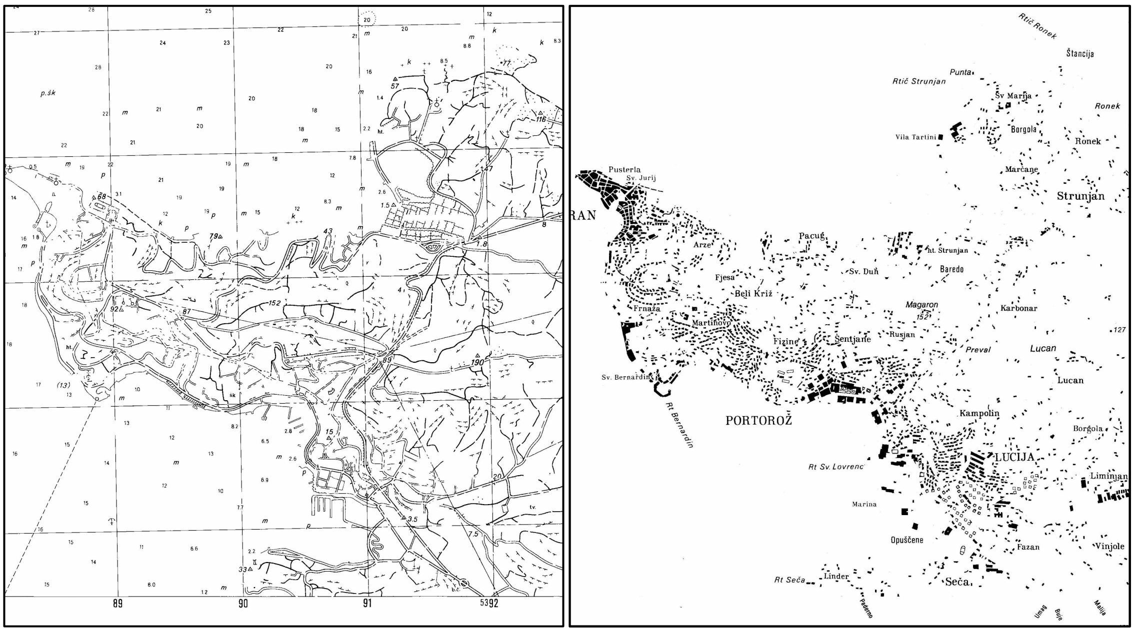


Figure 27. Black layer of paint is divided into V layer displays one type of information in black and Z layer which shows a different type of information highlighted in black

All other used dyes are left in the V system. In the preparation of the press, the simulation of spot dyes through CMY and two types of black ink with the values of Z_{max} and Z_0 in the infrared spectrum was introduced. The study opens up a new area for discussion of twin dyes to protect cartographic document. For the first time, the concept of twin dyes infrared mapping in Zagreb at the symposium Day fight in 2015 was defined [47]. At a conference in Vienna in the same year was introduced the work [48] in which the planned hidden text information displayed within the city with an equal share of coverage twin dyes to 40% of black K channels in the infrared spectrum. At a conference in the United States in 2015 [49], was presented the work which shows the preparation of printing plan of the city with graphics that show the separate layers of height of the terrain, water, green areas and boundaries of green spaces and built facilities. Six layers of dyes that indicate certain specified elements have been expanded by one layer of black infrared twin dyes spot dyes which carries double the items seen in the visual and infrared spectrum [50].

On the symposium Color Day 2016 [51] was presented the process of making the twin dyes spot color light green tone, which means all the green areas. There were 5 colors used in the map view, selected light green color to show the process of making the twin dyes mapping system. V and Z dye twins of the same color tone are mixed before printing, and the printed material is only visible in green in the infrared spectrum at Z = 40%, where all the other tones lose their information and the value of Z is 0. Two pictures, two pieces of information are physically connected via dyes. The development of dye twins used a selective application of the security graphic elements in print securities. By means of the feature of one selected color tone, IR information is set. In the visual part, a CMY dyeing system is set up, and the second twin component within the Z area is just K black ink. The dual reproduction is made of gray twin [52] for printing in neutral, gray, but also for other colors of the V spectrum.

1.5.1 Copyright

Although they are securities, cartographic works are not protected in copyright terms such as in the field of graphic arts, painting, sculpturing or other artistic or scientific field. The documents are not sufficiently protected from non-authorized alterations of their works. Authors of cards require protection for the extensive production of documents from which are expected accuracy, precision and details. Modifications can result in dangerous changes in the real state area. Not only is the duplication of copyright infringing parts unauthorized, but it is not allowed to edit the map because it might compromise the integrity of the author and change the outcome of the document, which must be protected because it carries important information. Technology development opened opportunities for simple modifications of reproductions. Facilated are ways of duplication without authorization. Not authorized reproduction of documents is dangerous because of the way the original can be used and tthe problem of trespassing authorship. Setting norms and systems development security dyes used in the prepress and digital and offset printing provides proof of authenticity of documents. With the usage of infrared twin dyes the protection can be build in within the map, in the shape of a mark [53]which marks the original work of the author.

1.6 Color profiles for highlighting graphic elements in print of maps and plans

Composition of color indicates the absorption of light of wave lengths in the visual and infrared spectrum depending on the composition of colorants. The current course of prepress cartographic documents uses 15 colors to display various graphical elements, and whose visual values gives standard print: black, two shades of gray, two shades of blue, two shades of brown, four shades of green, two shades of yellow, orange and red. Black and gray are used to display and create industrial facilities and their names, lighter blue for water and dark blue for the border water surfaces and objects related to the water, several shades of green for the different types of natural land cover and biological objects, brighter and darker brown for height and objects associated with the relief. Two tones of yellow graphic mark arable land and local roads, and orange and red are used to mark skyscrapers and classification of roads. The graphic form is carried out for each color in its separate layer, with a separate label. Brown color indicating the height of the terrain make clean record in a separate layer, and not mixed with the blue colors that represent water. All the layers of paint in preparation are black and white. Information about the color comes only after connecting all layers into a single document. By combining all the layers of different colors after press, it becomes evident that the piece of information on the amount and the other on water are presented over each other.A layer of black is the only one which determines the order of lamination not sue to tranparency. Edit appears only within a single, specific layer, which is the purpose of prepress in multiple layers. The work uses analysis of existing workflow prepress cartographic documents which showed that current methods of multicolored print of the original owner remains damaged, the information will remain subject to unauthorized modifications. Therefore, multi-colored print copies are prepared for visual expanding of the current situation with infrared protection.

For each technique of printing, digital and offset, an accompanying color setting for twin dyes is produced. Todays legislation is to designate graphical elements mapping system inadequate and imprecise determine on which color tones it is because they are given only RGB values which vary for each color settings, displays, printing machines and so on. Marking colors only in RGB space opens up a large space for unauthorized modification of the document and it can not achieve the same quality prints when you print the document in several different presses. In order to establish the print quality and precision of the use of color in determining the elements of the proposed new system of multilevel twin dyes that are defined by C, M, Y, K shares for offset and digital printing and expand the security component that has not been present as well in the press and preparation for printing of these types of securities which contain a lot of information about the area and the property, and is widely used in civilian and military use.

Table 3. The default color profiles in the labeling of graphic elements mapping system whose terminology comes from the world of making maps and plans.

Index	Name	RGB	Objects
1	black	0, 0, 0	built objects, except water names, frame, grid
2	gray	190, 190, 190	industrial objects
3	darker gray	150, 150, 150	rocks
4	darker blue	0, 175, 240	line elements, symbols of hidrography and water names
5	lighter blue	200, 235, 250	water surface
6	darker brown	150, 120, 90	natural and artificial dams
7	lighter brown	205, 145, 115	isohips, sand
8	green	0, 170, 90	lines of hedges, line elements, vegetations symbols
9	green 1	210, 230, 175	whitewashed forest
10	green 2	180, 220, 185	mixed forest
11	green 3	155, 215, 200	coniferoust forest
12	darker yellow	255, 245, 140	state and local roads
13	lighter yellow	255, 250, 225	arable land
14	orange	250, 170, 120	highways, state roads and skyscrapers
15	red	240, 100, 110	boarders

Determination of color profiles in one area, in this case, RGB, has insufficiently defined color tone for all that reproduction and printing machines should have the same visual standard. RGB color space indicates the current experience of colors on computer screen with its settings and calibration. This opens up the space to create a system that accurately defines the color of securities, and to give equal solutions to all reproductions. The colors, besides being defined, have controlled visibility in the infrared spectrum within which document protection can be successfully set up.

1.7 **Questionnaire**

The need for questioning security marking in prepress and printing documents cartographic content is detected. The survey was created for the purpose of determining the knowledge, needs and importance of authenticity of graphics that are running the process of making plans and maps, and in the present situation have a need to expand the methods of security. The survey was conducted on the publishers, users of maps and plans and designers. Their contribution is valued by answering a questionnaire that asks questions about safety and correctness of the information on the graphic print, quality records, methods of application documents and the use of printed information. The main chapters of issues related to document security and counterfeiting of designer products are:

- 1. Do you know the methods of protecting documents?
- 2. How do you assess the level of protection of documents and author's work?
- 3. What is in your opinion the most commonly falsified document?
- 4. In your opinion, which of these appliances facilitate forgery?
- 5. Have you ever suspected a forgery?
- 6. Have you personally ever had a problem caused by forged documents or product?
- 7. What methods of protection of documents and securities you know?
- 8. Are the cartographic documents such as maps and plans protected?
- 9. Do you think there are reasons for the introduction of protection through dyes in cartography?
- 10. What security features designers use today?
- 11. Are there reasons for the introduction of protection in design?
- 12. What is the job of a notary?

In the questionnaire, notaries were asked these extra questions:

- 13. How to check whether the document is original?
- 14. What happens with protection and issuing a certificate if a person brought a copy?
- 15. How long do you store documents?
- 16. In which form do you store documents?

2 OBJECTIVES AND RESEARCH PLAN

2.1 **Objectives and hypotheses of the Research**

The goal is to expand printing technology with newly defined multilevel security twin dyes that permits targeted placement of double information for visual and infrared spectrum of the graphic reproduction of spot colorants and their simulation with process colors.

H1 Mixing twin dyes gives equal solutions in experimental digital printing and offset printing in large editions.

H2 Expansion of eight-prepress to double number of dye sets of twins, determinates protection through all stages of printing and reuse.

H3 Using dye twins with IRD characteristics in multicolor spot printing can prove the correctness of the printed document and ensure the rights of authors.

2.2 Expected scientific contribution

The scientific contribution of this research relates to the setting methodology of protective twin dyes with the response in the visual and infrared spectrum. Recipes for the twin dyes to offset dyes and processing colors of digital printing and methods of security printing is improved. Expansion of printing technology is reflected through:

- standardization of processes of graphic reproduction of protected documents in the infrared region.
- definition of color twins through procedural dyes cyan, magenta, yellow, and carbon black, for the visual and infrared spectrum
- minimizing ΔE for test digital printing and offset printing of large editions.
- extension of the method of printing in the infrared mapping separation CMYKIR for a given L*a*b* value of spot dyes for each color tone and the default Z value.

In the dissertation are defined the phases of twin dyes for offset printing of large editions and test digital printing. Dyes are used for hiding graphic elements within a document for protection. Scanning or unauthorized reproduction of protected documents looses infrared component, and thus it is possible to distinguish the original from the fakes. This raises the new method and technology that defines the protection of documents through all phases of the press.

2.3 Experiment plan

The experimental work was divided into these phases of work:

- Hand mixing dye spot twins for offset printing
- Measure Z shares and turnout in a visual and infrared spectrum
- Spectral measuring of variations in shades of twin dyes
- Mixing twin dyes through CMYKIR^{DT} separation for digital printing
- Measurment of Z dye share
- Testing of prints on various substrates
- Budget and measuring variations in shades of twin dyes ΔE
- Planning and design of graphic elements for hiding
- Applying and prints with a double visual condition

The first phase of this work sets the method of manual mixing dyes spot twins with the response in the visual and infrared spectrum for offset printing dyes. Offset printing process dyes cyan, magenta, yellow, and carbon black are used and the grams mixed to obtain two dyes of different composition and response in the IR spectrum of a single color tone. Mixing is a new method of making dyes which are mixed prior to printing for large print runs. Subsequent measurement of Z shares and turnout in the two spectrums of individual dyes using RGB apparatus and image processing program is conducted. Determinating the L*a*b* values and the deviations in the color tones obtained by mixing dyes using spectophotometer followed. The next step is to make an experimental plan for manual mixing of dyes with controlled Z value of new dyes. New group V and Z dyes of the same color tones and different Z values, called the twin dyes, is made.

The second phase involves setting principles of CMYKIR^{DT} separation to produce twin dyes for proofing. RGB cameras and programming software for image processing determines Z share for all dyes. Mixing dyes depends on the printing technique, therefore a experiment of making twin dyes default color tones through iterations on different printing substrates is made. Numerical measuring variations in shades of twin dyes ΔE will show the success of the recipe. In the last stage of the designing graphical elements are to be concealed through twin dyes in the press featuring maps and plans. Two independent images related through content are created. The input black and white image that only the press will be informed about the color of each layer is prepared. They are protected graphics with the response given elements and of IR spectrum. The final step is the printing of protective duplicate pictures on paper and textiles.

2.4 **Materials used in the study**

The material used in the work includes color for offset and digital printing, paper for printing charts and plans, devices for colorimetric measurements and printing machines. The colors blend in a targeted way to mark the graphics on maps and plans. The models will be tested over a trial digital print where spot colors are simulated with process colors. Offset printing will produce spot colors from process colors. Trial digital and offset printing with spot dyes will take place on cartographic paper.

2.4.1 Process offset dyes and colors of digital print

All the spot colors are made from process colors according to the given recipe in the work:

Process dyes:

- Cyan
- Magenta
- Yellow
- Carbon black
- Transparent

Colors of digital print:

- C: 44973551 / 3 149 29
- M: 44973510 / 4 14 X 27
- Y: 44973509 / 4 149 29
- K: 44973512 / 4 14Z 30

2.4.2 Paper

Offset papers are made of secular fibers, made of cellulose pulp, with wood pulp and recycled paper. Papers are unbreakable, and they have good absorbency and high gloss finish.

High quality cartographic paper is made of high-grade raw materials, high strength and durability when bending. 100 grams of commercial paper "Cartographic Paper" are produced in the factory "Radeče papir" in Slovenia were used. The paper is white, unmatched (mat) and ecologically free of chlorine.

2.4.3 Textile

Cotton is a natural fiber obtained from a cotton plant. The material is a good insulator and absorbs great. Its quality depends on the purity, fiber length and staining. It is used for uniforms, work clothes, pants, jackets and for decorative purposes. This paper uses the printing on a monochrome, non-elastic and compact cotton fabric label:

- Cotton, kemper 300g, 16619-01, white

2.4.4 Forensic equipment for spectral analysis

- Spectrophotometer spectrum analyzer X-Rite SpectroEye
- Projectina Docubox forenzic system PIA 6000 / Multi-spectral Imaging Software modul

X-rite SpectroEye Spectrophotometer (Figure 1) was used to measure and control the prints. The device is used to measure the reflectance factor of the sample depending on the wavelength. The result measurement product is a spectrophotometric curve in the wave range of 400 nm to 900 nm. Data measurement is displayed numerically across multiple color spaces. In this paper, the important space L*a*b* and the determination of the color difference ΔE was set. For the determination of L*a*b* and ΔE color values, an average value of at least three measurements was used. In order to provide the spectrum with the spectrophotometer, the illumination, angle of view or viewing geometry is fixed.

Technical specification for X-rite SpectroEye device:

- Optical resolution: 10 nm (intern 3.3 nm)
- Range of measurement: 0 – 2,5D (Densitometry)
- Geometry 45°/0°: ISO 13655:2009; DIN 5033
- Measuring surface: Ø4.5 mm
- Densitometry standard: ISO Status A, ISO Status E, ISO Status I, ISO Status T, DIN 16536, DIN 16536 NB, SPI

- Standardn observer: 2°/10°
- Standard light source: A, C, D50, D65, D75, F2, F7, F11, & F12
- RS232

Figure 28. Spectrophotometer X-rite Spectroeye

Projectina Docubox forensic system PIA 6000 in this paper scanned the prints of twin dyed offset prints. Barrier scanning is a procedure for determining the originality of the print, used in determining the credibility of the securities. In the near infrared area, prints were scanned in the area at 1000 nm. The device has a limited area for scanning the document. The device performed colorimetric measurements and spectral analysis, which was extended to a near infrared spectrum

Technical specification for Projectina Docubox forenzic system PIA 6000 device:

- Optical resolution: 6,4 nm
- Integrated digital camera: 1,4 i 5
- Measuring surface: 182 x 136 mm
- Zoom optics: allows enhancement up to 140 x

Figure 29. Barrier scanning device Projectina Docubox forenzic system PIA 6000

2.4.5 NIR camera

Dual camera NIR or ZRBG consists of two systems. The first system is classic RGB, while the other records the Z value of radiation at 1000 nm using the solar NIR component. The camera allows to determine the differences in information from RGB and Z systems for each graphic. The camera is mobile and works in daylight.

Figure 30. NIR camerawith dual option of V and Z recording

2.4.6 Printing machine

Printers used:

- Dry toner: Printer OKI ES5431
- Inkjet: Digital HP 5000

- Offset: Heidelberg SpeedMaster 52-2P/2003

Figure 31. Printer OKI ES5431

Figure 32. Digital HP 5000

Figure 33. Offset Heidelberg SpeedMaster 52-2P/2003

3 EXPERIMENTAL WORK

The experimental work defines the principle of making dye twins for the default color tones, especially for offset printing of large circulation, and especially for digital test printing. For each color tone double twin dyes are made which are capable of absorbing light in the visible and infrared spectrum. In this paper, the term V (visual) dyes has the capacity to absorb light only in the visible spectrum, and Z (IR) dye has the capacity to absorb light in the visible and infrared spectrum. The new way of security printing featured for printing hidden information is observed in the visual spectrum in the 400-700 nm and NIR (near infrared) spectrum at 1000 nm. Dye twins serve for hiding of information within printed materials for protection. The information is hidden so that there is no visible change in the visual image and graphics. Hiding of the image relies on dyes. A combination of dyes achieves the desired color tone. In colometry RGB, L*a*b* or HSB systems are determined for visual perception of colors. Each color tone can be in real conditions of printing available with different proportions of CMYK colors. Together V twin and Z twin of one tone of color make the protected graphics. Protection is detected in the infrared spectrum using RGB camera. Visual presentation of graphics can not be copied and edited without losing Z components. Copy or scan playback loses the Z component. The creation of protected printed products and printed information requires identification twin dyes to the smallest size ΔE, ideally less than three because the human eye can not see the difference in tones at this value. Twin dyes in the visual spectrum were as close to each created a pair of twin dyes and measure numerical value of visual identification ΔE. Mixing spot twin dyes is a new principle of creation of the security dyes. A new planning tool for the same color tone, but with different properties in the visual and infrared spectrum, is created. Experiment consists of two phases of dye twins. Dyes for offset printing mixed manually measured each ratio of dyes in the recipe. Creating dyes for digital printing takes place in the program via computer.

3.1 **Mixing of process offset dyes for visual and infrared spectrum**

Models for printing with twin dyes are new because they are based on dyes that are mixed before printing or dyes recipe determined in the digital prepress. In order to keep the same color tone in large series recommended is the use of spot colors. Mixing before printing reduces dependence on external conditions. External conditions include temperature differences, weather and publishing requirements. Made are new groups of multilayer twin dyes of the same color tones, different recipes and equal visual value for offset printing. The principle of twin dyes is based on a new security system and the method of transmitting information. Twin dyes use their Z absorption of light at 1000 nm in the design of graphical solutions. Graphics are made of twin dyes of which the first was recognized in the twin V, and the other in the Z range. The dyes are planned with the aim of giving a response to the spectrum at 1000 nm. The value of each dye may be from 0 to 100, depending on the amount of light absorption in the infrared region. In the experimental setting colors for offset printing, the value of dyes is dependent to the amount of K dye in the recipe.

3.2 Experimental color setting

The experimental work tested the principle of hand mixing C, M, Y, K colorants offset printing process without default recipe. The experiment was used to develop the principles of controlled making the desired color tones necessary to designate graphical elements. Each dye is separate at the beginning of mixed 50/50 with transparent dye to achieve higher brightness of tone colors and prints. First mixing occurred without accurate measurement of each unit C, M, Y, K colorants. Hand-mixed shades obtained at different ratios are applied in a thin layer on the paper. After drying spectral measured are L * a * b * values of color tones. For each tone calculated is a forecast minimum of three values in order to obtain a more accurate average value. A number of shades from the world of cartography are created: shades of green, blue, brown. In the experiment, the feed is introduced in dyes and dyes with twins. The tones of color are mixed without components K, K was achieved in ratios C, M, Y colorants. For the twin was used the K colorant with the response in the visual and infrared spectrum. After drying, the layers of color are recorded by RGB camera to determine the absorption of light and visibility in the infrared spectrum. It has been demonstrated that the response in the infrared spectrum is not dependent on the color shade, but on the recipe.

Dyes can be mixed as spot colors before printing. For all of the colors, which are intended to be used in hiding information, procedures of twin dyes were introduced. Each tone of color joined at least two dyes having different absorption of light in the infrared spectrum. Thus the press can mark a document with graphics to be seen only at 1000 nm as the surveillance camera's prepared. RGB cameras that have two different filtering daylight are developed. The first camera sees muscular length Z at 1000 nm and the second camera sees range from 400 to 700 nm. This raises the systematization of twin dyes in order to determine the interdependence of process dyes for the real printing. For tones which have a Z value> 0 is calculated share of K components and thus Z value through computer software for image processing Adobe Photoshop is used.

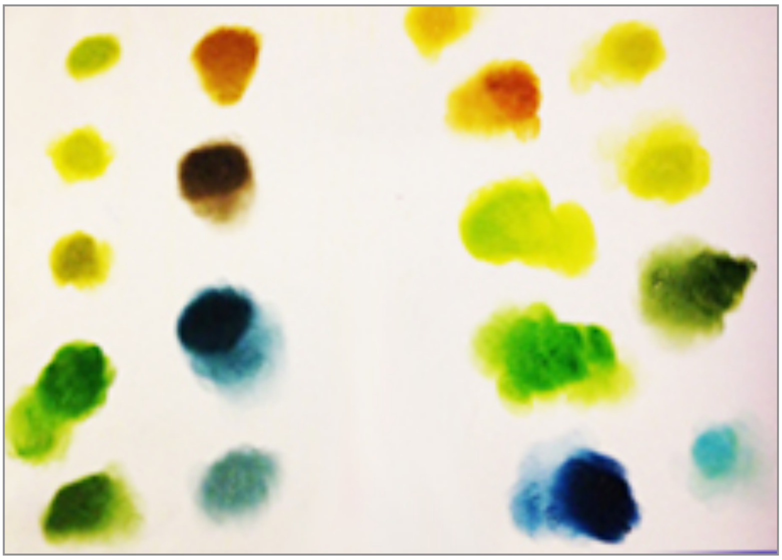


Figure 34. The visual spectrum, experimental hand-mixed shades spot dyes without recipe

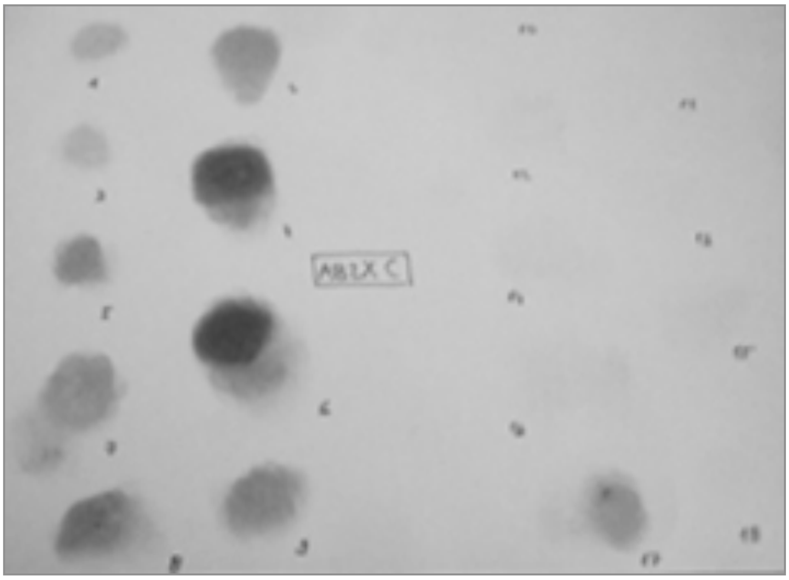


Figure 35. The infrared spectrum at 1000nm, experimental hand-mixed shades spot dyes without recipe

Table 4. The color tone of process offset printing dyes mixed without recipes: L*a*b* and Z values of the color tones

Page	Index	L*a*b*	Color	Z (%)
AB2XC	1	71, -14,68		44
	2	56, 13, 52		50
	3	79, -7, 78		41
	4	46, 2, 19		67
	5	69, -5, 60		56
	6	54, -15, -9		63
	7	62, -32, 47		54
	8	67,-20, 34		61
	9	78, -13,-3		54
	10	81, 4, 73		0
	11	90, -8, 62		0
	12	71, 12, 64		0
	13	89, -10, 67		0
	14	87, -12, 84		0
	15	71, -21, 35		0
	16	78, -29, 60		0
	17	66, -20, -17		0
	18	84, -26, 1		0

The table shows two tones that look similar to the naked eye. The color tone AB2XC No.3 and No.14 have close L*a*b* value, but tone of No. 3 has a value Z = 41, and tone No.14 Z is 0. Dye No. 3 has a response in the visual and infrared spectrum and is considered along with twin dyes and tone No.14 has a response only in the visual spectrum, while in the infrared is losing information. Tone No.14 is the V dye twin.

After establishing the principle of making color tones of V and Z dyes, the experiment was to mix recipes for new pairs of twin dyes for set color tones. Process offset colorants C, M, Y, K scale have been mixed in grams. Then the visual value was calculated by using the spectrophotometer of L*a*b* value of color deposited on the paper. Layers are then recorded with infrared camera to determine the visibility in the infrared spectrum. The mixed V dyes have content only in the visual spectrum, their Z is 0. The absorption properties of dyes are used in order to have caused response in the infrared spectrum. Some dyes have a strong response to the Z value which is conducive to development of CMYKIR separation. The value of Z is calculated by measuring the K component in the imprints recorded with the infrared camera.

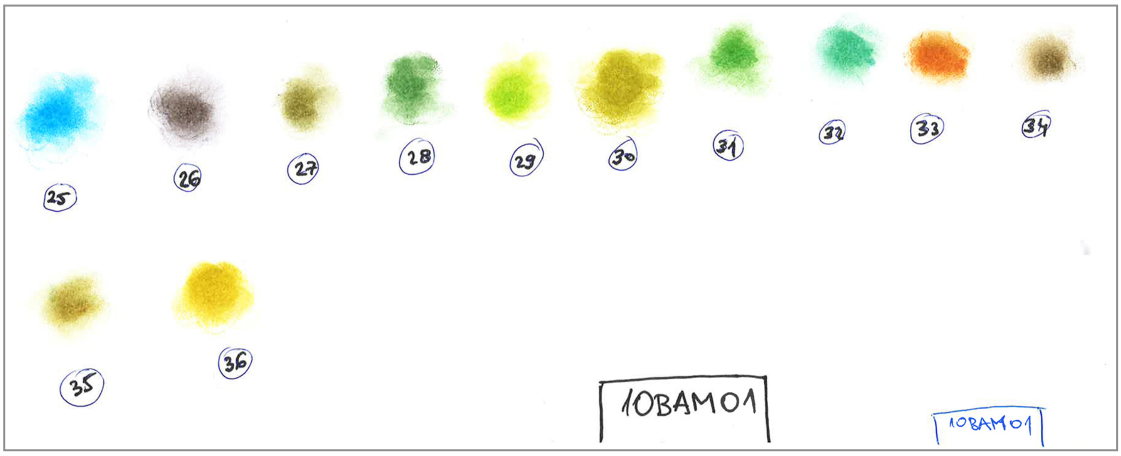


Figure 36. The visual spectrum, experimentally hand-mixed shades of spot dyes with a given recipe, with no response in the infrared spectrum

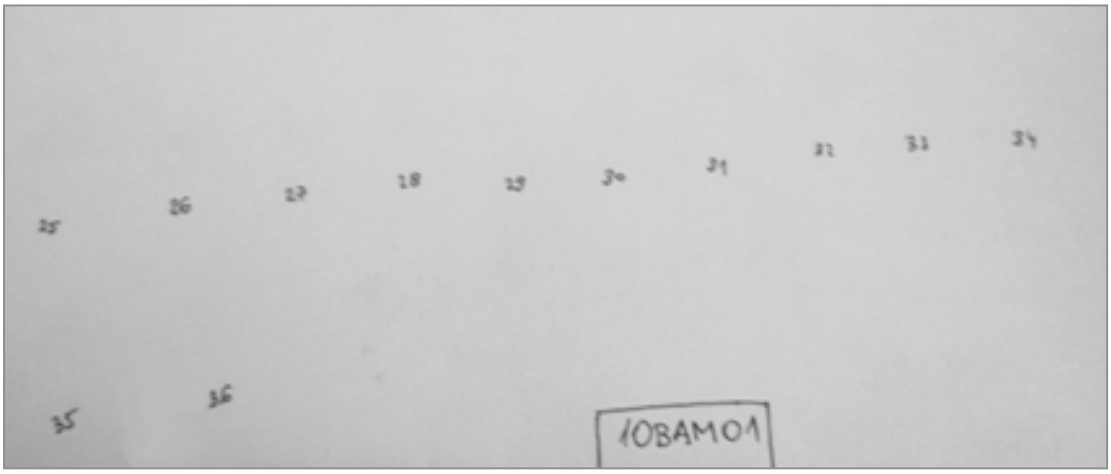


Figure 37. The infrared spectrum at 1000nm, experimentally hand-mixed shades of spot dyes with a given recipe, with no response in the infrared spectrum

On the visual and infrared image of the same print color we see that the proportion of Z component and visibility in the infrared spectrum does not depend on the color shade.

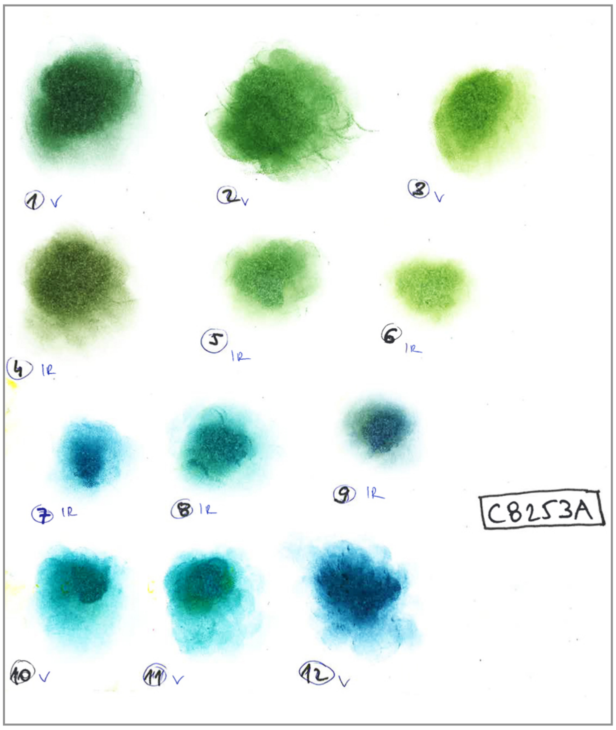


Figure 38. The visual spectrum, experimentally hand-mixed blue and green shades spot dyes with a given recipe in the visual and infrared spectrum

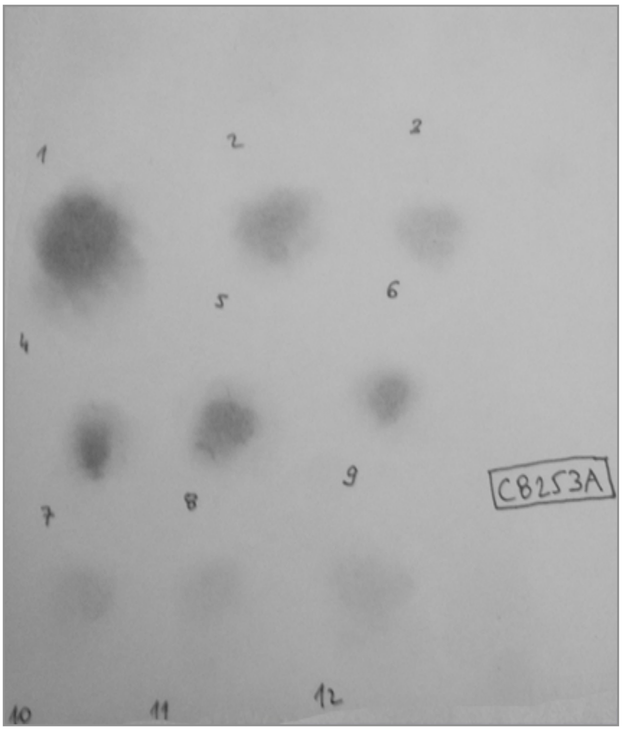


Figure 39. The infrared spectrum at 1000nm, experimentally hand-mixed blue and green tones spot dyes with a given recipe in the visual and infrared spectrum

It is not important whether the tone is darker, like dark brown or light like light yellow, but the essential composition and the recipe mixture of certain tones. We see the visual characteristics of twin dyes where the naked eye green and blue color tones look very similar to each other, while watching with RGB camera, we see their different properties of light absorption. Even the appearance of darker tones disappear completely when we consider them in the near infrared range while their Z couples retain visibility at 1000 nm.

The infrared spectrum does not provide the experience of color, therefore all the prints of monochrome dyes with more or less Z response, our eyes see as more or less gray prints. Z dyes absorb infrared light, and the absorption is reflected in the description of monochromatic color tones and colors.

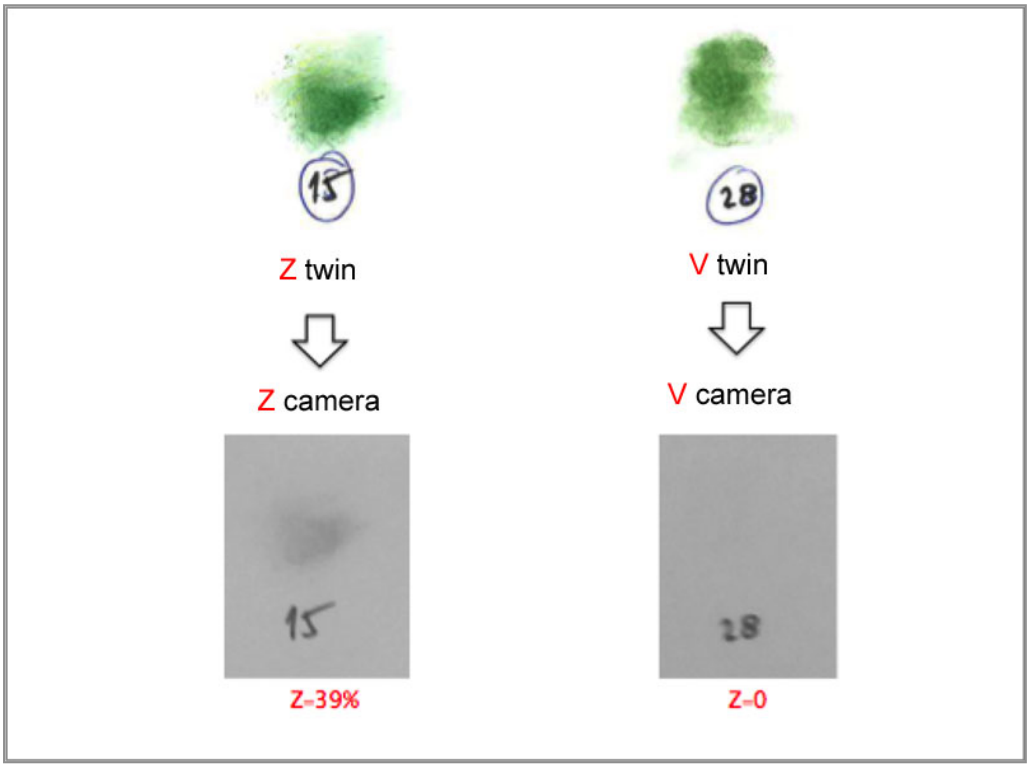


Figure 40. Scheme of the principles of mixed twin dyes of spot dyes

The example of the green dye shows the system of making twin dyes. Selected lighter green for offset printing is mixed as physical dye with a request that both mixed dyes visually look the same, but have different response in the infrared spectrum. The resulting impression of mixed colors is checked with the ZRGB camera. It reveals that the Z twin of the color green has a response from Z = 39% in the infrared spectrum, current V twin dye of the same color tone becomes "invisible" or looses information. This procedure creates a recipe for which any color tone of the map system can be made as a twin dye.

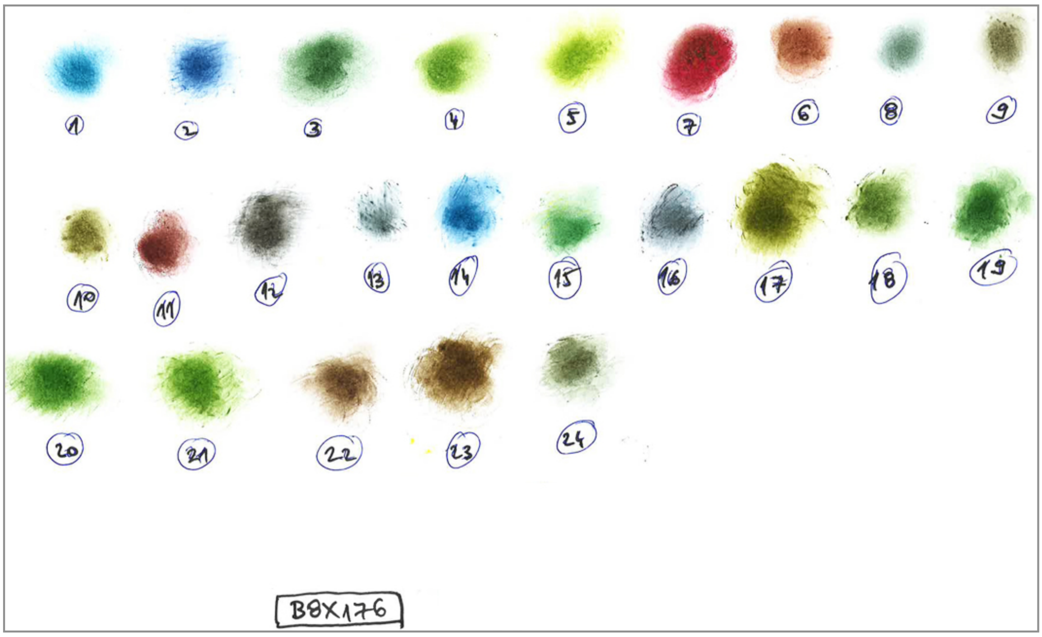


Figure 41. The visual range, experimentally hand-mixed tones spot dyes with a given recipe

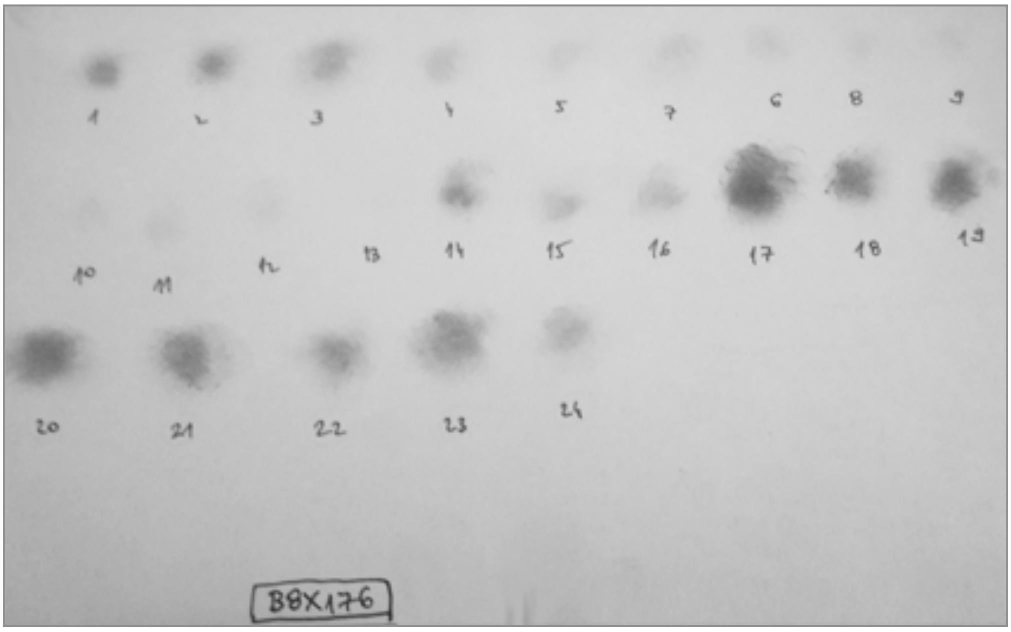


Figure 42. The infrared spectrum at 1000nm, experimentally hand-mixed shades spot dyes with a given recipe

The principle of making and mixing twin dyes can be applied to a wide variety of color tones. The system is not limited to specific color tones, it is not a particular method of print. In the visual representation we see that different recipes for mixing color tones have a response in the IR spectrum can have a different proportion of Z components, and Z component varies from Z_{min} where the fingerprint response in the IR spectrum was very bad, but still visible, to where Z_{max} visibility in the infrared spectrum was very strong.

Mixing recipes are shown in the Z dyes and their rates of C, M, Y, K in grams. The dyes where Z = 0 , the K share of the black dye is also K = 0. From the calculated and measured colorimetric values of process colorants cyan, magenta, and yellow created shades Z is 0. For some tones, it was necessary to add another transparent components to achieve greater brightness.

Making twin dyes becomes a method for accurately determining the composition of dyes in the replacement procedures of C, M, Y (state Z_0) with the C, M, Y, K (state Z_{max}). The criteria for quality twins is equal to absorb light in the whole range of the visual spectrum. Until the invention of InfrareDesign and CMYKIR separation, the feature of absorbing dyes as an element to create a separate, invisible graphics was not observed. Gemini became visual method for correct separations, crossings from RGB to CMYK state respecting CMYKIR separation. "Visual" means that the two images are composed of common composition and dyes that are individually visible only with the design point of view. Since there are two pictures on the same site, the instrument can "see" the state of the image Z and visually with the naked eye can identify other files. Dyes which have two in the Z state are used for graphics that will be viewed by RGB camera. Dual RGB camera will show two pictures. In parallel observation of the situation in the visual and NIR spectrum, it makes it easier to locate hidden information.

Table 5. The color tones of process offset printing dyes mixed with the recipe

Page	Index	L*a*b*	Color	Z (%)
C8253A	1	73, -19, 13		0
	2	72, -23, 24		0
	3	78, -16, 33		0
	4	67, -12, 22		57
	5	74, -21, 25		47
	6	76, -21, 34		40
	7	76, -20, -11		57
	8	78, -23, -1		55
	9	72, -14, 0		48
	10	74, -32, -8		0
	11	78, -29, -6		0
	12	75, -14, -13		0
B8X176	1	67, -19, -13		52
	2	57, -7, -21		50
	3	57, -20, 16		46
	4	68, -21, 36		37
	5	75, -19, 49		35
	6	64, 16, 22		36
	7	54, 36, 13		36
	8	69, -13, 8		37
	9	62, -7, 18		40
	10	60, -6, 29		41
	11	49, 19, 14		40
	12	54, -7, 7		36
	13	66, -10, 2		33
	14	67, -14, -18		42
	15	70, -24, 20		39
	16	63, -8, 0		38
	17	53, -4, 78		52
	18	63, -13, 29		47
	19	62, -20, 23		56
	20	69, -20, 30		55
	21	69, -20, 36		50
	22	61, 5, 20		49
	23	55, 5, 25		47
	24	63, -10, 17		43
10BAM01	25	80, -25,-27		0
	26	58, -1, 8		0
	27	68, -5, 33		0
	28	69, -23, 24		0
	29	82, -19, 65		0
	30	72, -5, 59		0
	31	70, -34, 35		0
	32	73, -39, 13		0
	33	68, 26, 49		0
	34	73, 0, 22		0
	35	70, -2, 41		0
	36	78, 2, 70		0

Table 6. The recipes for V process offset dyes

V dyes (Z=0)			
Page	Nr.	L*a*b*	C, M, Y, K (g)
C8253A	1	73, -19, 13	1, 1, 4, 0
	2	72, -23, 24	1, 1, 6, 0 (+2g trans.)
	3	78, -16, 33	1, 1, 9, 0 (+8g trans.)
	10	74, -32, -8	3, 0, 2, 0
	11	78, -29, -6	3, 0, 2, 0 (+1.5g trans.)
	12	75, -14, -13	3, 1.5, 2, 0 (+1.5g trans.)
10BAM01	25	80, -25,-27	1, 0, 0, 0 (+0.5g trans.)
	26	58, -1, 8	1, 1, 1, 0
	27	68, -5, 33	1, 1, 2, 0
	28	69, -23, 24	2, 1.5, 2, 0
	29	82, -19, 65	3, 1, 4, 0
	30	72, -5, 59	1, 1, 2, 0 (+0.5 trans.)
	31	70, -34, 35	2, 1, 2, 0
	32	73, -39, 13	3, 1, 2, 0
	33	68, 26, 49	0.5, 1.5, 2.5, 0
	34	73, 0, 22	1.5, 2.5, 3.5, 0
	35	70, -2, 41	1.5, 2.5, 4.5, 0
	36	78, 2, 70	1.5, 2.5, 6.5, 0

Table 7. The recipes for Z process offset dyes

Z dyes			
Page	Nr.	L*a*b*	C, M, Y, K (g)
C8253A	4	67, -12, 22	1, 1, 9, 1 (+8g trans.)
	5	74, -21, 25	0.3, 0.3, 3, 0.5
	6	76, -21, 34	0.3, 0.3, 6, 0.5
	7	76, -20, -11	4, 0, 0, 1
	8	78, -23, -1	4, 0, 1, 1 (+3g trans.)
	9	72, -14, 0	4, 1.5, 1, 1 (+3g trans.)
B8X176	1	67, -19, -13	2, 0, 0, 1
	2	57, -7, -21	1, 0.5, 0, 0.5
	3	57, -20, 16	1, 0.5, 1, 0.5
	4	68, -21, 36	1, 0.5, 3, 0.5
	5	75, -19, 49	1, 0.5, 4, 0.5
	6	64, 16, 22	1, 1.5, 4, 0.5
	7	54, 36, 13	1, 2.5, 4, 0.5
	8	69, -13, 8	2, 2.5, 4, 0.5
	9	62, -7, 18	2, 3.5, 5, 0.5
	10	60, -6, 29	2, 3.5, 6, 0.5
	11	49, 19, 14	2, 4.5, 6, 0.5
	12	54, -7, 7	3, 4.5, 6, 0.5
	13	66, -10, 2	3.5, 4.5, 6, 1
	14	67, -14, -18	0.5, 1, 0, 0.5
	15	70, -24, 20	0.5, 1, 1, 0.5
	16	63, -8, 0	0.5, 2, 1, 0.5
	17	53, -4, 78	0.5, 2, 2, 1.5
	18	63, -13, 29	1, 2, 2, 1.5
	19	62, -20, 23	1.5, 2, 2.5, 1.5
	20	69, -20, 30	1.5, 2, 2.5, 1.5
	21	69, -20, 36	1.5, 2, 3, 1.5
	22	61, 5, 20	1.5, 2.5, 3, 1.5
	23	55, 5, 25	1.5, 2.5, 3.5, 1.5
	24	63, -10, 17	2.5, 2.5, 3.5, 1.5

The dyes shown in Table 7 are respected and K carbon black dye. The recipe is K colorant mixed in terms of a minimum of 0.5 g to 1.5 g. Using the minimum share of the black component to the color tones that were lighter. It is concluded that with increasing the share of K components, the Z value of the visibility of print colors in the infrared spectrum increases. Recipes for dyes in the response in the visual spectrum and Z dyes with the response in the visual and infrared spectrum are set. Between 48 previously created color tones were found couples with similar visual values that make the V and Z twin color tone. Five pairs of spectrograms which were carried out to determine the coincidence of C, M, Y and K share were selected.

Table 8. Experimental recipe for pairs of twin dyes

Twin dyes					
Page	Index	L*a*b*	Z (%)	C, M, Y, K (g)	Color
10BAM01	28	69, -23, 24	0	2, 1.5, 2, 0	
B8X176	15	70, -24, 20	39	0.5, 1, 1, 0.5	
Page	Index	L*a*b*	Z (%)	C, M, Y, K (g)	Color
C8253A	3	78, -16, 33	0	1, 1, 9, 0 (+8g trans.)	
C8253A	6	76, -21, 34	40	0.3, 0.3, 6, 0.5	
Page	Index	L*a*b*	Z (%)	C, M, Y, K (g)	Color
C8253A	12	75, -14, -13	0	3, 1.5, 2, 0 (+ 1.5g trans.)	
C8253A	7	76, -20, -11	57	4, 0, 0, 1	
Page	Index	L*a*b*	Z (%)	C, M, Y, K (g)	Color
C8253A	11	78, -29, -6	0	3, 0, 2, 0 (+1.5g trans.)	
C8253A	8	78, -23, -1	55	4, 0, 1, 1 (+ 3g trans.)	
Page	Index	L*a*b*	Z (%)	C, M, Y, K (g)	Color
10BAM01	27	68, -5, 33	0	1, 1, 2, 0	
B8X176	19	60, -6, 29	41	1.5, 2, 2, 1.5	

3.2.1 Creation of a new scale of twin dyes for offset printing

The experimental work sets twin dye recipes for spot color of equal visual (RGB and L*a*b*) condition, and a different Z value. Experimental work includes targeted creating pairs of twin dyes of desired color tone. Spot dyes joins double feature of the principle of twin dyes. New pairs of twin dyes are manually mixed offset process colorants C, M, Y and K. After, the mixed color print is made on 160 gr paper. All the colors used for the planning documents as a spot color with dual conditions: the visual spectrum and invisible in the infrared and visual spectrum and in the visible infrared spectrum. Recipes for making the fight "twins" who have the same visual experience tons of colors and different feature of absorbing infrared light are set.

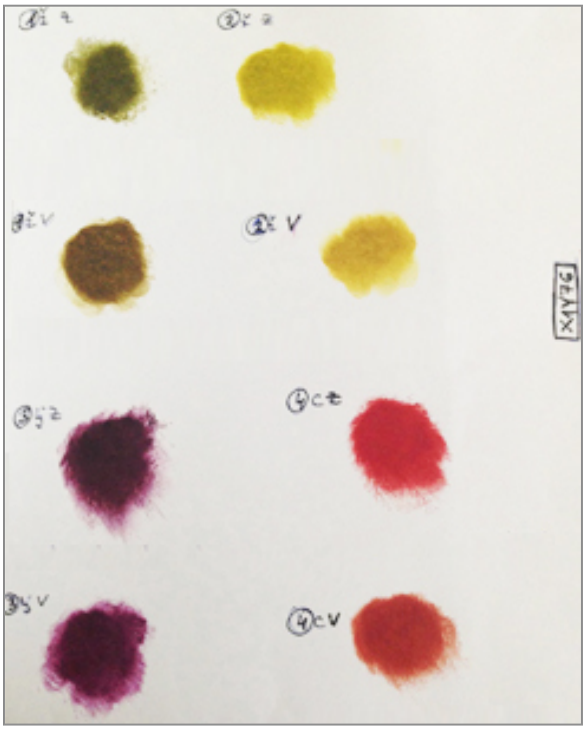


Figure 43. Offset mixed twin dyes in the visual spectrum

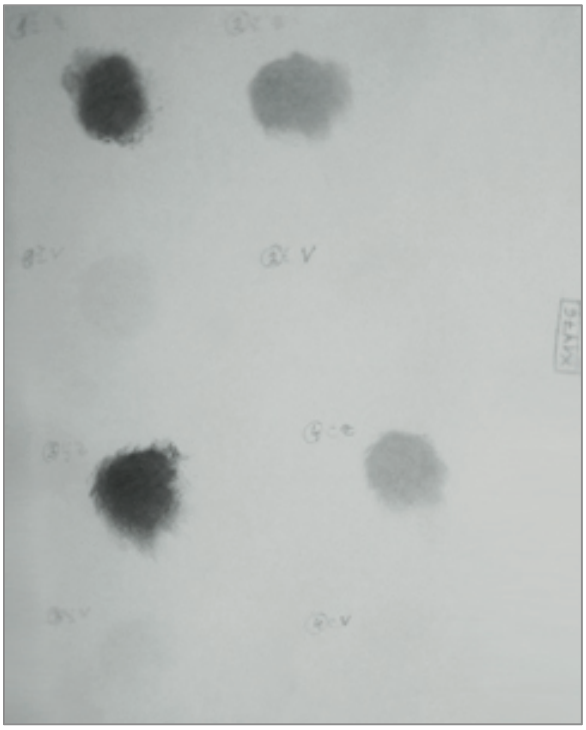


Figure 44. Offset mixed twin dyes in the infrared spectrum at 1000nm

Table 9. L*a*b* values and the recipe C, M, Y, K colorants X1Y76

Page	Index	C, M, Y, K (g)	L* a* b*
X1X76	1V	0.10, 0.20, 1, 0	41, 3, 27
X1X76	1Z	2, 0, 1, 0.20	43, -3, 29
X1X76	2V	0.10, 0.20 , 2, 0	70, 2, 66
X1X76	2Z	0, 0, 1, 0.1	68,-2, 67
X1X76	3V	0.10, 0.70, 0.10, 0	34, 26, -1
X1X76	3Z	0, 0.80, 0, 0.20	31, 15, 5
X1X76	4V	0.01, 0.80, 1, 0	41, 41, 28
X1X76	4Z	0, 0.80, 1, 0.01	42, 51, 29

The objective of defining security twin dyes which are used to design targeted hidden double information for visual and infrared spectrum is set through offset printing process dyes cyan, magenta, yellow, and carbon black. Offset printing technique inflicts a new way to protect securities through twin dyes. The novelty of the method of mixing and creating more twins for offset printing is created.

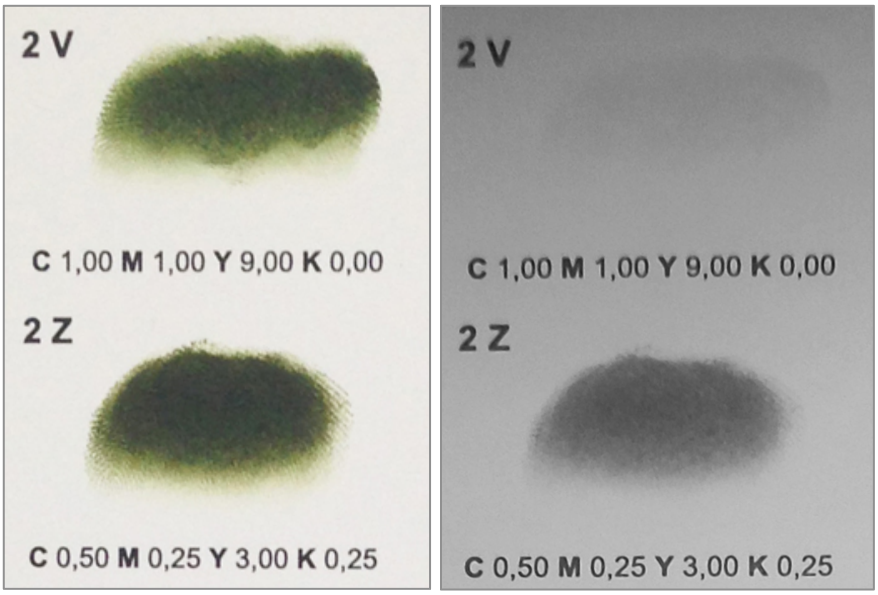


Figure 45. Dye twins for offset printing visible in the visual spectrum, but only 2Z also in the IR spectrum at 1000nm

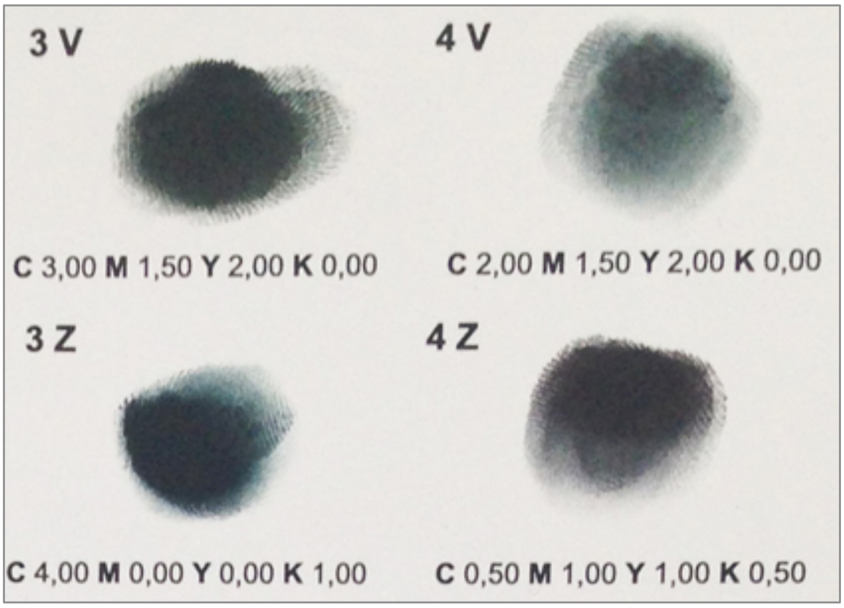


Figure 46.Dye twins for offset printing in the visual spectrum, twin dyes 3V, 3Z and 4V, 4Z

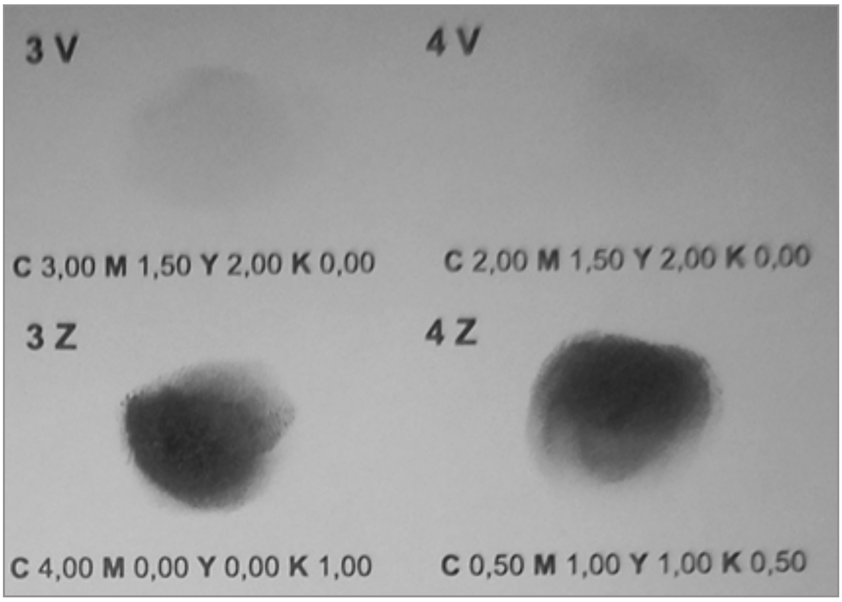


Figure 47. Dye twins 3V, 3Z and 4V, 4Z for offset printing in the IR spectrum at 1000nm

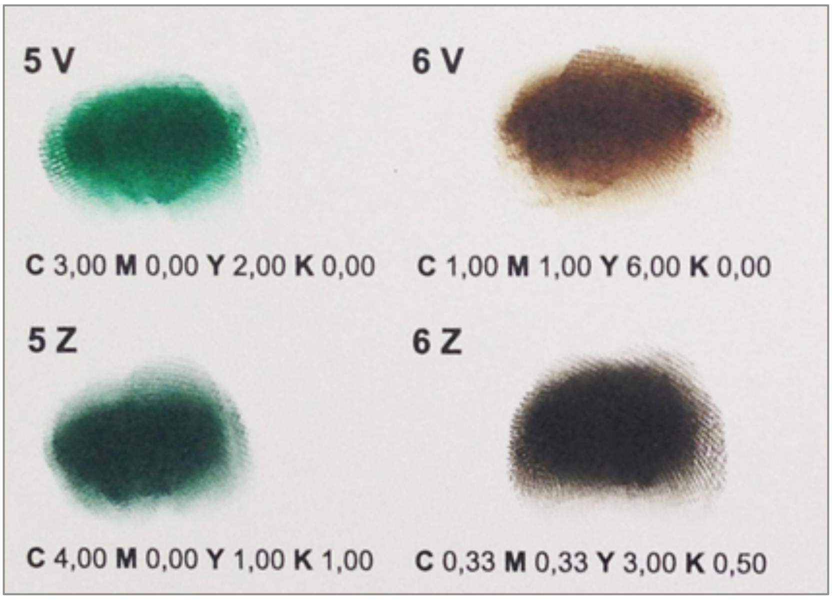


Figure 48. Dye twins for offset printing in the visual spectrum, twin dyes 5V, 5Z and 6V, 6Z

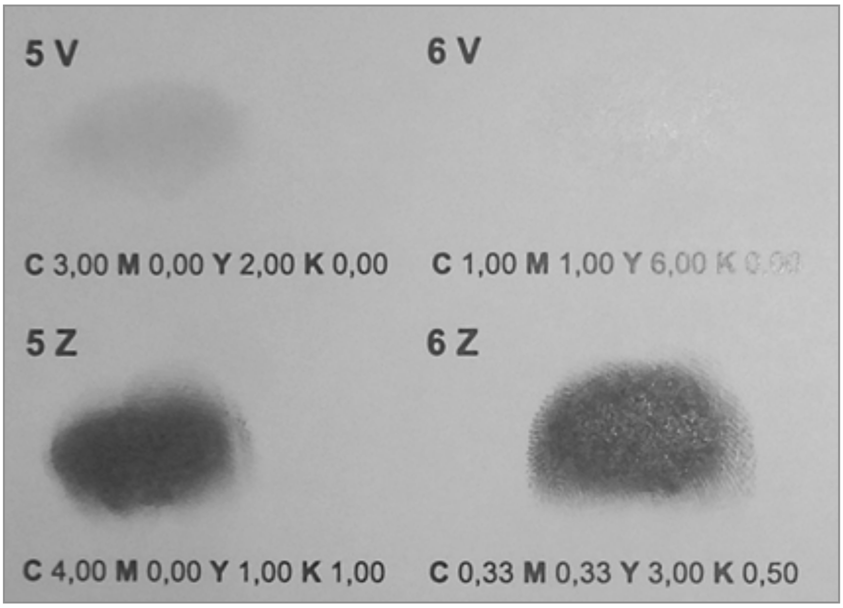


Figure 49. Dye twins 5V, 5Z and 6V, 6Z for offset printing in the IR spectrum at 1000nm

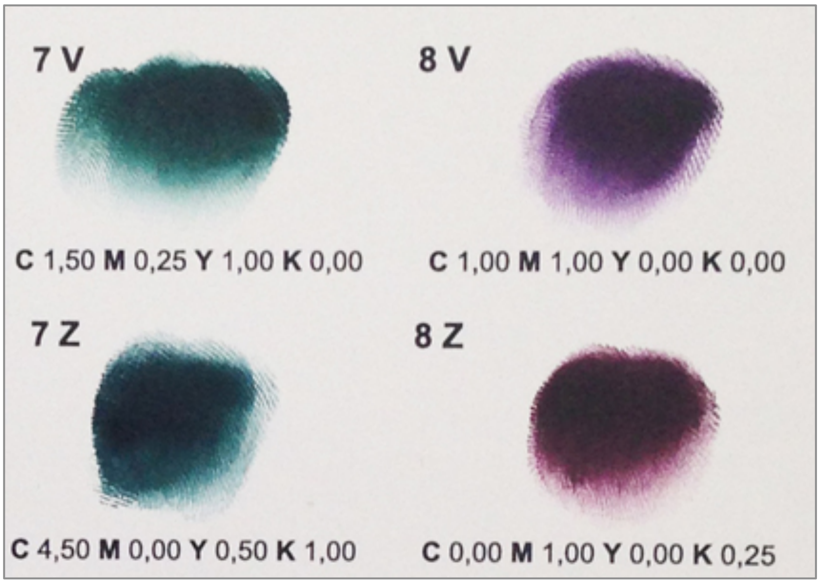


Figure 50. Dye twins for offset printing in the visual spectrum, twin dyes 7V, 7Z and 8V, 8Z

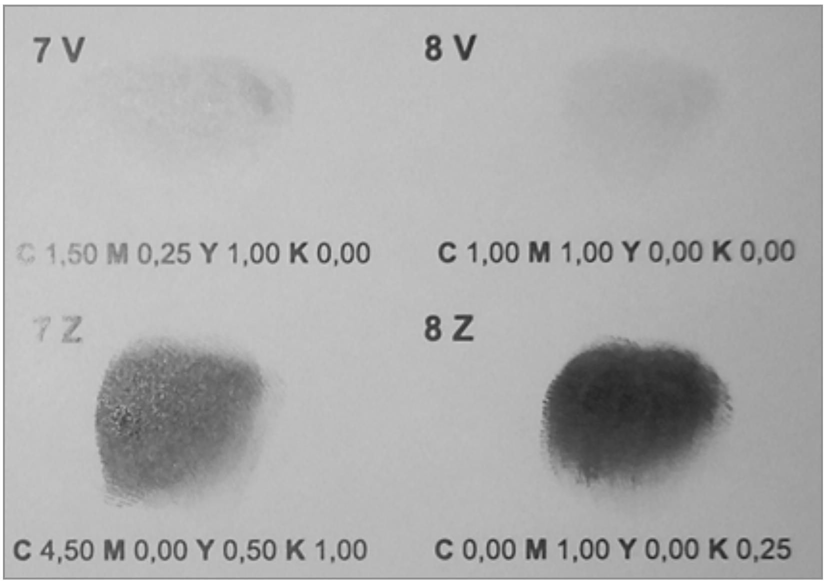


Figure 51. Dye twins 7V, 7Z and 8V, 8Z for offset printing in the IR spectrum at 1000nm

Colorimetric measurements for recipes C, M, Y, K of offset printing process dyes are measured in the visual L*a*b* values. Tested recipes are recorded by IR camera and the images of the established division of light absorption in the Z twin dyes. Fingerprint exposed to a wavelength of 1000 nm demonstrates the success of the experiment in which a pair of twin dyes give no response.

Table 10. L*a*b* values and recipes C, M, Y, K dyes 2-8

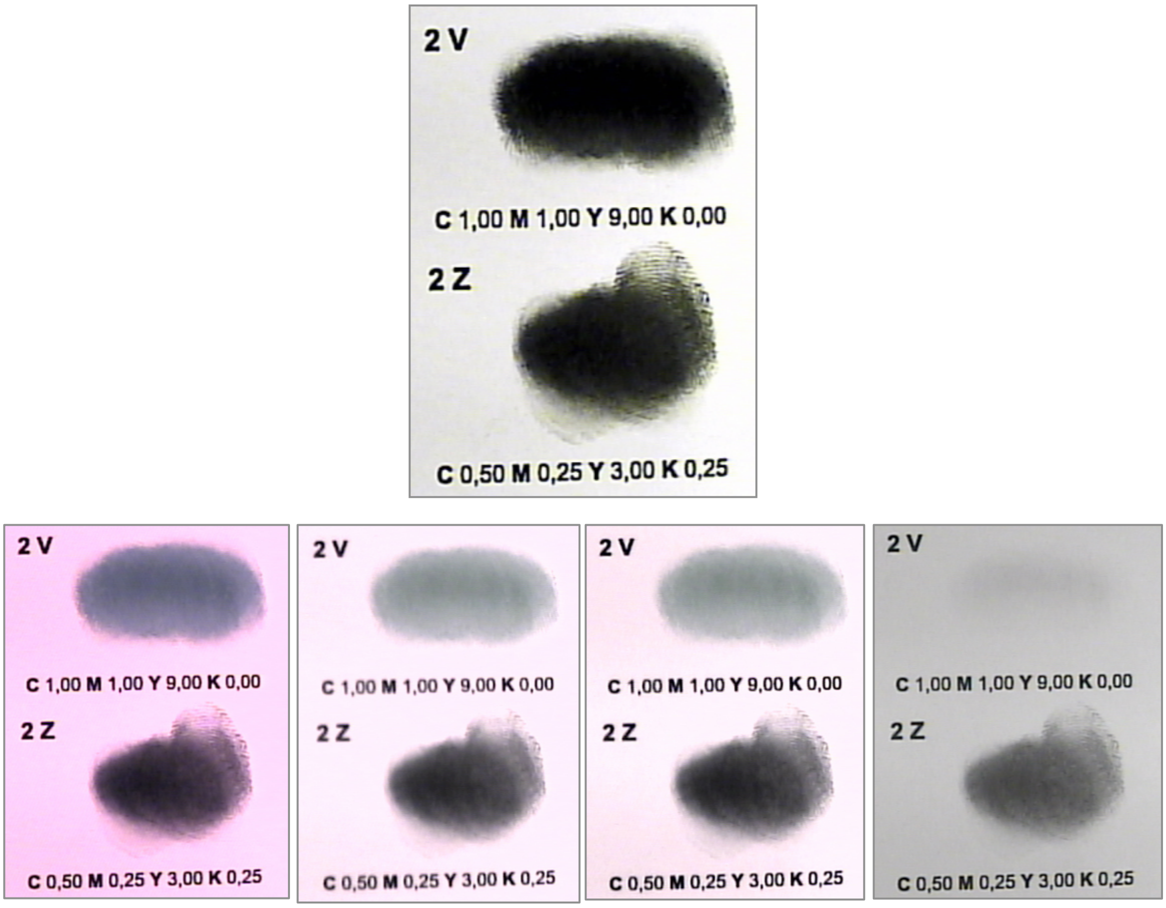
Index	L*a*b*	C, M, Y, K (g)
2V	24, -9, 10	1, 1, 9, 0
2Z	30, -8, 13	0.5, 0.25, 3, 0.25
3V	33, -3, 3	3, 1.5, 2, 0
3Z	31, -5, -2	4, 0, 0, 1
4V	20, -1, 1	2, 1.5, 2,0
4Z	26, 0, 2	0.5, 1, 1, 0.5
5V	40, -40, 10	3, 0, 2, 0
5Z	33, -7, 1	4, 0, 1, 1
6V	32, 7, 14	1, 1, 6, 0
6Z	27, -1, 5	0.33, 0.33, 3, 0.5
7V	25, -10,-1	1.5, 0.25, 1, 0
7Z	27, -8, -3	4.5, 0, 0.5, 1
8V	23, 8, -5	1, 1, 0, 0
8Z	28, 10, 4	0, 1, 0, 0.25

Control prints was conducted by barrier scanning in default wave lengths. This test is to plan the light absorption in the visual and near infrared spectrum and subtraction of each of C, M, Y, K components.

Table 11. Z values and recipes C, M, Y, K dyes 2-8 in grams

CMYK recipe(g)	Z(%)
1, 1, 9, 0	0
0.5, 0.25, 3, 0.25	39
3, 1.5, 2, 0	0
4, 0, 0, 1	66
2, 1.5, 2,0	0
0.5, 1, 1, 0.5	65
3, 0, 2, 0	0
4, 0, 1, 1	52
1, 1, 6, 0	0
0.33, 0.33, 3, 0.5	32
1.5, 0.25, 1, 0	0
4.5, 0, 0.5, 1	24
1, 1, 0, 0	0
0, 1, 0, 0.25	64

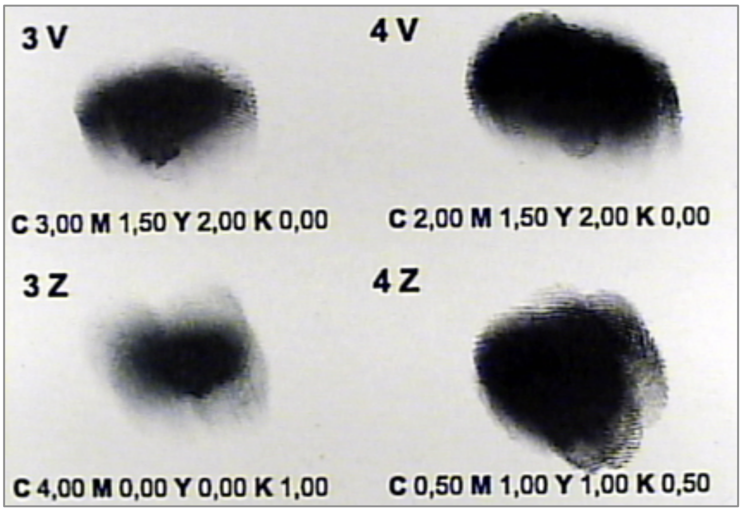
Barrier scan shows absence of certain parts of the visual spectrum. The first barrier cuts are made for the yellow component at 570 nm. Another cut at 695 nm for magenta. The third barrier is cut on the border of the visual spectrum at 715 nm for cyan. A last scan was done at 850 nm in the near infrared spectrum. At 850 nm, yellow, magenta and cyan fully reflect infrared light and the absorption takes place exclusively on the black K dye. In the last barrier latch remains only the absorption of light at 1000 nm. Barrier scanning, the differences in the absorption of light lost between the V and Z twin dyes. Imprints of 7 selected pairs of twin dyes of which only the Z twin dye remain visible above 1000 nm are shown, which proves the success of the recipe.

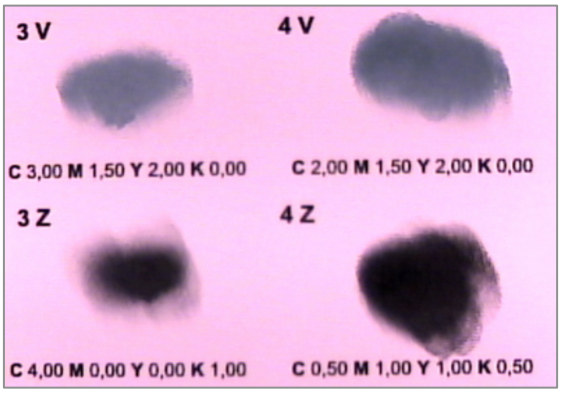


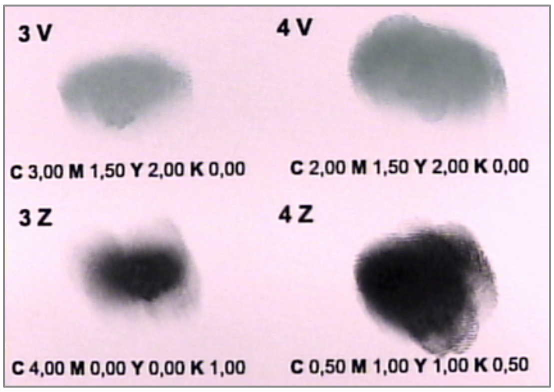
a b c d

Figure 52. Display of barrier cuts at 570nm, 695nm, 715nm and 850nm of twin dyes 2V and 2Z

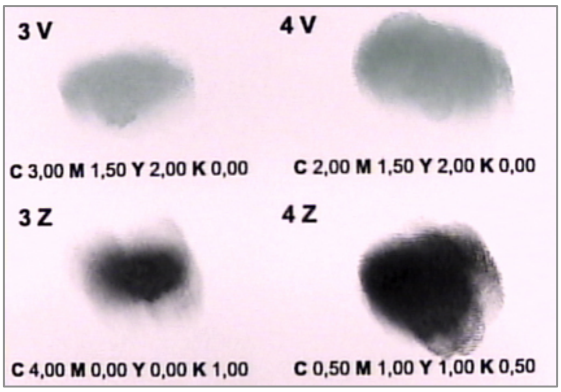
Barrier scan was performed in order to control the planned absorption of light in the visual and infrared spectrum. Thus subtraction is checked on each of the components in the process of color printing. After isolated yellow, magenta and cyan, in the final scan remains the only infrared light absorption at 850 nm. On the go it can be seen that the absorption of infrared light stays only on the colorant twin that contains K. This proves that information can be hidden within pictures placed inside the black layer color or black channels in digital printing. Other dyes which do not contain the K component and are not included in the K channel are not the carrier of the information.

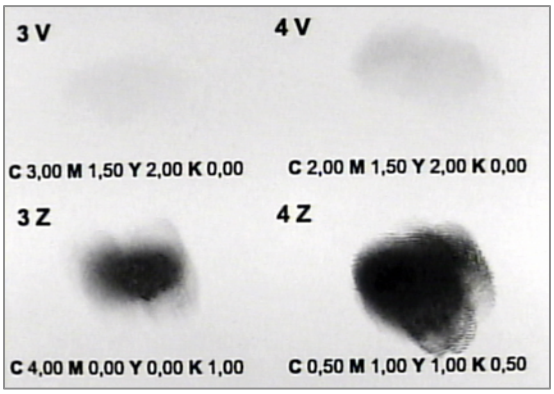






a b





c d

Figure 53. Display of barrier cuts at 570nm, 695nm, 715nm and 850nm of twin dyes 3V and 3Z, 4V and 4Z

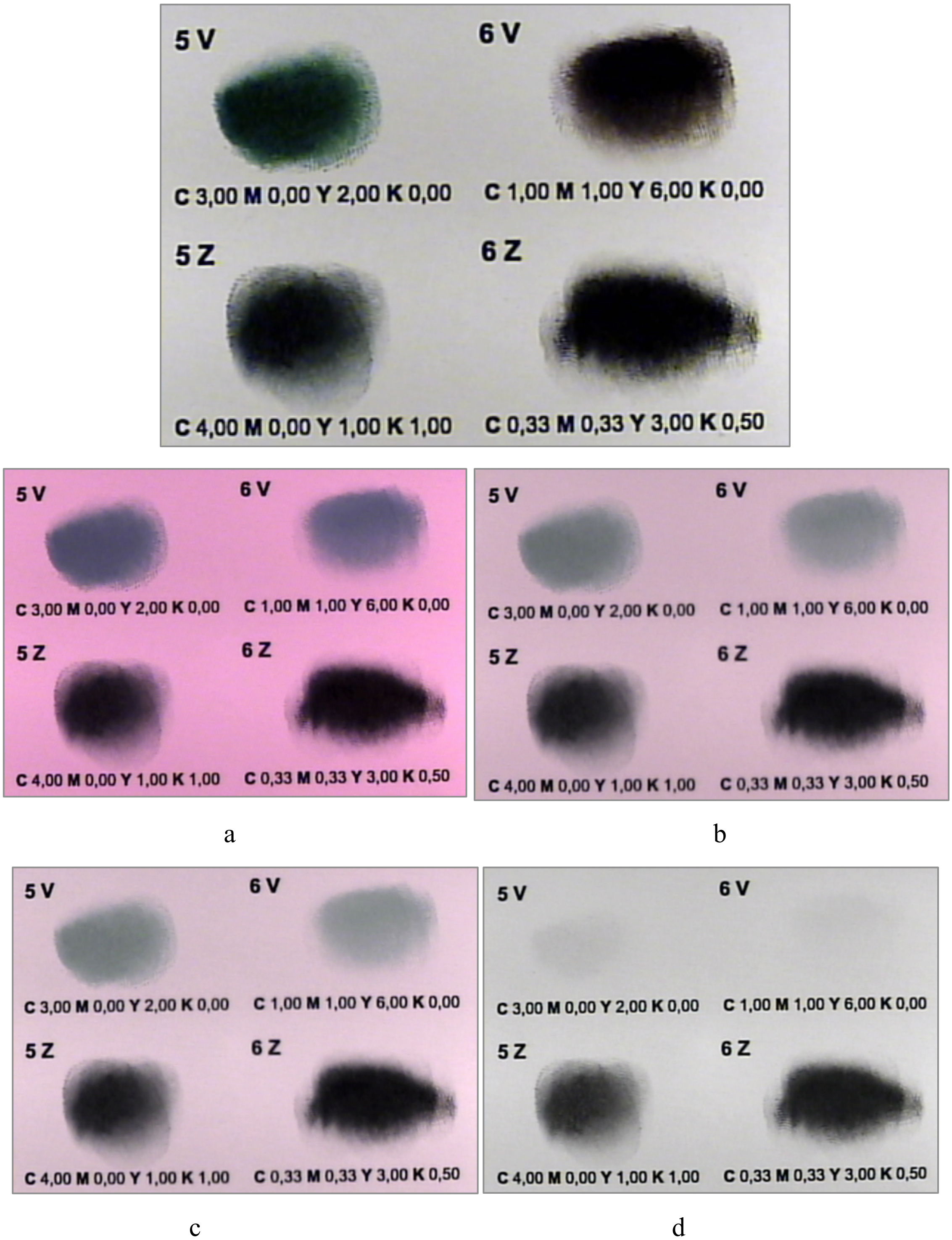


Figure 54. Display of barrier cuts at 570nm, 695nm, 715nm and 850nm of twin dyes 5V and 5Z, 6V and 6Z

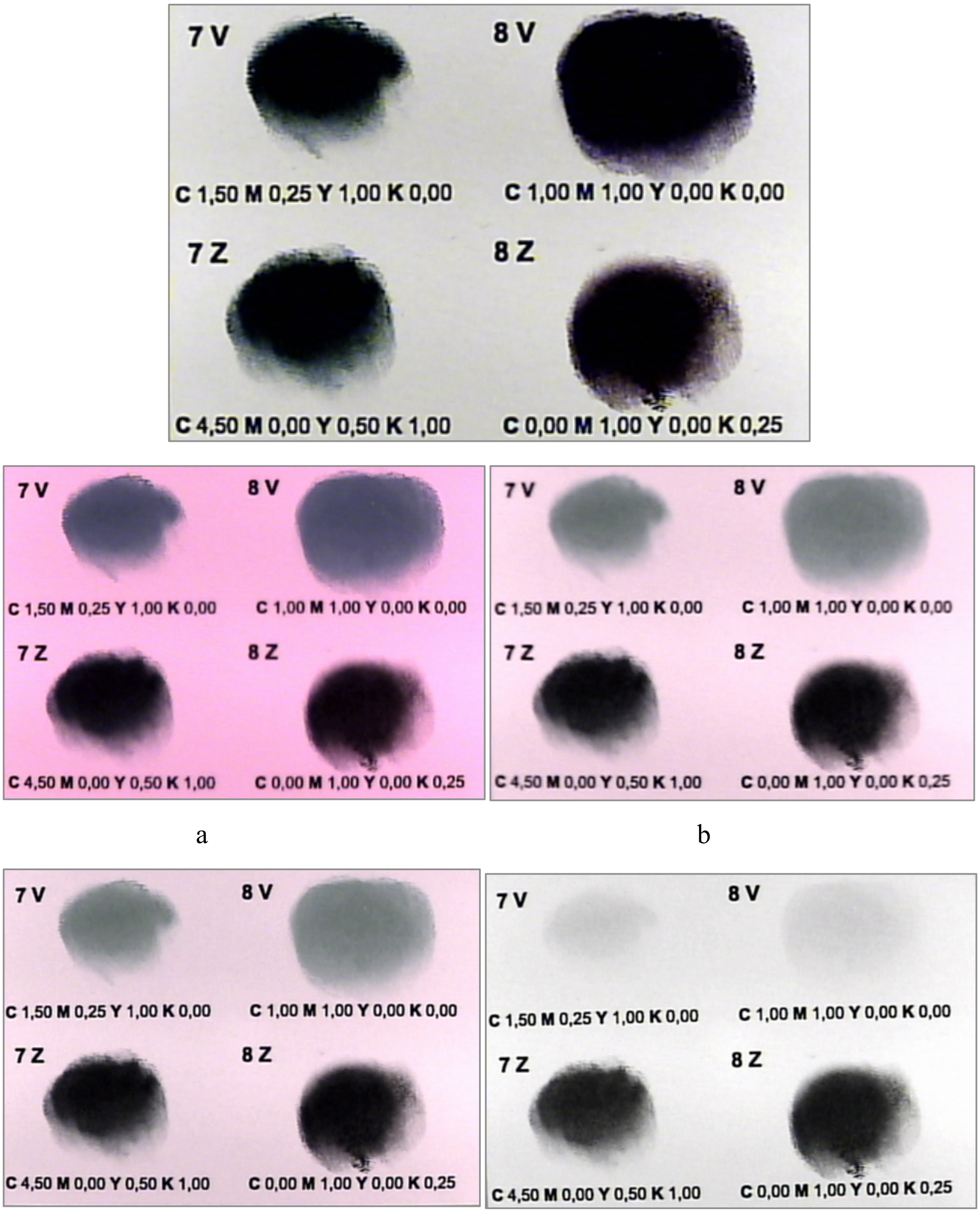


Figure 55. Display of barrier cuts at 570nm, 695nm, 715nm and 850nm of twin dyes 7V and 7Z, 8V and 8Z

3.2.2 ΔE for offset twin dyes

To control variations in shades of twin dyes, numerical value of equalization of the experience of color tone ΔE was calculated. In this work, only the color tones that have measured the difference ΔE<6 were taken into account because in offset print there is greater tolerance in the differences in shades of color of the V and Z dye. Hand mixing dyes spot has a lot less precision of the process of making dyes for digital printing and therefore respects ΔE<6 as being a good value for equalization of twin dyes. Seven pairs of twins gray, green, brown and reddish tones are shown. With the naked eye it is clear that the twin dyes 2V and 2Z have the greatest visual similarity, which is confirmed by AE = 3.45. The conclusion is that the recipe for making twin dyes dark green tone successful. In contrast, the difference between 5V and 5Z extremely high and beyond the boundaries of usability. With the naked eye 5Z seems little darker, but after colometrical measurements it is clear that to achieve the desired tone color that visually fits in twin dyes one has to do many changes in the recipe. Then the value of 7V and 7Z is also ΔE<4 which is our default required value ΔE<6 as well. Twin dyes 3V and 3Z and 4Z 4V and have value ΔE> 4 but still <6. Pairs of dyes 6V and 6Z and 8V and 8Z have a large variation in tone color visual infrared twin. In this study are eligible couples 2V and 2Z and 7V and 7Z with the smaller values ΔE, respected 3V and 4V and 3Z and 4Z.

Table 12. ΔE twin dyes 2-8

Index	L*a*b* V/Z	ΔE
2V i 2Z	24, -9, 10 / 30, -8, 13	3,45
3V i 3Z	33, -3, 3 / 31, -5, -2	5,02
4V i 4Z	20, -1, 1 / 26, 0, 2	5,08
5V i 5Z	40, -40, 10 / 33, -7, 1	32,23
6V i 6Z	32, 7, 14 / 27, -1, 5	15,64
7V i 7Z	25, -10,-1 / 27, -8, -3	3,67
8V i 8Z	23, 8, -5 / 28, 10, 4	12,26

Table 13. Choosen ΔE twin dyes and color tones of twin dyes

CMYK (g) twin dye pairs V/Z	V	Z	ΔE
1 , 1, 9, 0 / 0.5, 0.25, 3, 0.25			3,45
1.5, 0.25, 1, 0 / 4.5, 0, 0.5, 1			3,67
3, 1.5, 2, 0 / 4, 0, 0, 1			5,02
2, 1.5, 2,K0 / 0.5, 1, 1, 0.5			5,08

The difference in color tones between the visual and infrared twin dyes is visible to the naked eye. The study found that if the human eye can tell the difference between tones, creating twin dyes will not be successful. A new color gamut for offset printing which carries information in a visual and infrared spectrum was created. The principle of making twin dyes in the Z as a tool in shaping the hidden graphical elements was set. Twin dyes are suitable for conventional offset printing technique. Such protective dyes allow an infinite number of ways of creating graphics for the protection of documents. In any unauthorized manipulation of the protected document, the infrared element is lost.

3.3 CMYKIR^{DT} separation

A large number of planned colors in graphic topographic maps simulate the press with just four process colors. For digital print, technology extends the simulation connection dyes different response in the visual and infrared spectrum. One tone of color join the two dyes of different composition and properties of the two spectrums to test digital printing. Gemini dyes proofing is programmed for digital printing form for printing with process color components, according to IRD procedure. The procedure CMYKIR separation implies the possibility of manipulation response channel CMYK images in the infrared spectrum. The question is CKYKIR^{DT} separation of twin dyes for the color topographic securities.

Digital printing is more available than ever. At the same time, the manner of making fake reproductions. Small print runs have introduced the practice of digital printing. Existing software color settings do not specify the use of twin dyes. This raises the new setting for digital printing protective infrared twin dyes. In the test print to spot dyes simulate the process where two dyes do not have the same visual properties in the infrared spectrum, while exist the same visual properties of the visual spectrum. Their spectrograms should be as similar in the visual range of length from 400 to 700 nanometers. The dyes have positive values at 1000 nm, therefore the C, M, Y colorants are observed only in the visual spectrum. Twin dyes demonstrate a technology of mutual hiding of two integrated graphics printed together in the same place. Development of twin dyes that have the same visual values (L*a* b* / RGB) and the different Z values is the starting point for the calculation of Z-regression. A new mathematical model Z-regression as a special form of CMYKIR separation is proposed. The aim is to calculate a color setting with a fixed value of coverage K channels, and for all colors.

A new algorithm that will allow calculating the value of X_{25} for all shades of colors and replacing X_{25} depending on X_0 is set. This is a completely different approach to separation and has a purpose: the default value K prior to the separation of C, M, Y lets you create hidden images in reproduction that human eye can not see and is allocated for display with infrared glasses. Printing process with dyes in raster conventional technology is designed bymulticolored security printing. Given recipe color mixing process for the preparation of color twin dyes, the Z-regression can be used to create a spot of color by using the security type. The conventional color separation means the finished color settings (color settings) are available in image editing programs. For all types of printing exist decorated items that separate the image into four channels which are set to the default printing techniques.

The conventional CMYK separations only deal with adjusting the colors in the visible spectrum regardless of the characteristics of these colors in other parts of the spectrum. The difference according to CMYKIR separation is: the value of K channels is set in advance for each pixel separately, before the start of the separation. Value with the information coming from the external image has become a guiding principle for future K channels. As in conventionalised CMYK separation, and CMYKIR separation, playback will visually show K channel. In CMYKIR separation, the K channel is shown only when we look at the image with an infrared camera. Specifically, carbon black dyes have strong absorption in the infrared spectrum. In the infrared spectrum, speaking from the surveillance camera or other infrared camera will not see cyan, magenta, and yellow component in the reproduction. There are models that have worked CMYKIR separation. There are no color settings which would solve the hidden default image in the K channel. CMYKIR separation gives the solution of controlled management with K channel.

3.3.1 The process of mixing color twins for test printing

The share of individual dyes in pairs of twin dyes are set to zero and 25% of the value of black dyes. Standard models to describe the color are added value Z. The value of Z is read at 1000 nm. In pairs V and Z dyes are derived experimentally by printing. Numerical visual equalization experience color tone calculated the value report. In this experiment was used the process of dyes that simulate stop dyes through trial digital printing. For four color tone in the experiment are made double twin dyes for each of the color tone. The value of the infrared twin: the value of Z = 25 is set for all dyes with the response in the IR spectrum. Twin dyes are defined through the process of dyes: cyan, magenta, yellow, and carbon black. Using GCR method increased the K content to the desired Z value of a reduced share of CMY components.

The offered set of twins will be used as inputs in the regression analysis and calculation of parameters in between. We receive a single raster printing procedure for determining the state of a pixel at 25% coverage carbon black channel. C0 (cyan), M0 (magenta), Y0 (yellow) of the pixel coverage percentages are the only input to calculate the CMY value in the range from zero to 25% coverage of the image I. These values are formed conventionally in the separation of the RGB / CMY for the general " non ". Color management is provided solely for the viewing area and does not refer to any specific requirements for the infrared area.

3.3.2 Color profiles of color twins in digital printing

In digital printing are printed sample pairs of different color profile. Graphic programs have defined options of color settings, but in creating new profiles of dye twins, the default color management is turned off. Color management defines its own color space settings. In another experiment, they conducted measuring and optimizing equality of twin dyes pairs for the default color tones. The purpose of the experiment is to achieve a two-tone color that visually look as similar, but has different absorption of light in the infrared spectrum. Among the created pairs of twins, the twin color dyes has the value Z = 0 and Z has the twin color value Z = 25%. Recipes for couples dyes with the same visual experience, but a different response in the infrared spectrum are set. For all the color of water there are numerical values of CMYK and L*a*b*.

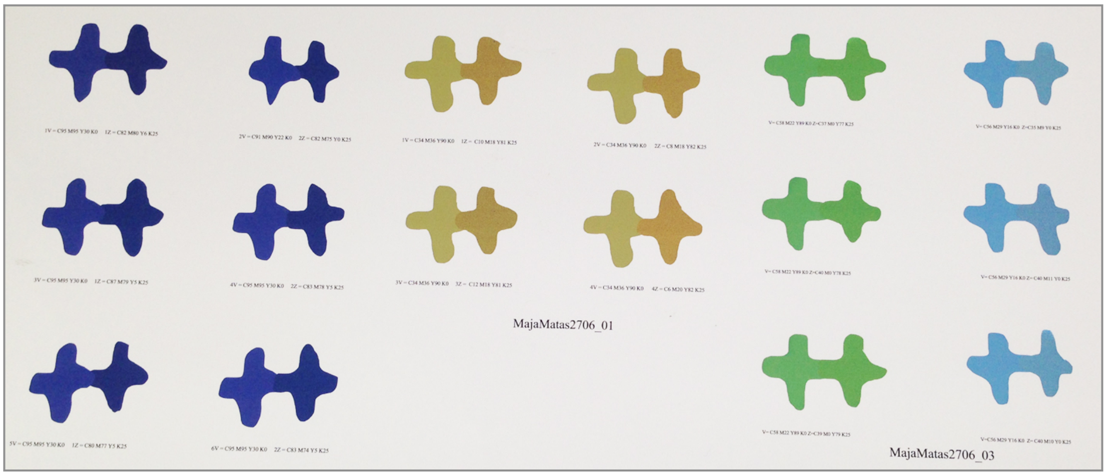


Figure 56. In the visual spectrum - dye twins process dyes for digital printing

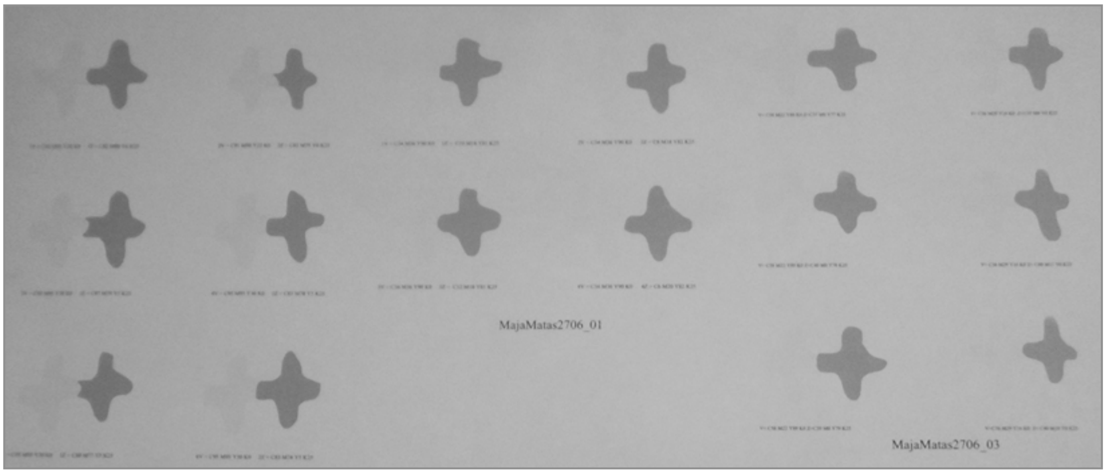


Figure 57. In the infrared spectrum at 1000nm - dye twins of process dyes for digital printing

An experiment in which the printed patterns twin dyes measure twins serves to determine the degree of matching of the visual tone and for the spectrophotometer X-Rite SpectroEye to measure ΔE parameters. Measured color values with an accuracy of at least three measurements for each tone officers. The measurement results in determined deviation ΔE. Scanning system is set at 25% coverage. These relations are not used for coverage of over 25%. Extensive experiments of measuring the infrared spectrum showed that the hidden image was sufficiently recognizable by default graphics with 25% of the value Z. Therefore, the value of the coverage of the Z graphic is continuously reducing the maximum opacity of 25% before the CMYKIR separation. Darker and lighter areas are obtained as a condition between X_0 and X_{25}.

Table 14. Values L*a*b* and recipe CMYK for dye twins of process dyes

Name	C, M, Y, K	L*a*b*
Dark blue 1V	95, 95, 30, 0	41,46 7,00 -34,21
Dark blue 1Z	82, 80, 6, 25	37,49 7,46 -31,37
Dark blue 3Z	87, 79, 5, 25	37,86 4,36 -32,15
Dark blue 4Z	83, 78, 5, 25	38,02 5,05 -31,61
Dark blue 5Z	80, 77, 5, 25	38,18 5,06 -30,14
Dark blue 6Z	83, 74, 5, 25	38,37 3,07 -30,78
Dark blue 2V	91, 90, 22, 0	41,58 6,62 -36,72
Dark blue 2Z	82, 75, 0, 25	37,67 5,97 -32,82
Brown 1V	34, 36, 90, 0	67,09 -6,97 38,37
Brown 1Z	10, 18, 81, 25	63,24 0,06 39,32
Brown 2Z	8, 18, 82, 25	63,68 1,46 40,37
Brown 3Z	12, 18, 81, 25	62,93 -1,03 37,49
Brown 4Z	6, 20, 82, 25	63,99 3,66 40,41
Green 1V	58, 22, 89, 0	64,03 -30,87 31,17
Green 1Z	37, 0, 77, 25	63,68 -28,66 34,27
Green 2Z	40, 0, 78, 25	63,37 -29,03 33,67
Green 3Z	39, 0, 79, 25	63,95 -29,28 34,30
Light blue 1V	56, 29, 16, 0	63,45 -9,95 -25,43
Light blue 1Z	35, 9, 0, 25	64,77 -9,78 -18,06
Light blue 2Z	40, 11, 0, 25	63,39 -8,15 -19,57
Light blue 3Z	40, 10, 0, 25	64,23 -9,94 -19,07

Table 15. Values ΔE of twin dyes at Z=0 and Z=25

Twin dyes	Z=0	Z=25	ΔE
Dark blue 1V and Dark blue 1Z			4,9
Dark blue 1V and Dark blue 3Z			4,56
Dark blue 1V and Dark blue 4Z			4,82
Dark blue 1V and Dark blue 5Z			5,24
Dark blue 1V and Dark blue 6Z			5,57
Dark blue 2V and Dark blue 2Z			5,19
Brown 1V and Brown 1Z			8,22
Brown 1V and Brown 2Z			8,94
Brown 1V and Brown 3Z			7,49
Brown 1V and Brown 4Z			11,14
Green 1V and Green 1Z			3,58
Green 1V and Green 2Z			3,55
Green 1V and Green 3Z			4,09
Light blue 1V and Light blue 1Z			7,4
Light bluea 1V and Light blue 2Z			6,36
Light blue 1V and Light blue 3Z			6,5

3.3.3 Determining ΔE for process dyes

Digital determination of tones for twin dyes has a higher degree of precision and the possibility of minor and faster iteration of hand mixing spot colors. In order to check the color profiles and their acceptability for impressing The pictures, made the instrumental measurement of their difference in color tone. Variations in tones set ΔE numerical values are lower in twin dyes digital printing. ΔE obtained values vary for the same color tone when printed in different printing press or on different paper. The values vary if the same color tone is printed on other positions. This proves uneven coating dyes in the printing process and not the perfection of the printing press.

When we want to hide the text, it uniformly needs to be implemented in the entire territory of the infrared spectrum. Such task of "uniformity" entails that all spectrums end the Z point to 25% coverage. We use 25% of twins in the infrared spectrum, Z value is the same for all colors in the infrared spectrum, regardless of whether it is blue, light blue, black or green. The experiment shows that the value ΔE is drastically different for the same color tone with digital print on different paper and printing machines. For playback of rich tones, tones with greater ΔE can be useful in setting up dual information. From this measurement is clear that there is a a need of new setting colors to correct printed color tones. At a press fit tones twin dyes are printed in different positions. The resulting ΔE values can vary for the same tones of colors printed in different positions. This is an indication of errors in the preparation of printing forms and coats in the printing process. If you change the paper, the original dyes requires new recipe of composition dyes resulting from the process range. Criterion decision "visual equality" twins is based on minimization procedure ΔE. The discussion extends to print when the same twins use two different papers. It turns out that it is necessary to carry out re-stamping and determine new recipes of twins. For each combination of "paper / color dyes", a new recipe of mixing dyes is determined which will result in new parameters of Z-regression.

Different types of paper were used as would be seen to be the same recipe twin dyes behave in other conditions of the press. Each paper and printing machine produces different results. It's made more proofs in digital printing with 4 different colors. Each box has a different color tone value $CKYKIR^{DT}$, with differences of 1% of the next adjacent sample. Within a segment color tones are from left to right changed by adding cyan process dyes, and from top to bottom by adding value to magenta. Within all segments of one color gradually is increased the share of yellow color from one of the upper to the lower column.

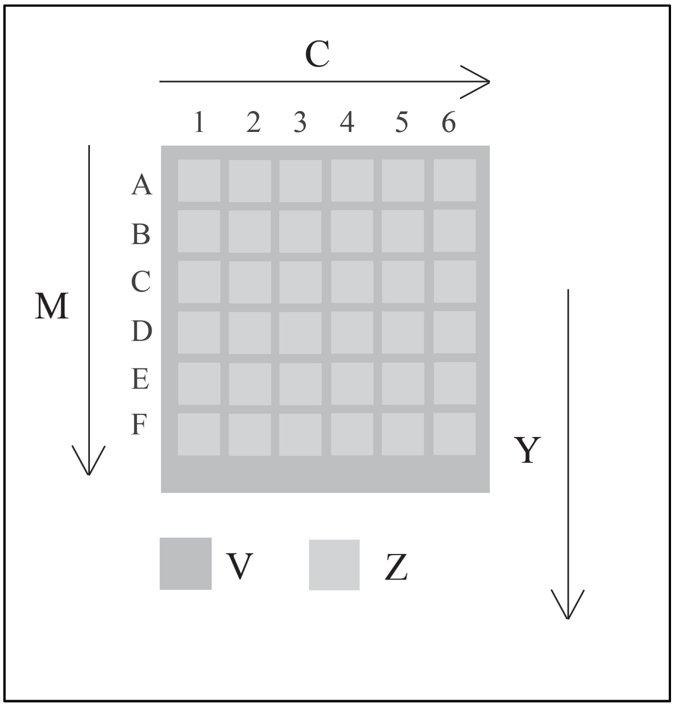


Figure 58. Iterations within a square that represent the tones of one color

In the first iteration are printed 216 iterations in dyes for one tone color. For all four colors, this combination of 864 tones of paint in the first iteration. The experiment took into account patterns of tones that had the minimum ΔE. From chosen samples was created a new iteration, all this ΔE were unsatisfactory. The selected pattern is set in the central position, and from it are derived other samples. Experiments were carried out on two different securities. Measured different L*a*b* values of the prints, the changing of paper. It has been shown that the same recipe colors behave differently depending on the type of paper and print. Therefore, each recipe mixing twin dyes $CKYKIR^{DT}$ separations related to the type of printing form.

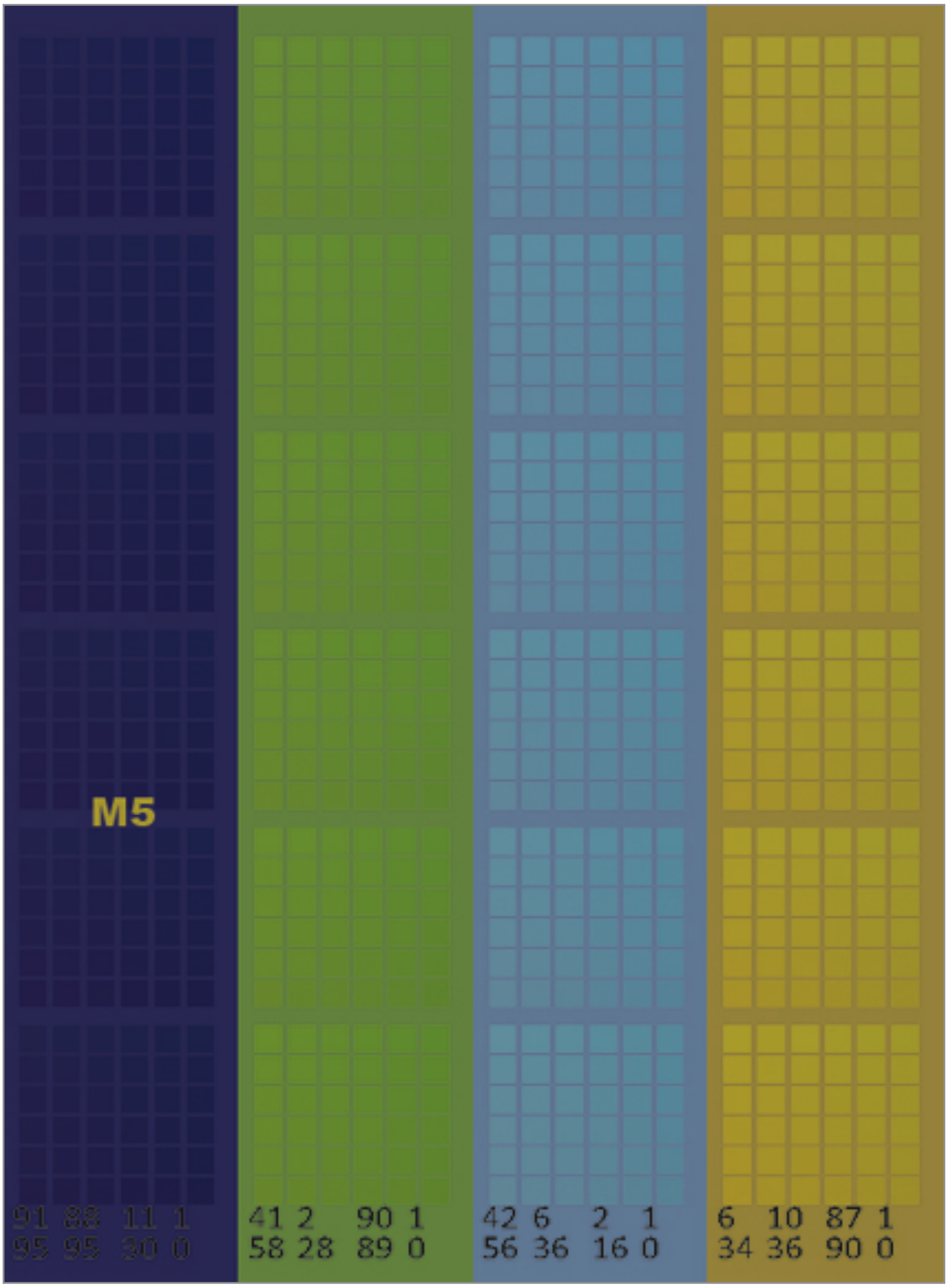


Figure 59. Settinge ΔE values for four colors

For all the iterations that contain hundreds of different color tones, for evaluating differences in shades, crucial is the human eye. Tones that are visually matched and thereby have little value measured differences in color, are ideal for forming graphics that carry hidden information in the visual field, which is revealed in infrared spectrum using the ZRGB apparatus.

Experimental methods are defined by color twins Z and V, and IR formulations were determined by entering K at 40%. Five pairs of twin dyes color tones from the cartographic world were mixed: dark blue, light blue, green, brighter brown and darker yellow. Figure 60 shows pairs of twin dyes for digital printing. In pairs left twin means in dye, and right with dye. The colors whose terminology is moving from the world of making plans and maps are used: dark blue, light blue, green, brighter brown and darker yellow. It uses 40% twin equal value for all colors in the infrared spectrum, regardless of the color tone. The table shows the L*a*b* values of all five pairs of twin dyes. From the values is visible the minimum deviation between the values Z and L*a*b* components.

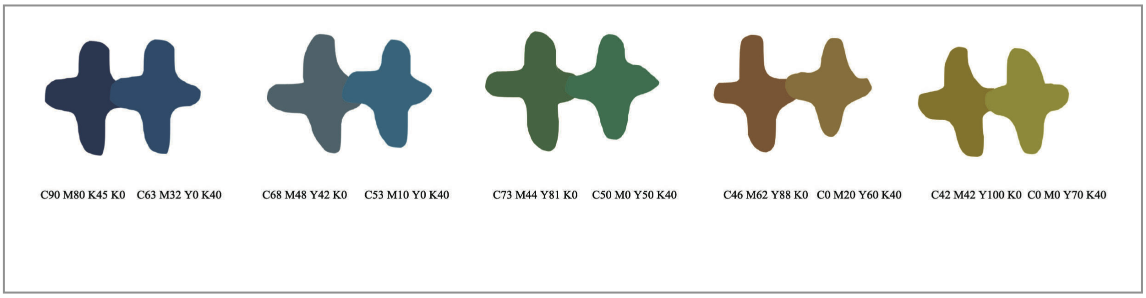


Figure 60. Pairs of twin dyes in the visual spectrum

Table 16. L*a*b* values of twin dyes

	V			Z		
Name	L*	a*	b*	L*	a*	b*
Darker blue	45,19	-5,29	-25,41	44,18	-5,17	-21,11
	44,86	-5,31	-25,46	44	-5,06	-21,26
	44,6	-5,31	-25,78	44,05	-5,12	-21,68
	44,8833333	-5,3033333	-25,55	44,0766667	-5,1166667	-21,35
Lighter blue	52,31	-12,86	-15,1	52,06	-10,65	-16,17
	52,11	-12,94	-15,07	51,97	-10,69	-16,1
	52,1	-12,91	-15,6	51,72	-10,81	-15,99
	52,1733333	-12,903333	-15,256667	51,9166667	-10,716667	-16,086667
Green	54,88	-24,02	9,07	53,64	-23,41	11,11
	55,07	-24,43	9,12	53,87	-23,73	11,4
	54,92	-24,3	9,6	53,77	-23,59	11,64
	54,9566667	-24,25	9,26333333	53,76	-23,576667	11,3833333
Lighter brown	57,69	5,15	23,27	59,35	6,62	26,63
	57,83	5,14	23,71	59,15	6,82	26,25
	58,27	4,77	23,68	58,93	6,8	26,59
	57,93	5,02	23,5533333	59,1433333	6,74666667	26,49
Darker yellow	66,34	-7,14	39,47	64,65	-6,18	36,98
	66,4	-7,09	39,72	64,6	-6,15	36,75
	66,34	-6,68	39,47	64,62	-6,12	36,46
	66,36	-6,97	39,5533333	64,6233333	-6,15	36,73

Table 17. ΔE of twin dyes Z=0 and Z=25

Name	CMYK V	CMYK Z	ΔE V i Z
Darker blue	90 80 45 0	63 32 0 40	3,71
			4,02
			3,84
			3,856666667
Lighter blue	68 48 42 0	53 10 0 40	2,89
			3,04
			2,27
			2,733333333
Green	73 44 81 0	50 0 50 40	2,8
			2,09
			1,51
			2,133333333
Lighter brown	46 62 88 0	0 20 60 40	3,97
			3,95
			4,05
			3,99
Darker yellow	42 42 100 0	0 0 70 40	3,65
			3,48
			3,49
			3,54

Spectrogram (Projectina Docubox) describes precisely how to achieve the best results in the equalization of the values of two dyes. No matter what the principle of equal experimental mixing of dyes, the spectrogram shows that they do not always have all the values of the individual called the composition of the mixture up or down, or dyes C, M, Y, K are treated separately in the colorimetric measurements and setting recipe for twin dyes. The two dyes have firmly determined rates of absorption of light at 1000 nm. C, M, Y components and dyes in mixture have no absorption in the visual spectrum, hence their spectrograms in the range of from 400 to 700 nm are very similar. What is also similar to the visual value of things in accordance. Spectrogram indicates the places where the need for correction composition formulations of dyes in the next iteration is. The paper spectral analysis is extended to the near infrared spectrum. Colorimetric measurements show the results for five twin pairs of color table 16. and 17. The graphs area of 400 to 500 nm is defined proportion of the components Y, 500 to 600 of the compound M, 600-700 nm C. Area 700-850 is skipped in the range of 850 to 1000 nm to observe K component in the near-infrared regions.

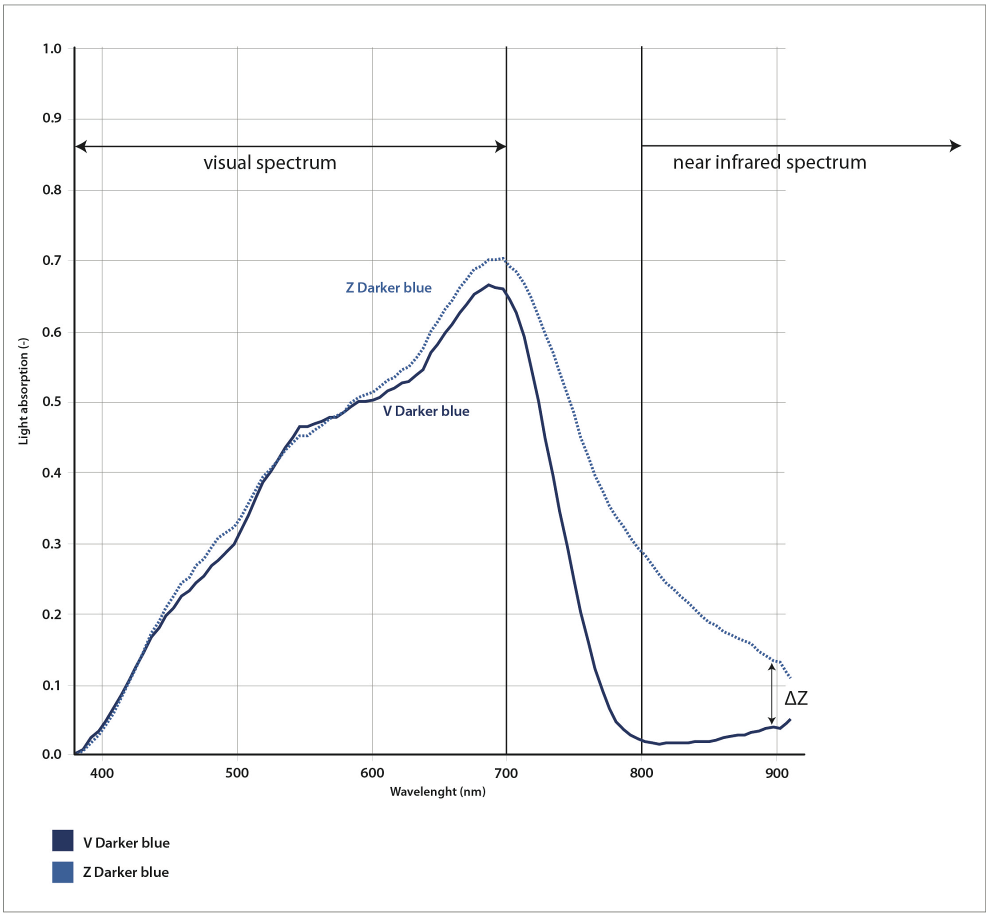


Chart 1. Spectrogram color twin dyes named: Darker blue; ΔE = 3,85 (Table 17.)

Chart 1 shows the spectrometer twin dyes a darker blue color tone recipe V: C90 M80 Y45 K0 and Z: C63 M32 Y0 K40. On spectrograms dashed line shows the curve Z dyes. Solid line shows the curve in V dyes. In the visible region of 400-700 nm, it is evident that the two curves almost overlap, while the 850 nm near infrared is completely separated. This is the proof that the two dyes in the visual spectrum look the same in the NIR (near infrared) range, even if the information loses colorants, dyes and Z remains visible. Visibility with dyes is determined by the 40% share of K components in this paper. After measurements were obtained, a clear guidance on which way the recipe of twin pairs can be altered to achieve the best results. The visual part of the spectrum in the range of from 400 to 500 nm observes Y component colorant twins. For color tone darker blue conclusion is that the dyes almost overlap which is a very good result and means a visual tie. Spectography determines what changes the recipe needs. The graph shows that it is necessary in the recipes in the twin minimally add components Y or Z, and in the recipe twin minimally subtracted share Y dyes to curves overlap. This principle is in the range of 500 to 600 nm visible minimum deviation in the proportion of M components. Increasing M components with twin dyes or reduction of M component in the dyes, and a greater visual equivalence between color tones. From 600 to 700 nm, we observe the maximum deviation which is therefore in this area needed to increase the proportion of C dyes for the twin dye and reduce the proportion of C dyes in the recipe with twin dyes. In the area of 850-100 nm deviation curve at the chart is very high, which is positive because it shows that the visibility achieved divergence of K shares in the infrared spectrum.

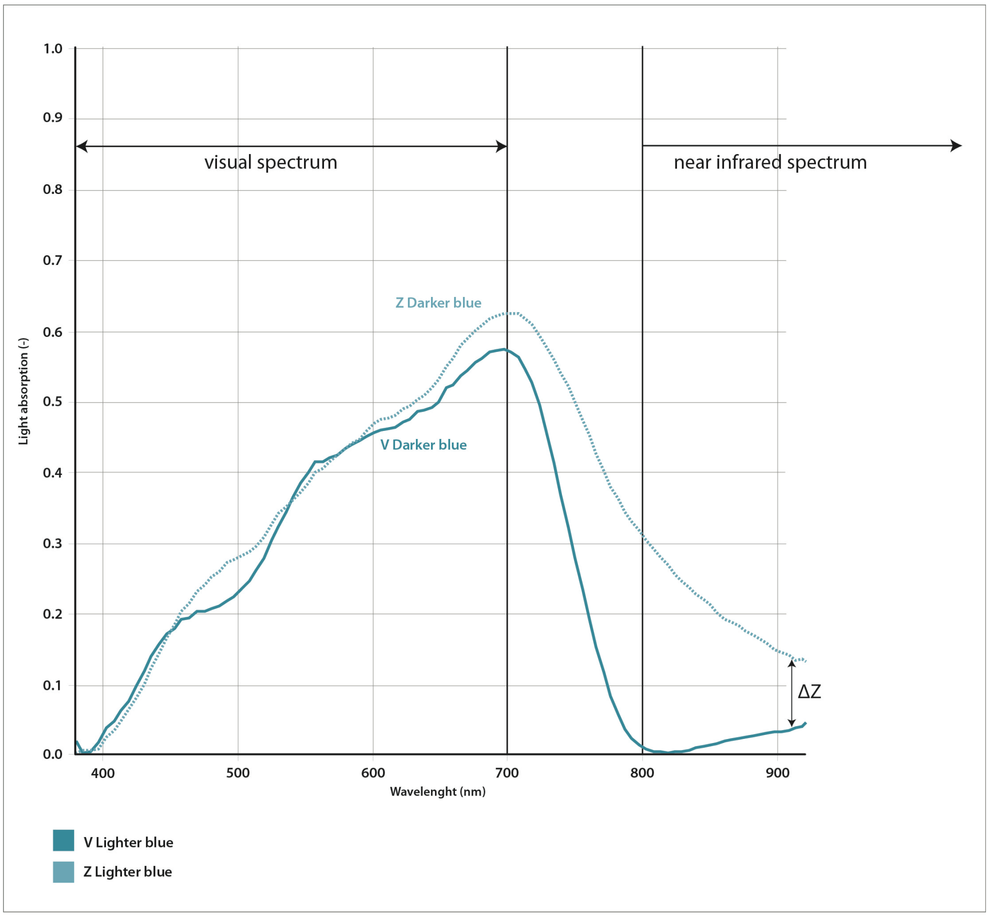


Chart 2. Spectrogram color twin dyes called: Lighter blue; ΔE = 2,73 (Table 17.)

Chart 2 shows the spectrographic measurements of twin dyes for the bright blue color tone. The area from 400 to 700 nm is observed as a whole visual range, but in certain areas: 400-500 nm, 500-600 nm, 600-700 consider share individual C, M, Y, K and Z components of the colorants. As in the previous example, it matches very well in the dyes Y at 400 to 500 nm. The result can be improved by adding Y share in V twin and reducing Y shares for Z twin dye. In the area of 500-600 nm, the difference is reduced and it is necessary in much smaller amounts to add in recipes M dye in the V twin and reduce M shares for the Z dye. In the field of 600-700 nm it is necessary to reduce the share of C in Z dyes or increase the C content in V dyes. The proposed changes are in order to achieve visual uniformity of color tones. In the area of 850 to 1000 nm is visible a clear difference response between two dyes in the infrared bright blue color tone.

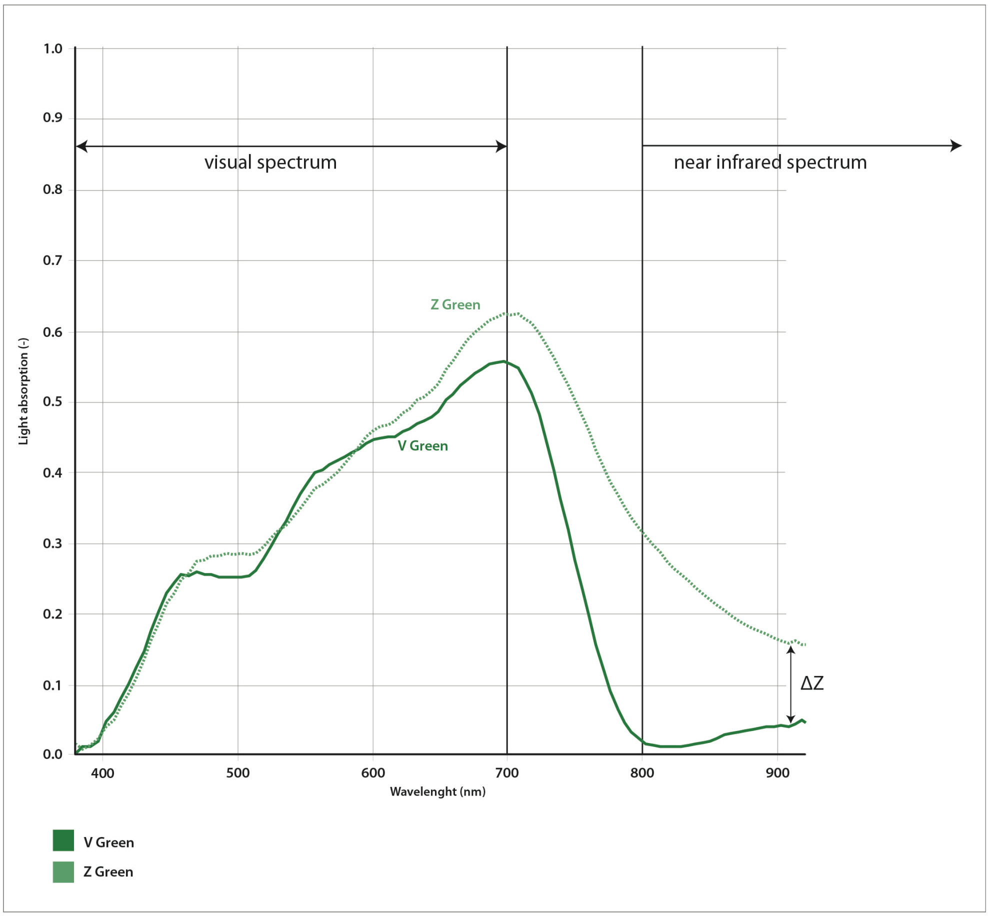


Chart 3. Spectrogram color twin dyes called: Green; ΔE = 2,13 (Table 17.)

Chart 3 shows the relationships in the recipes in the Z twin dyes green color tone.

In the area of 850-100 nm it clearly shows the curve moving away and thus having a different visual experience in infrared area. The differences are with the naked eye and are not a large presentation at the spectrogram in clear proportions. The recipes in the dyes is to raise C components and reduce M coponents to achieve better overlap of the V and Z curves. In contrast, the same result is achieved by reducing C and an increasing M component in the recipe of Z twin.

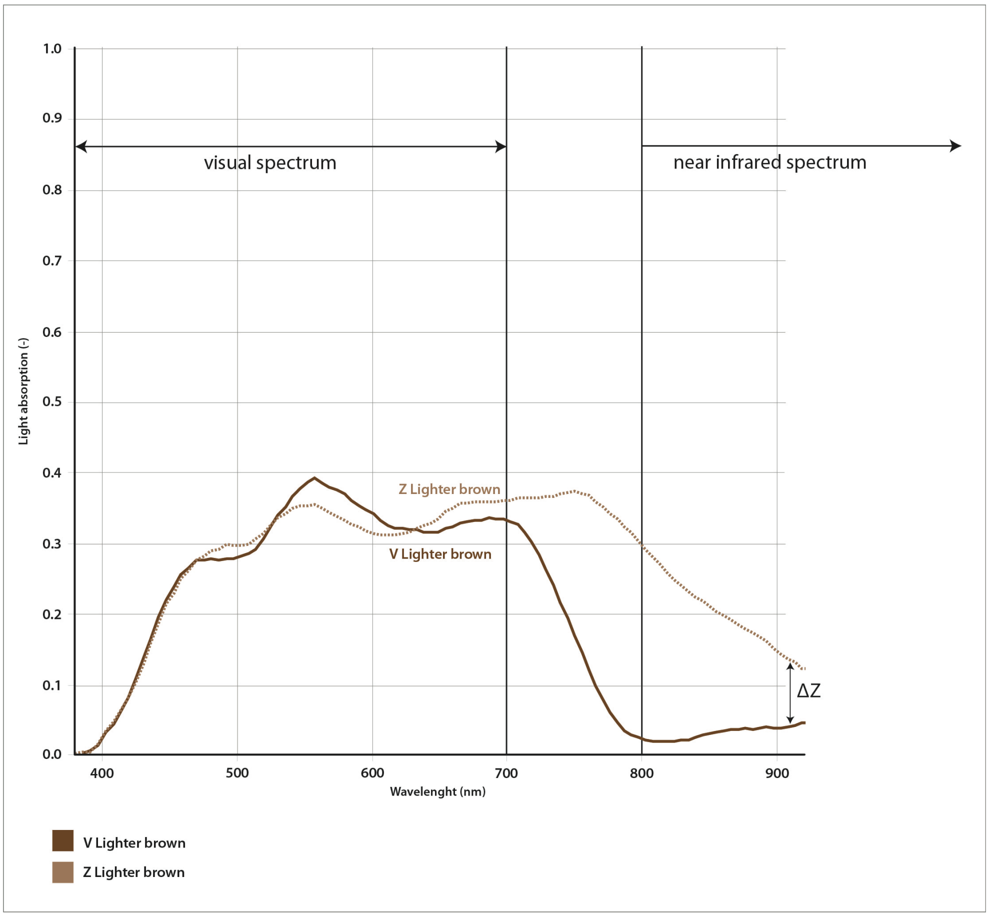


Chart 4. Spectrogram twin dyes color names: Lighter brown; ΔE = 3,99 (Table 17.)

Spectrometer of lighter brown color tone shows great overlap in the V and Z recipes for the Y component of twin dyes, while at 500 nm leads to smaller differences. From 500 to 600 nm, it is necessary to increase the share of M in Z recipes or reduce M share in the recipe of the V dye twin, and on 600-700 increase the C share in the V recipe or reduce the C in the recipe for Z dye.

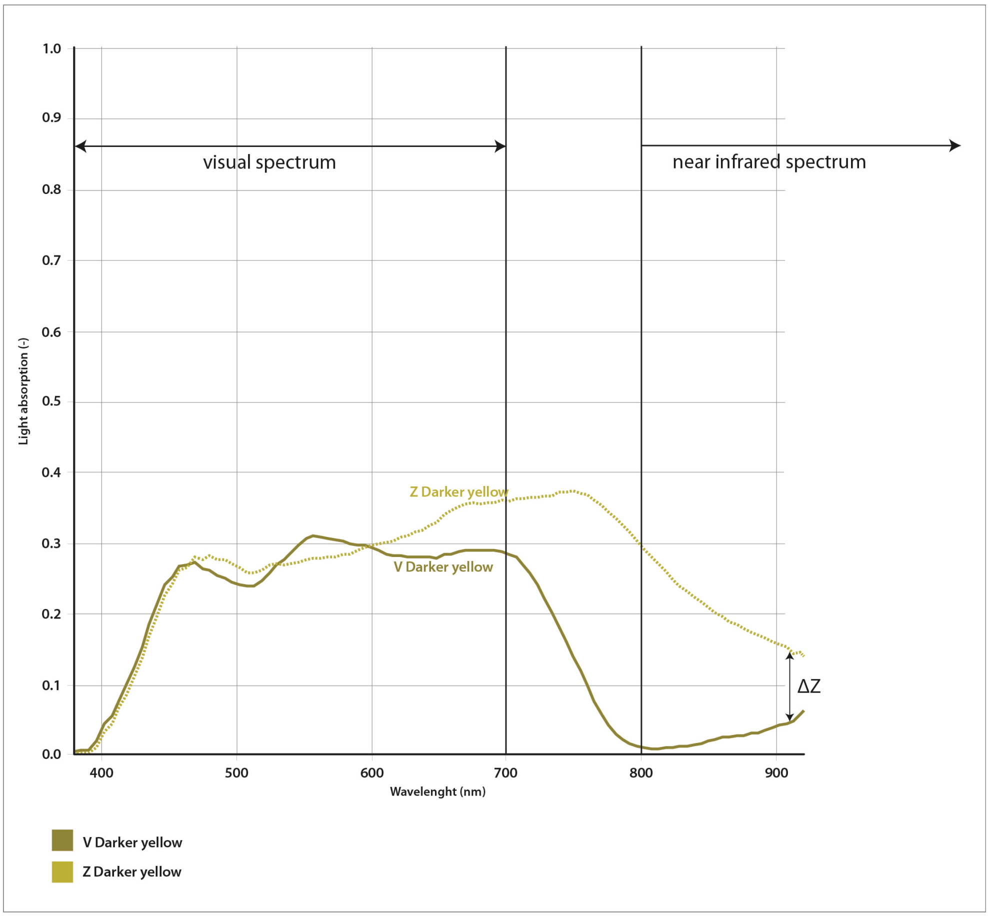


Chart 5. Spectrogram color twin dyes called: Darker yellow; ΔE = 3,54 (Table 17.)

On spectrograms darker yellow color tone is observed to apply the same conclusions as for dyes of lighter brown color tone. From 400 to 500 nm, the curves overlap, 500-600 nm is required or increase the share of M in Z recipes or reduce M share in V dyes, and 600-700 nm increase in C share of V dye or reduce the C share in the Z dye. The space of overlaping of the curves from 400-700 nm marks the value ΔE shown in Table 17.

From 850 nm the ΔZ space between the curve V and Z dyes was observed. ΔZ indicates the differences in the shades of two colors in the near infrared spectrum. In the visual spectrum is ΔE difference in color tones very small, which proves that it is achieved for the two dyes to visually look the same, to have the same visual experience. Two with the color of 850 nm are visually substantially different in absorption of light.

Infrared graphics in cartographic system is a new area of protection at all stages of development. This dissertation introduces methods of connecting the two files, depending on what kind of results we want to achieve and what are the technologies available. With infrared graphics protection is achieved through all parts of the printing process. Protection must not be visible to the naked eye. At the same time is achieves the control of the validity of mixing certain colors and provides the same color tone in all reproductions. On all the maps we want the same color tones indicating a large area like those that indicate areas of forests and meadows, rivers and the sea. And in that area would infrared graphics have a new role on large projects. Any error made in shades of color printing gives prints a result which makes the hidden Z visible.

3.4 **Colors and dyes for Infrared cartography**

The experimental chapter presents the processes of creating twin dyes defined through all production stages of making it necessary to achieve the quality of the record. In this chapter, through the design, the use of twin dyes has been performed by hiding the graphic elements through requests. Infrared security print as an extension of the printing technology is introduced.

Document multiplication and editing technology is so developed that it requires a new dimension of protection in the expanded space. Digital printing and modern scanning technology make it difficult to identify original copyrighted documents apart from counterfeit. Automation has entered the printing industry, which is why various top-quality protection proposals have to be developed. A new information system with infrared features was created.

The adding of infrared properties to dyes in the prepress with the goal of the distinction of originals from copies is suggested. For all the given color tones, twin dyes which have the same visual value and different responses in the infrared spectrum are made. Visually, the two dyes are composed of different recipes, different compositions, and to the naked eye they look the same. By using infrared devices such as ZGRB cameras, two dyes can be separated so that one remains visible in the infrared spectrum and the other disappears.

Today's copying technology of maps uses color tones prescribed by law. Since the official geodetic practice has only set RGB color values, it is possible to make double dyes for those colors which have the same response in the visual spectrum and different in the infrared spectrum. Based on the equalization of the spectrum of pairs of dyes in the visual part, a proposal of the degree of absorption of light in the infrared part is given. The procedures of dye twins are introduced for all the colors used to display the cartographic system in the print of maps. Each color is associated with two different dyes with different possibilities of absorption of light in the infrared spectrum. Maps and plans are printed with spot dyes mixed before printing. For test printing is used digital print which simulates spot color. This is a raster simulation with process colorants. In this work, dyes for maps are treated as spot colorants. New twin dye models were introduced with the aim of introducing IRD theories for the protection of print plans and maps.

Printing takes place with spot dyes for each layer separately. Layers of similar tones are merged into a unique print form. All layers are interpreted in four-color printing. The black layer is interesting because it contains several types of information and color separation with different Z values. Preparation of the map takes place in separate layers. The layers fit into each other with lighter tones to darker ones at the top. By merging all layers, a complete map with all the information is obtained. Twin dyes integrate two spectrums, visual and infrared, and are used to create a dual state of the document for protection purposes. All layers of V and Z dyes in the mapping system by merging make a protected document printed by the conventional method. The color separations were made on the cards in two colors of the same tone and different compositions. The dual state is displayed - the map is visible in full and the isolated elements can be seen at 1000nm. For visual differentiation of the same two layers of tones of color, we use a Z camera. The use of two cameras, RGB and Z, is used to determine the origin of maps by completely separating the selected V and Z dyes in the twin color CMYKIR separation system. The procedure set out in this paper creates formulas by which we can create dyes for any visual color tone of the cartographic system. The color mixing recipe for the cartographic system includes printers and publishers. At the same time, a new method of dyeing has been set up, respecting the established state requirements. It emphasizes the gain of control by implementing infrared features with dyes for offset and digital printing. Color Blenders of the same visual state (L * a * b / RGB), different Z values, a special form of CMYKIR separation are set for spot colors and process colorants. The paper introduces and applies the dual state of Z separation to the cartographic system and the printing of spot dyes by placing color information in a dual state. The method of making topographic maps with the introduction of a safety infrared press extends. Spectral color analysis was extended to a near infrared spectrum.

The system of twin dyes is used to mark and extract certain information inside the map. Cartography is rich in various details that are separated. The use also extends to adding additional graphic elements that are not part of the visual map, but additional information is visible in the infrared spectrum. Selected details are made in a twin color system using the surveillance camera visual area that can make additional distinctions that are not visible to the naked eye. The dual state of separation Z is applied to the cartographic system and the printing of spot dyes by placing the default colors in a dual state.

Maps are securities because with them ownership can be proved, the state of an area today, built elements, boundaries, and even establish and prove history. This speaks of the importance of protecting printed information on the produced maps. The era of digital manipulation requires a new dimension of map protection. The protection is present in the digital record and in the press resulting from the original document. The reproduction of such a dual-state document has two images, a map as a whole, and planned separate information from the Z layer. The dual state of Z separations on the document is displayed. New twin color twitter recipes and use for printing protected maps have been developed. The predetermined elements in the Z layer remain visible in the infrared spectrum at 1000 nm. Such protected maps can not be copied or scanned without loss of the Z component. The importance of cartographic data and digital printing is to protect the work of authors in all the processes of graphic preparation and printing. It is possible to check the originality of documents using twin dye dual infrared and visual properties. It ensures the originality of the document and protects copyrights.

Every publisher, printer, map user, determines their level of involvement in the safety infrared component. Such a map can not be changed, ie; forged. The infrared dye property disappears in the attempt to capture, scan, or any other reproduction technology. The visual state of the topographic map with infrared colors is the map without the IRD extension. This procedure doesn't hurt the artistic part of the map.

3.5 **Results of the questionnaire**

The survey reveals the problem of lack of security features, not only on maps but on other graphic products. The importance of studying new technologies and color and printing capabilities in product design has been noted.

The questionnaire was filled by 72 respondents, all of whom have high qualifications. Respondents are between 25 and 65 years of age and these are people who work actively in the field of design, printing technology, cartography, law, economics. The first question asked was whether they know the methods of protection of the document, 64% said they knew it, 9% did not know, and 27% answered that they were not sure. On the second question about the degree of protection of documents and copyrighted works, about half of the respondents, 46% answered that the degree of protection was unsatisfactory. The results of the first two questions from the survey questionnaire show that most respondents are familiar with protection methods but consider their degree unsatisfactory. It is shown that respondents recognize the importance of applying protective features. People who are not in daily contact with government documents or authorships are unsure whether I would recognize their protection and whether the existing level is satisfactory.

According to the majority perception, 73% of respondents believe that the most commonly falsified product is money. Such an opinion was to be expected because all respondents were in touch with banknotes. Therefore, it is not surprising that in the same proportion of 9% of respondents it is considered that the most common crimes are cadastral plans, 9% maps and 9% design works.

When questions of the aforementioned devices make it easier to counterfeit, respondents have argued that they are considered as computers and copiers, and in a slightly smaller number scanners, and only 7% think it is a photo camera.

The following questions related to the personal experience of the respondent with a forged document. Surprisingly, the answer is that after most people think that they are most likely to counterfeit money, to the question of whether you've ever suspected a forger, 38% answered that they suspected a counterfeit design product. 23% of respondents never doubted the forgery personally, while in the same percentage of 8% they received the document, plan and securities. More than half of the respondents argued that they had personal problems with the forged document or work, in the case of proof of ownership, forged documentation, and the purchase of counterfeit designer clothing in equal proportions.

When asked about knowing the protection method after the most widely used watermarks and hologram protection methods, security dyes occupy the third place with 17%. The result shows that an increasing number of people are aware of the use and importance of dyes in security print.

The following questions concerned the protection of cartographic documents and design protection. 50% of respondents do not know if documents such as maps and plans are protected, but 73% believe that there are reasons why protection should be introduced in color cartography.

The results show that as many as 92% of the respondents believe there are reasons for introducing protection in the design. The examinees believe that design is the most effective protective element to create a complex design that is not easy to copy. Today's technology makes it easy to copy even complex motifs because most are not made manually, but computer-generated.

Finally, the respondents questioned what the job of the notary was and concluded that more than half considered that it was checking the originality of the documents until no one believed to issue copies of non-original documents.

The following questionnaire related to notaries and methods of document verification by experts. A survey of the role of notaries has shown that few of them use document authentication instruments, and that instrumental verification is not a rule in practice. Based on the knowledge and experience of the documents, they are visually inspected without any instruments and their ratings are authentic. There are even methods that a notary uses to test their doubts, which do not relate to authentication policies such as water and watermark to check whether it is original or printed. If there is any doubt as to the authenticity of a document, the notary shall refuse to certify or confirm, but the person requesting the certification is recorded with all the information and may be in charge of the law.

If a person does not bring the original but a copy, there is no copy of the copy. There is a possibility of verification of the copy but it is stated that the copy is verified. The notary public is authorized to confirm that the transcript, ie, a copy of any document agrees with its original, that is, with a certified copy or a certified copy of the original document. Each confirmation specifies details of whether the document is damaged or if there are any visual items that have been modified, inserted or deleted.

There are different deadlines for the storage of documents, most of them in paper form and from 3 to more than 7 years stored in archives. It is concluded that the development of technology and new advanced methods of counterfeiting requires additional authenticity checks using the equipment and the protection that is safe and easy to perceive and recognize.

The survey has allowed new demands for the protection of all types of printers. The conducted research has shown the importance of introducing a new security system that protects documents, maps and designs and design products throughout all phases of production. Through a conversation with public notaries, a common problem has been discovered in detecting a person's identity, especially when the photo on a personal document does not resemble a person standing in front of a public notary.

3.6 The system of double images in the layered prepress of maps and plans

The application of a new safety print through twin dye is shown through a six-color coloring system. Process printing colors are only displayed when all six spot colors are joined. On such a record CMYKIR graphic preparation of merging two information, visual and infrared, is applied. Before the process print, we can observe channels that show a decrease in process coverage due to the Z image, which is intended for the infrared spectrum. Layers by topographic colors are suitable for editing and printing with spot colors. It is an original record from which different maps, parts of maps and preparation for CMYKIR separation are merged.

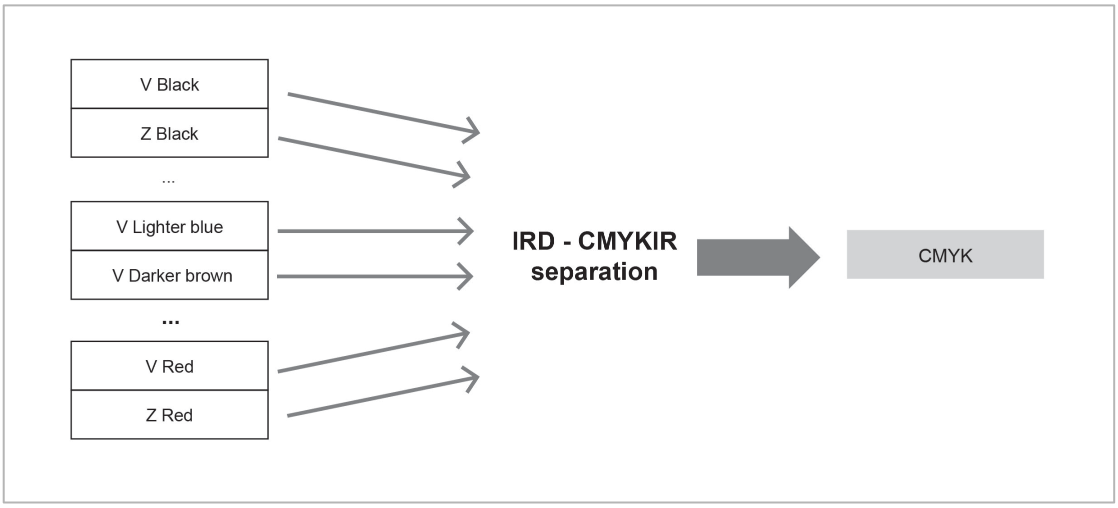


Figure 61. Process of CMYKIR separation in infrared mapping

The first degree of individualisation is the determination of Z values for the use of dual dyes. It is suggested that this number is maximized to get all the stronger infrared effect visible with the ZGRB camera. Each color can be assigned a maximum of Z. Such a case can be used for offset printing. Different solutions are possible for digital printing because digital printing has its own limitations. In offset printing, two parameters are introduced: color transparency and color order. The black color is usually not transparent, making it difficult for the choice of print order. The important element is the order of coverage. In six different colors, from which the brightest color of sepia, which determines the height of the terrain, is the last one made. In contrast, the dark blue color that marks the depth of the sea has to be made after the water surface of the sea so that the light blue color does not cover the depth information. The last color is black because it carries the names of cities and other important information. In offset printing this element is not important because the colors are transparent.

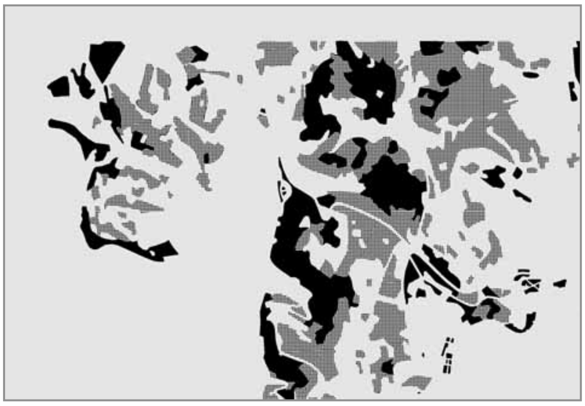


Figure 62. Light green; gardens and green surfaces

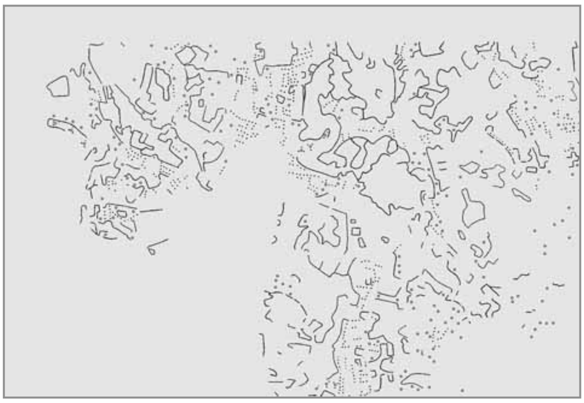


Figure 63. Dark green; fences

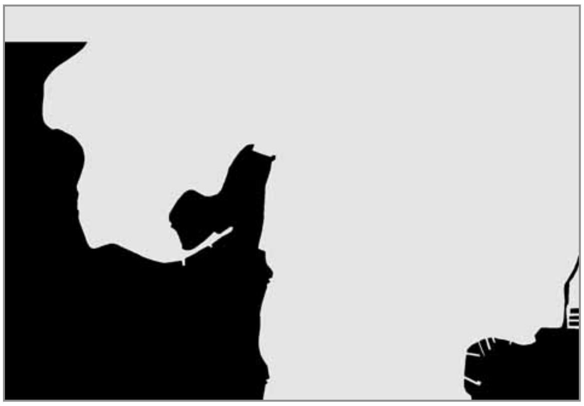


Figure 64. Light blue; sea and coast

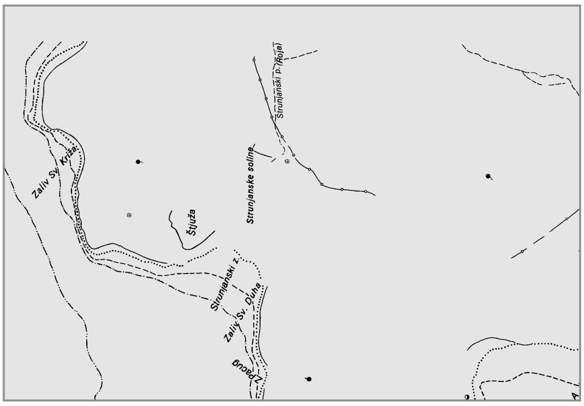


Figure 65. Dark blue; rivers and sea depths

Figure 66. Sephia; terrain hights

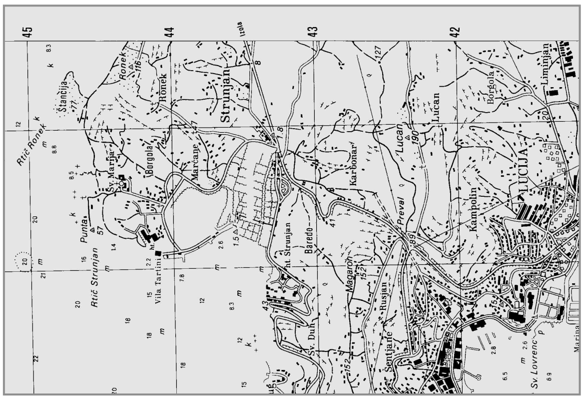


Figure 67. Black; houses, names, roads

Because of the positioning of the parts of the image itself, the print with black is the first. No other offset color will cover the black color. This discussion highlights a great deal of difference in the preparation of digital printing, off-print and digital printing. Although both preparations start from the spot channel, each layer is associated with visibility. The pictures are prepared for the visual spectrum. Connecting the prepared image with the other layers will give a security topographic map that carries the information for the ZRGB camera.

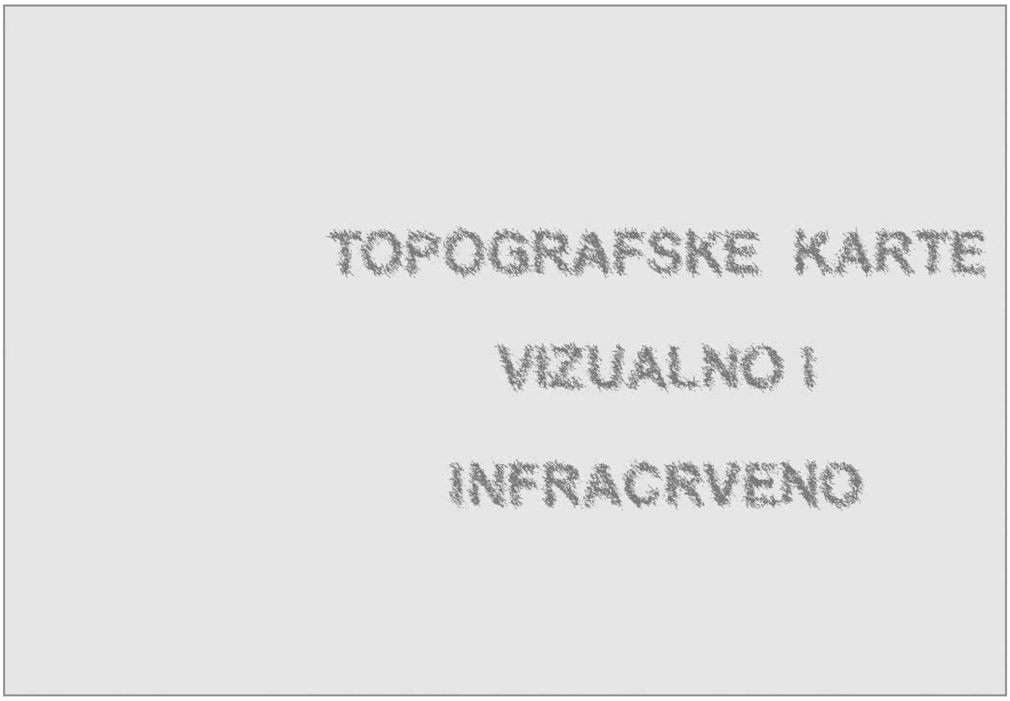


Figure 68. Planned hidden text rasterised with needle raster, Z image at 1000nm

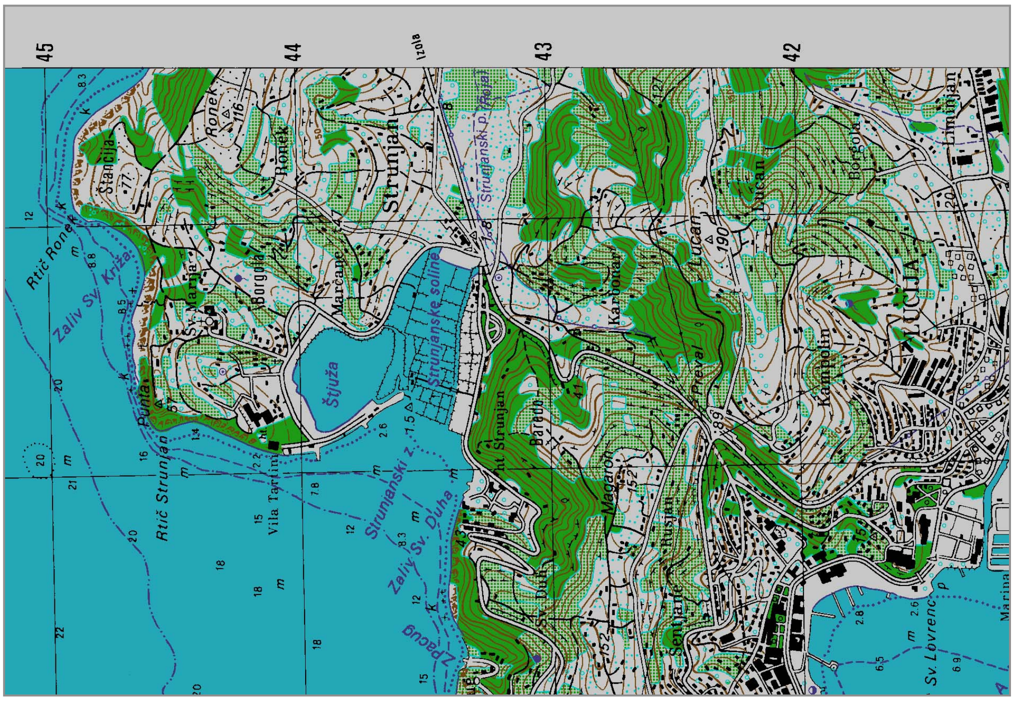


Figure 69. Map in print, made with CMYKIR connection of V and Z image

The barrier scanning of the imprint was carried out by subtracting the process color components. The last scene shows IR absorption at 1000 nm. The absorption remains only on the Z color, or the K channel as the carrier of the Z information.

Figure 70. Scanned maps with barriers at: 570, 715 and 1000 nm

Figure 71. Default Z imageand realized Z image at 1000 nm

The input Z image (Figure 71) differs and the realized image Z, which will be seen on the Z camera of 1000 nm. These deviations are expected since the topographic map has low-coverage colors, up to white surfaces. Excerpt from the input and output Z image "TOPOGRAF" is shown in Figure 70. Infrared graphics are reduced. It depends on the topographic map itself and where the Z graphics are located.

3.7 **Design and production of protective Graphics**

Experimental work has shown that it is more difficult to hide another IR image if it is in the image in which we hide little color. Therefore, cartographic graphic products are complex for performance because they contain a small number of colors with which all information should be integrated. Very few colors available make the mapping area interesting for the production of precise recipes of twin dyes.

In the printing of cartographic information, each color marks another element on the map. Black denotes built objects, paths and names of places, brown indicates the height of the terrain, blue the water surface, dark blue the names of the water, light green various covers and vegetation, dark green the border of the green areas. In memory, all layers are black, and color information of a single layer comes from RGB values as the basis for CMYKIR separation. By combining all layers, a full color image is created.

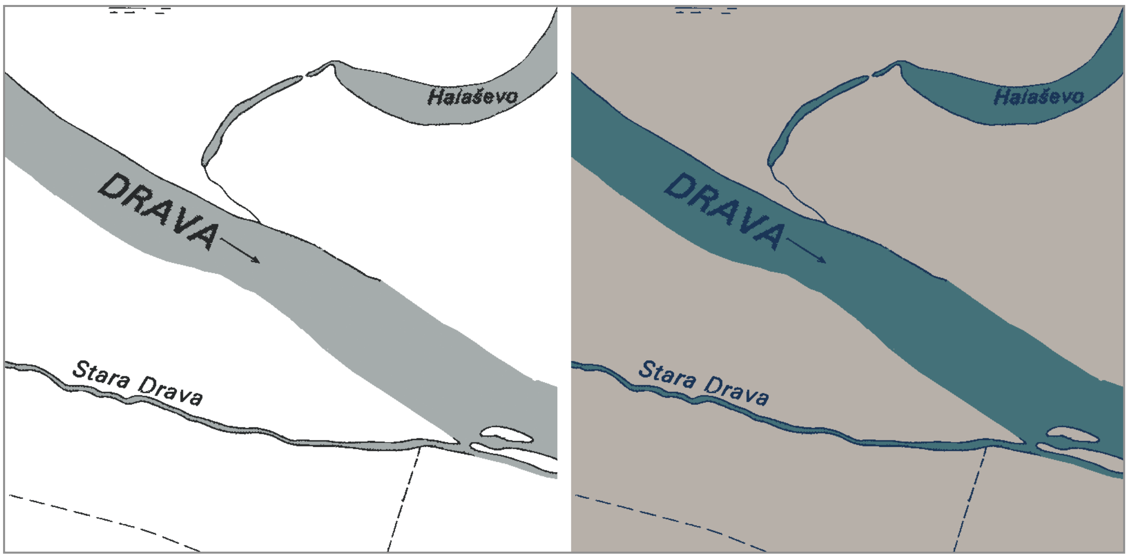


Figure 72. Blue layer in the computer memory and in print

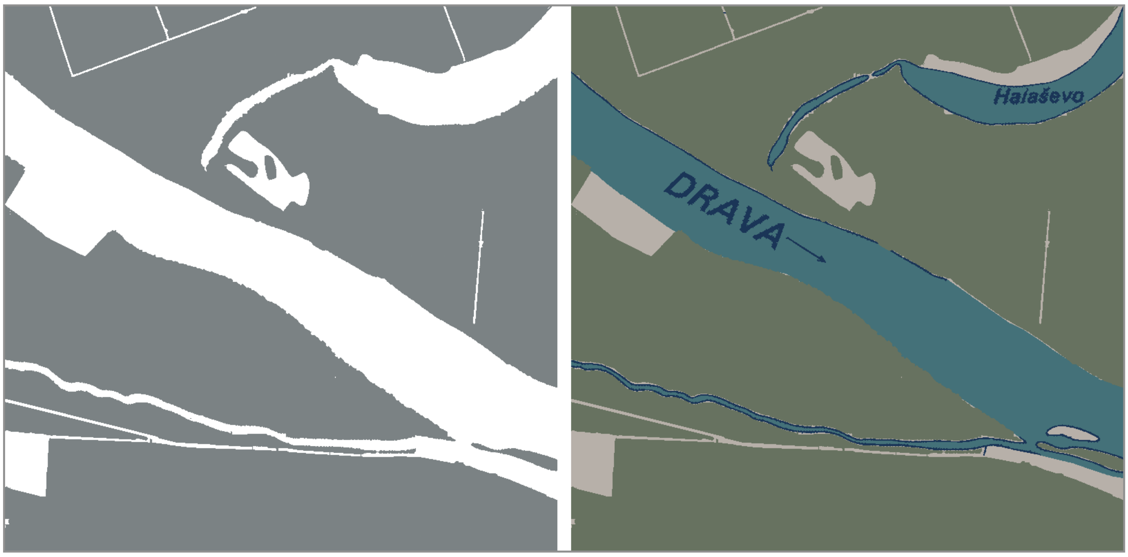


Figure 73. Lighter green layer in the computer memory and in print

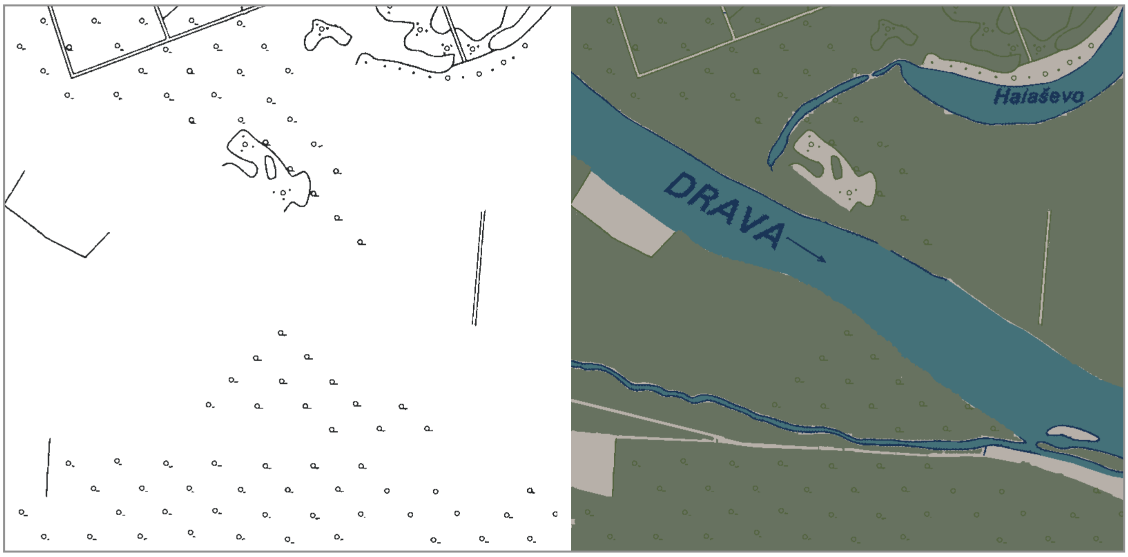


Figure 74. Darker green layer in the computer memory and in print

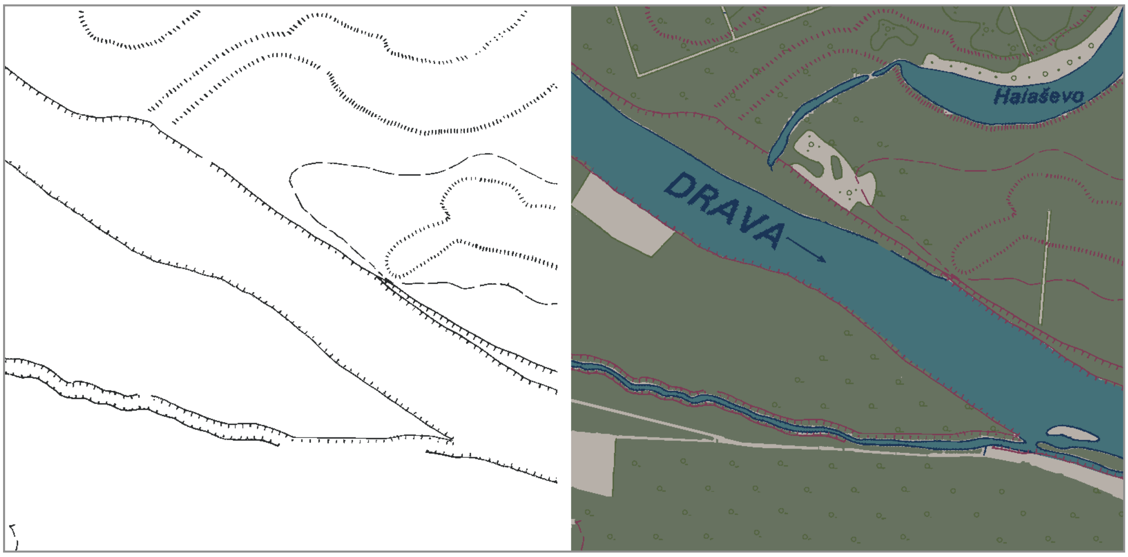


Figure 75. Red layer in the computer memory and in print

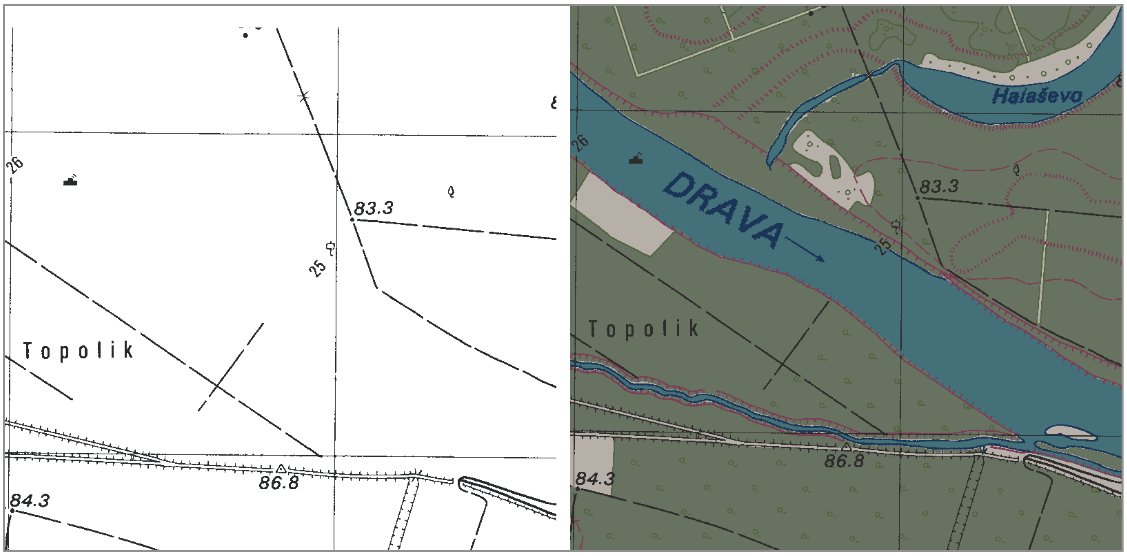


Figure 76. Black layer in the computer memory and in print

In the cartographic field there is a standard, limited number of colors used to mark all details. Much of the information on the map serves as a medium for adding additional hidden information. IRD would help a lot because the information can not be hidden when there is no color on the print.

In this paper, the maps have been modified for the purpose of the experiment. The original document contains white areas that do not contain color information and can not add hidden graphics. Experimentally, on the original document of the map, three different levels of color picking of white surfaces and, at the same time, all other color tones were made to hide the information. Color tones on double-hidden maps are subtracted to the gradient of 20%, 30%, and 40%.

0% 20% 30% 40%

Figure 77. Original map and color tones raised to 20%, 30% and 40%

Increasing the darkness of the tones results in the loss of purity of the lighter tones of color. The tampering also affects the clarity and intensity of the IR display that is detected by the NIR camera. On the map with tones raised to 20%, the purity of lighter tones of color is not significantly compressed, and the possibility of hiding IR images and lighter tones is openned. The visibility limit of hidden information was tested at three levels, setting different map texts to 20%, 30%, and 40% of tones. The double IR images are made for SWOP color settings.

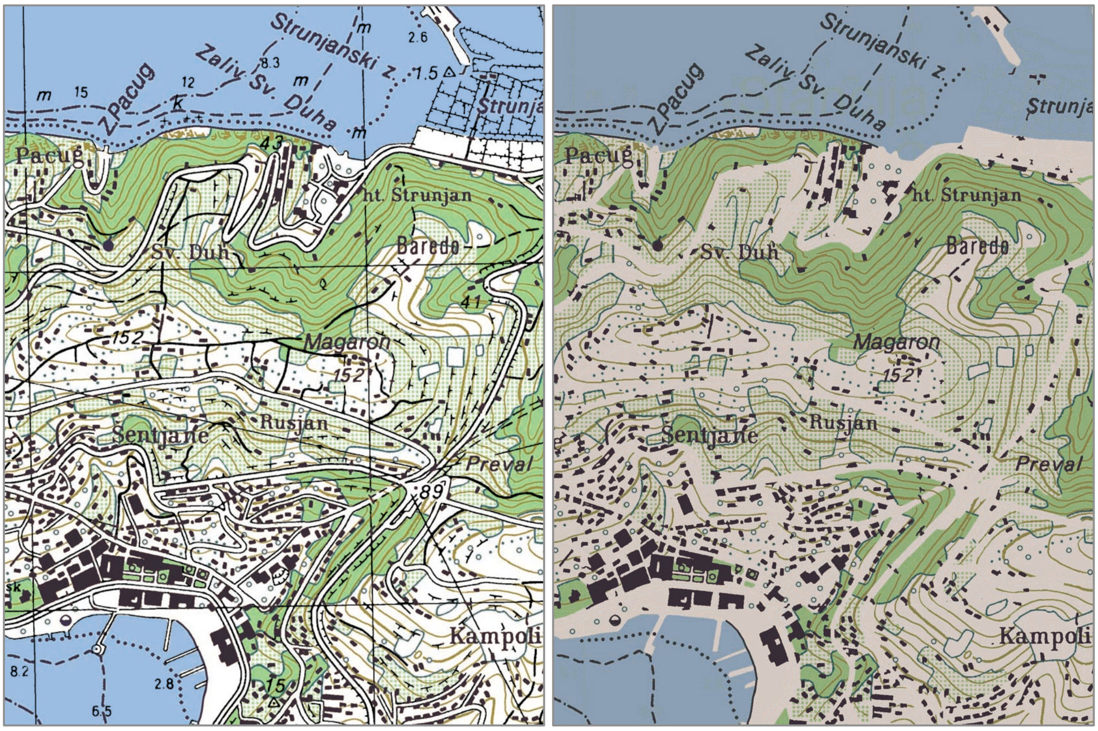


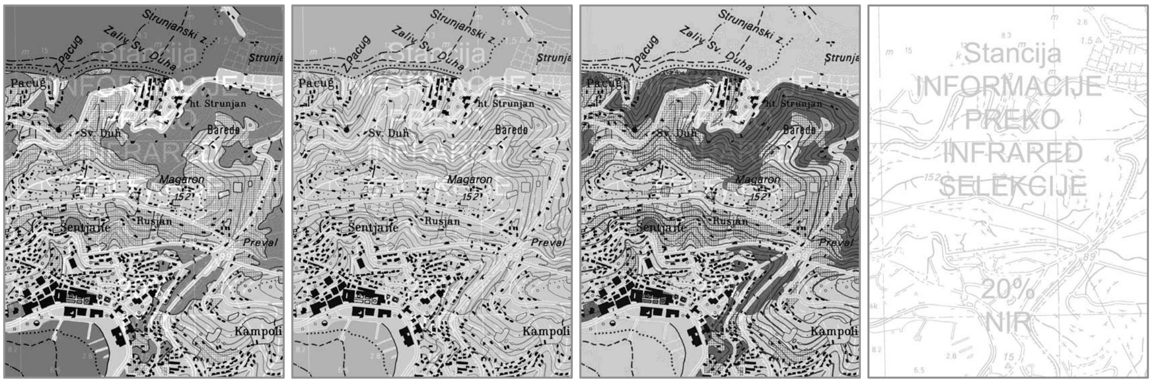
Figure 78. Original map and color tones raised to 20%

Table 18. Color tones raised 20%

Raised 20%	X0	X40	RGB
blue	54 30 21 0	41 17 8 20	133 155 176
green	49 21 63 0	37 4 56 20	138 170 113
sephia	50 50 80 0	38 39 72 20	137 123 64
green (line elements)	91 62 69 0	85 50 59 20	21 81 80
black	96 95 94 0	90 88 80 20	31 4 31
gray	20 20 20 0	1 8 8 20	211 199 192

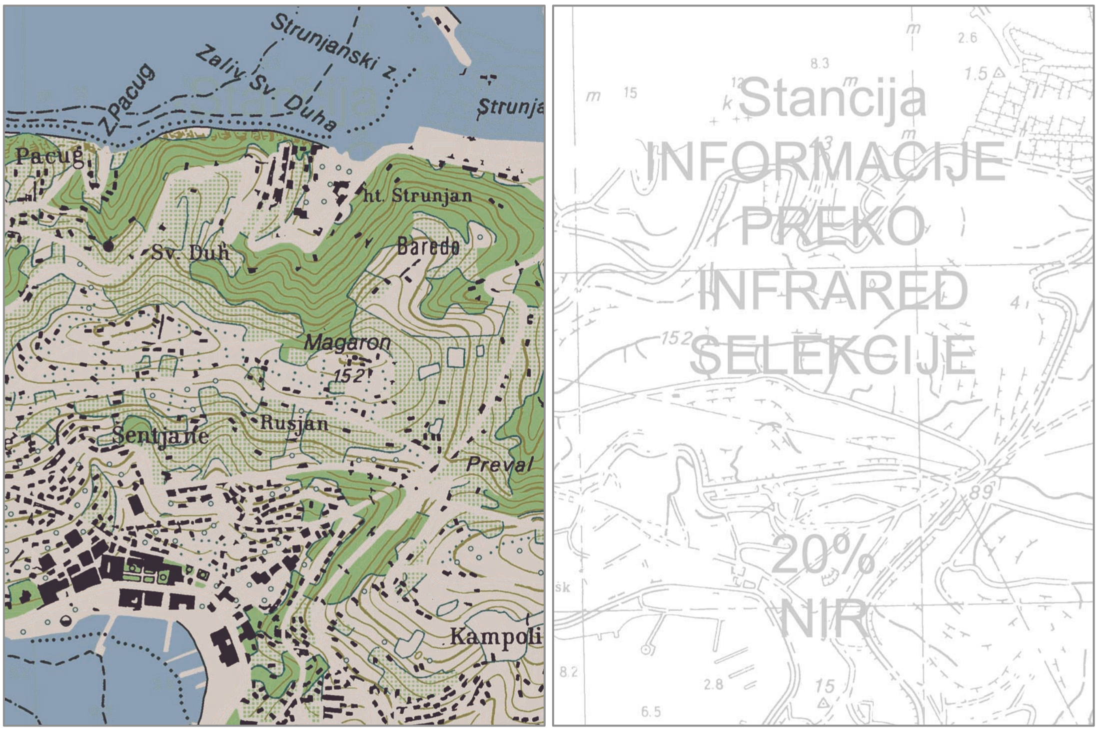
The minimum clear visibility of the hidden Z information was achieved at 20% of the color tones, as the lower limit of the NIR camera usage. Hiding is difficult because of the brightness of the tones, and the response to the NIR spectrum is minimal but visible.

Input information was set within the K channel through the CMYKIR separation of control in the two spectrums. Placed text is only visible in closed infrared spectrum.



C M Y K

Figure 79. Map at 20% , CMYKIR separation with set hidden information



V map (20%) Z map

Figure 80. Map in V spectrum on 20% raised color tones andin NIR Z spectrum

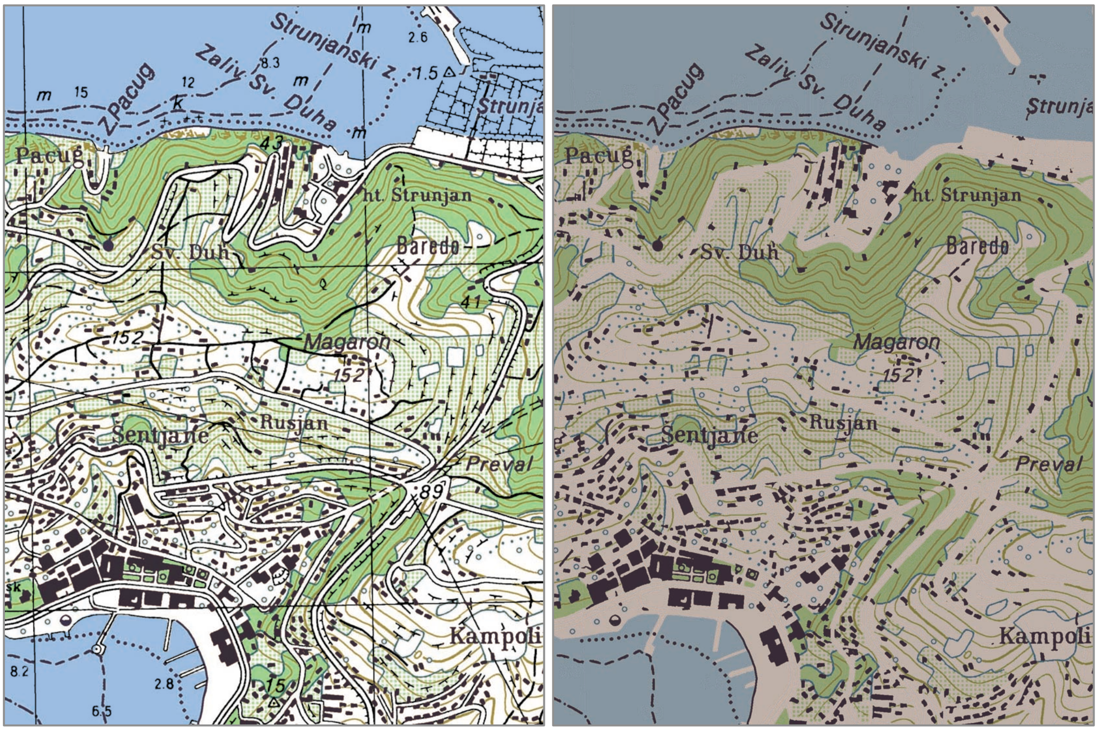


Figure 81. Original map and color tones raised to 30%

Table 19. Color tones raised 30%

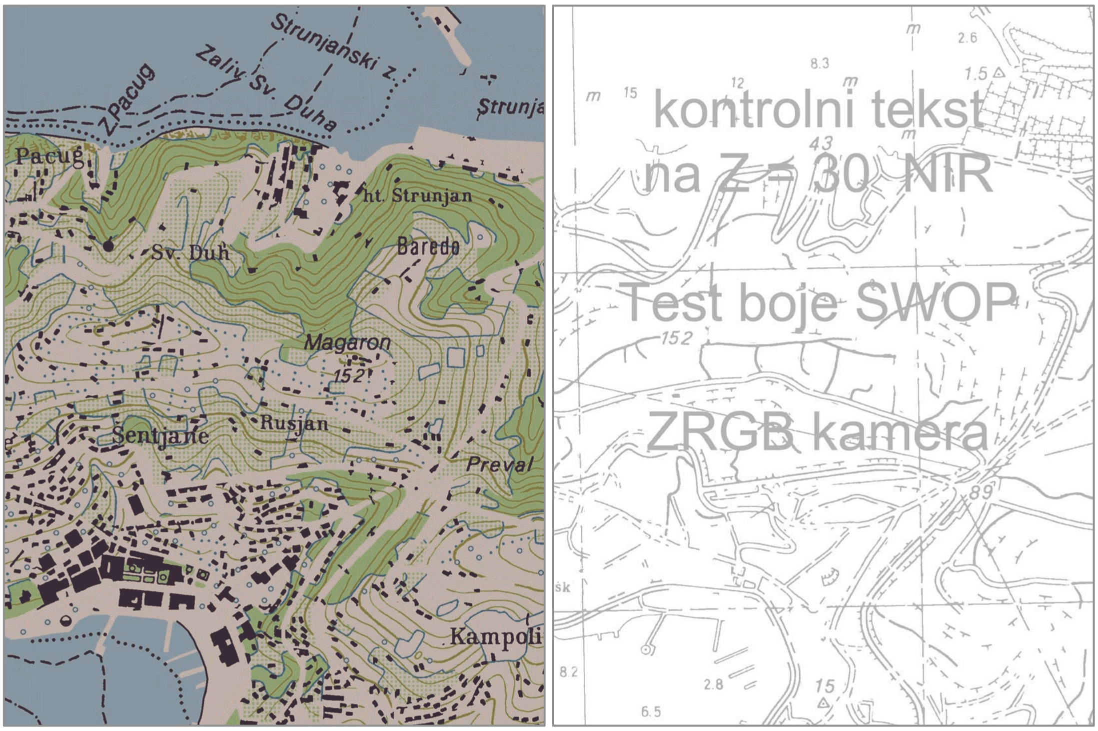
Raised 30%	X0	X40	RGB
blue	55 35 30 0	37 16 12 30	127 142 154
green	50 30 64 0	32 7 52 30	135 153 104
sephia	53 54 86 0	33 38 74 30	128 112 49
green (line elements)	88 60 50 0	77 43 45 30	38 83 90
black	95 96 93 0	86 87 73 30	32 0 31
gray	30 30 30 0	3 13 12 30	186 171 162

The visibility intensity of hidden information in the NIR spectrum increases with hiding within darker tones. At 30% of the color tones, a clear departure from the original document is clearly visible. Proportionally is increased the visibility of hidden information in the IR spectrum using the NIR camera.

Information in the K channel of raised color tones at 30% is more noticeable with the use of NIR camera compared to the map of raised color tones at 20%.

C M Y K

Figure 82. Map at 30% , CMYKIR separation with set hidden information



V map (30%) Z map

Figure 83. Map in V spectrum on 30% raised color tones and in NIR Z spectrum

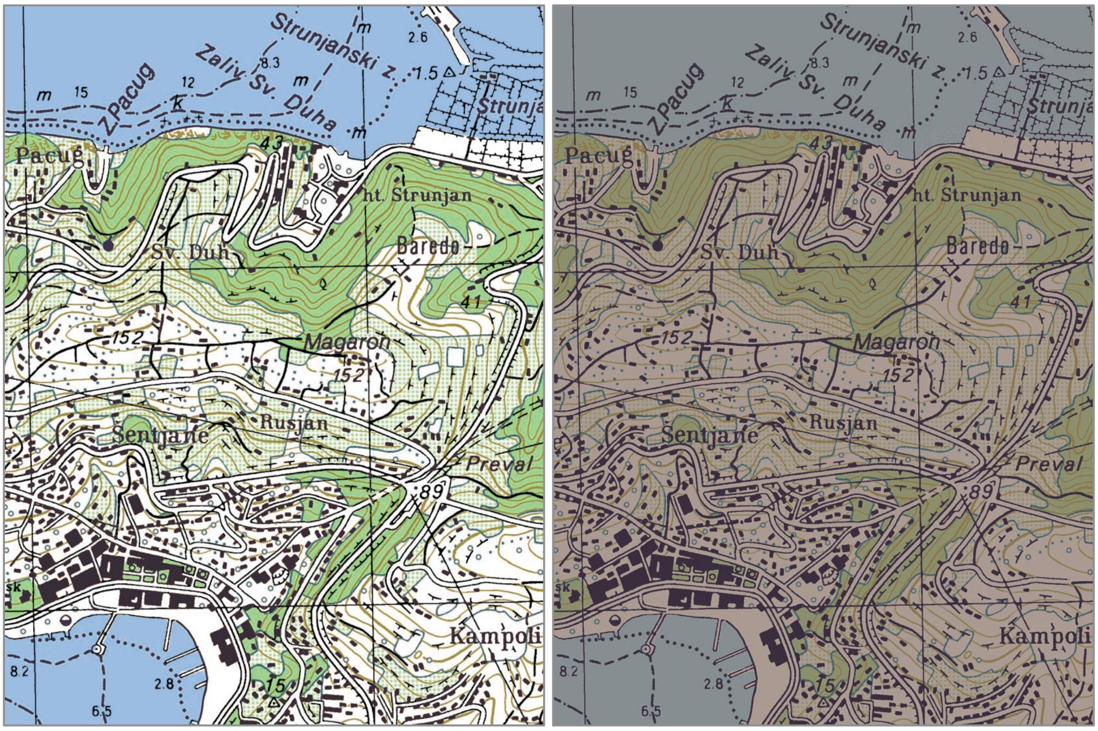


Figure 84. Original map and color tones raised to 40%

Table 20. Color tones raised 40%

Raised 40%	X0	X40	RGB
blue	56 40 38 0	27 11 12 40	128 136 140
green	52 40 63 0	22 10 43 40	134 138 101
sephia	50 56 77 0	18 32 58 40	138 113 66
green (line elements)	87 61 62	70 32 39 40	43 85 90
black	94 94 85 0	78 77 56 40	38 7 42
gray	40 40 40 0	0 14 13 40	167 150 141

Increasing the color tones to 40% gives the optimal visibility of the Z picture, but the deviation from the original map is visible to the naked eye. The visibility of information in the V spectrum is reduced and the visibility of information in the Z spectrum is increased.

C M Y K

Figure 85. Map at 40% , CMYKIR separation with set hidden information

V map (40%) Z map

Figure 86. Map in V spectrum on 40% raised color tones and in NIR Z spectrum

3.8 Design and implementation of dye twins in infrared mapping

The design of the IRD method is a new task set before designers and technologists. We live in an increasingly complex world where there are more and more complex and layered information. This method is a completely new way of designing and new designing tools. Connecting two contents, V and Z, is the special theme which opens for designers. The designed garment is printed in double vision. In the visual spectrum it shows a map of the city of Osijek, where the designer was born. The appearance of the original map has not changed substantially. White background is built on a light gray to better hide the details in Z figure.

The usage of infrared cameras reveals the content that is associated with the visual image but has a different artistic expression. While the map in the NIR spectrum disappears, typographical can be observed the children's song lyrics «Zeko i potočić». Not only is the song memory of childhood in Osijek from the designer herself, but the author of lyrics is also from Osijek. The possibility of multi-layer connectivity of information to work together without disturbing each other artisticly opens a new area for designers.

Twin dyes allow making IRD solutions to a variety of materials such as in the dissertation proven on paper and cotton textile. For each material it is necessary to create new recipes for twin dyes with corresponding colors. The fabric will not be dyed by colors for printing on paper, but will operate in a new way. In hiding text in double figure we want to be similary implemented in the entire territory of the infrared spectrum. Task of similarity is to entail that all spectrums end the Z point in the same default coverage. In this paper it is set Z = 40%. The first stage of individualization of infrared graphics is determining Z values to use dual dyes. It is proposed that the number maximizes, determining maximum with each color, for much stronger infrared effect. Such an approach is particularly desirable for offset printing where the parameters are introduced for sequence printing dyes and transparent colors. Black dye restricts story structure, the order of the press as the only dye that is generally not transparent. In digital print are implemented transformations in $CMYKIR^{DT}$ process dyes. To determine the position in the image and characteristic black color, printing black color layer is first. Connecting the two images shown in the cartographic graphics by using a small number of colors must mark a large number of information.

Figure 87. Clothing iten designed with double imaging in the V and NIR spectrum

Figure 88. Clothing item designed with double imaging in the V and NIR spectrum

The map shows the map of the city of Osijek with all the elements of water areas, green spaces, constructed buildings. For a double image in digital printing is set algorithm CMYKIR^{DT} separation. Single tone color is associated with a continuous space replacing CMY and K channel that enables separation. Two independent images, map and typographical message, merge algorithms of computer graphics. The motif of the visible image in the original specification had a white background, but raised the value of the gray background tone for optimizing the infrared effect. The design is subordinated to the possibilities of technology that determine the minimum amount of tones within which can be accommodated hidden graphics. The correction of the color tone of the original background of the city plan does not change the skin strong visibility. Black channel contains a different, hidden, information from the rest of the graphics. The typographic message is placed in carbon black K channel which becomes the carrier of information.

The designer is the carrier of a task that has the ability to create visual information that meet the set requirements and the hidden level to contribute. New task in the design of dual graphics is hiding typography within the visible image and having a sufficient readability in the IR spectrum. Infrared features create an information system within the augmented reality. Information shall be marked, stand out and hide in the infrared spectrum, and visible image is saved. Some channels double images displayed would postpone the lack of information from the K channels through the remaining C, M, Y channels.

Figure 89. Infrared map graphic on textile– all channels of CMYKIR^{DT} separation

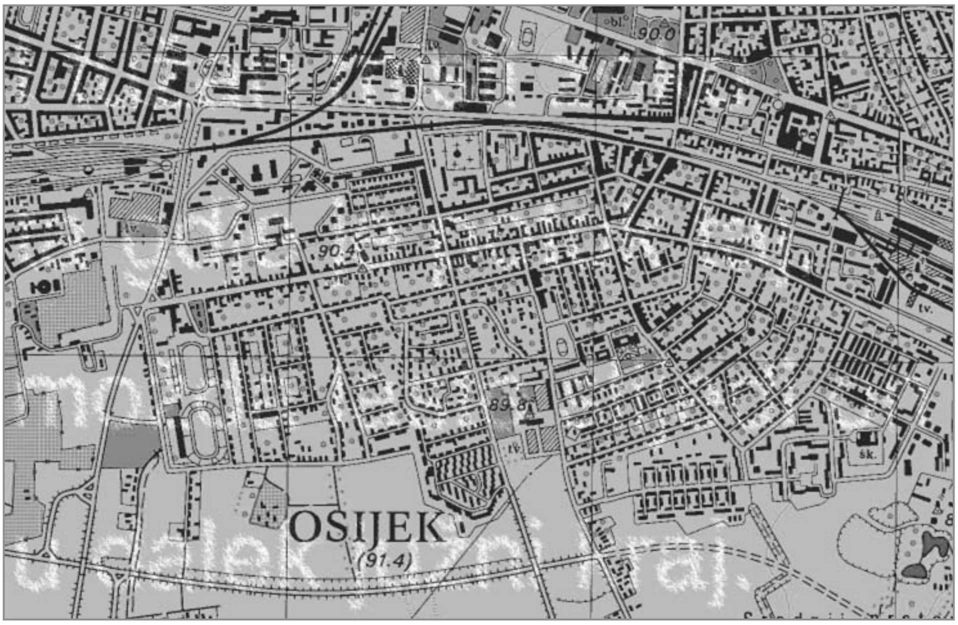


Figure 90. Cyan channel - Infrared map graphic on textile

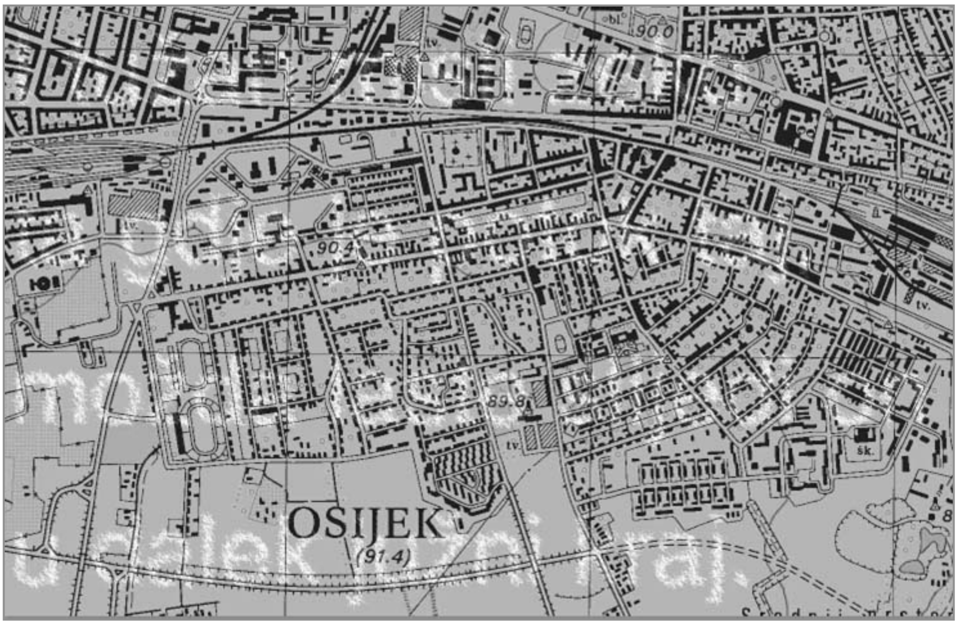


Figure 91. Magenta channel - Infrared map graphic on textile

Figure 92. Yellow channel - Infrared map graphic on textile

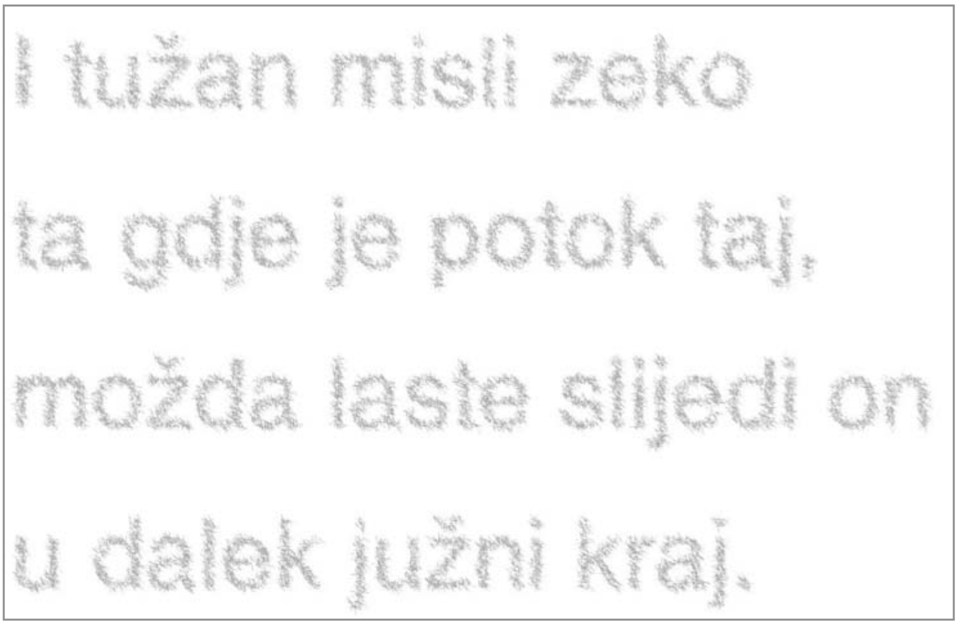
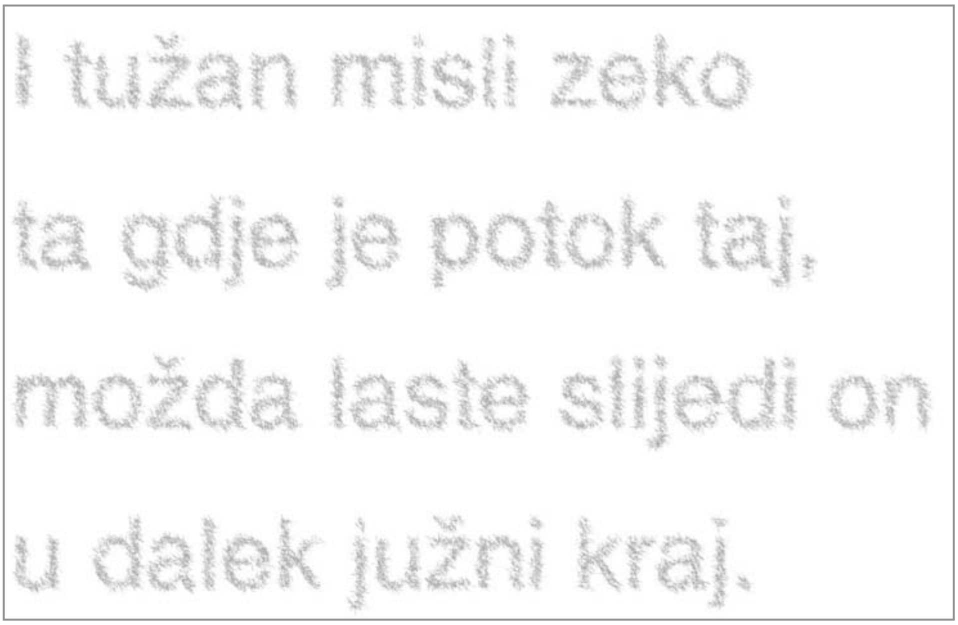


Figure 93. Black channel - Infrared map graphic on textile

V spectrum

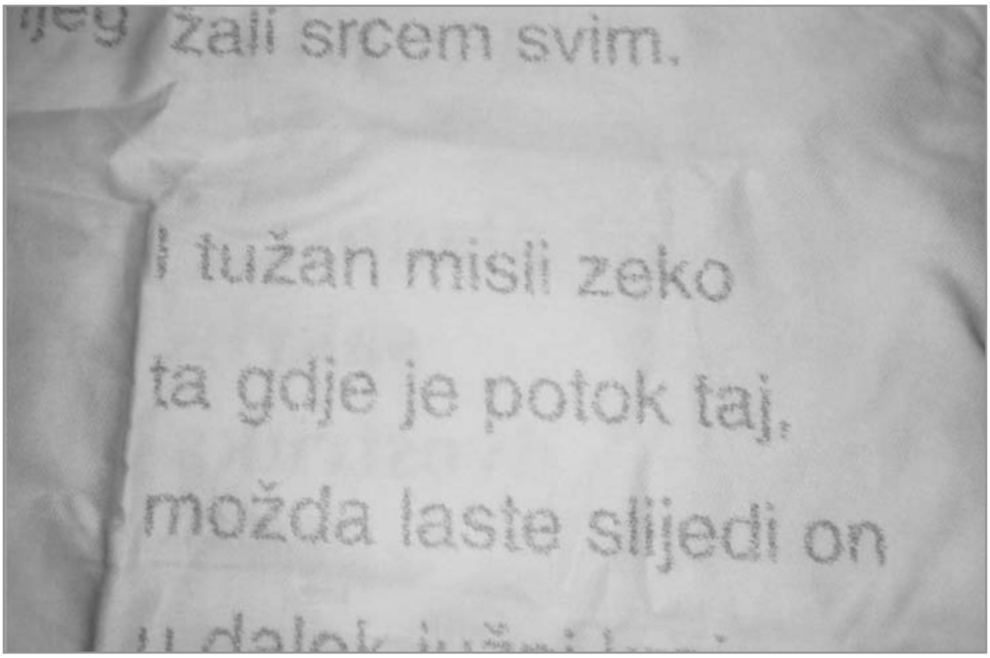


Z spectrum

Figure 94. Map with all connected layer (V)and Z layer of the CMYK^{ID} separation -Infrared map graphic on textile

V spectrum

Figure 95. Infrared map graphic on textile,visual display of carbon channel C, M, Y – K

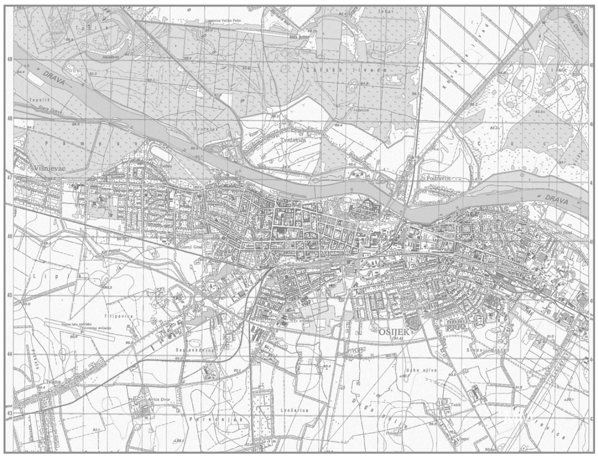


Z spectrum

Figure96. Infrared map graphic on textile, IR display of carbon channel K = Z

The design of double images creates dependence on motives in the visual V spectrum and near the infrared Z spectrum. Cartographic motives are formed through twin colorants in both spectrums, depending on the desired effect and type of use. Plans and maps are used to mark the road and determine locations that give the designer protection reasons through two spectrums. Infrared security printing has a widespread use, and the design presented uses planning capabilities through twin dye properties. The reasons for the hiding are shown in the paper through several suggestions: design of clothing and textile printing, integration of naturally photographed photographs and plans with cartographic motives.

A naturally captured photo visible in the V spectrum and a spatial plan concealed in a close infrared spectrum. The new method allows the integration of hidden map information within a seemingly pleasant visual that is with the content unrelated to the map. The map is hidden behind naturally captured graphics and it is revealed with the use of the IR camera.

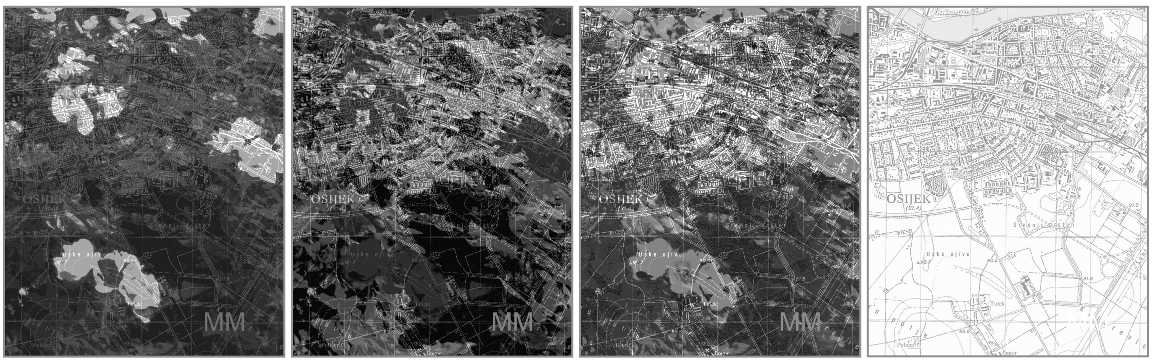


V Z

Figure 97. Photograph with flower motive RGB + Z hidden map information

A segment of the double image is enhanced showing the part of the photograph with flower motive and the signature of the author. On the visual photograph there is no indication that it hides information of a map showing built objects and roads and the name of the place shown on the map.

Figure 98. A segment of the photograph in RGB + Z hidden part of the map



C M Y K

Figure 99. CMYKIR separation with the planned map in the K channel

The same map of Osijek was used in the experiment (Figure 87. – 96.) with the map in the V visual spectrum and in the experiment (Figure 97. – 99) in which the map is hidden in the Z spectrum showing posibilities of the usage of infrared cartography.

4 DISCUSSION OF THE RESEARCH RESULTS

The map is the basis for the design through the IRD method and the creation of twin dyes. Graphics based on cartography serve as a new area of study of IRD twin dye technology. The dye colors can also be applied in classical cartography. Pressure security is an old topic but with brand new innovations through IRD for documents with graphical preparation in layers. The color layers are arranged separately and are stacked one on another. Dark blue on to light blue, dark green on lighter green layers etc. By merging all layers into a single document, a complete map with all the information is obtained. Much of the map information serves as a medium for adding additional hidden information.

The system of layers is subject to change of information for particular layers which require digital protection applied by duplicating the document for a twin dye layer. The twin dyes have the same visual value (L*a*b* / RGB), and different Z values. The multitude of information in cartographic documents offers a great space for manipulating information. In cartographic elements, two cameras, RGB and Z are used to determine the originality of the document. The full separation of V and Z colorants in the CMYKIR separation system is enabled by using two cameras. A new recipe for mixing twin colors has been set up, including printers and publishers. The new system emphasizes the gain of document control through the implementation of infrared features with inks for offset and digital printing. Protection is achieved at all phases from graphic preparation to print, via digital records that remain in archives. With the CMYKIR separation technology and the use of twin dyes, an original type of digital map security has been introduced. A new feature of dying twin color printing was developed. Twin dyes that integrate two spectrums - visual and infrared, create a dual state of the document. The protection was achieved by using a twin dye made for the selected layer of paint. The double layer number is applied to the dye in preparation for the separation printing information. All layers are merged into the press and make a protected document. Everything is printed using a conventional method. The dual state of Z separations is shown on the map. The new print has infrared characteristics. Such maps can not be photocopied or scanned without losing the infrared component. Copyright protects the originality of the document. The document is protected by its content and purpose. This also depends on the level of protection. The paper provides a systematic application of protective elements on maps and plans with a clearly defined method of protection through dyes.

Protective printing is carried out with special twin dyes that are made prior to printing. It is possible to position hidden visual information in any part of the print job. Multicolored solutions are made for recipes for each printing technique and printing form. The possibility of content linking of two images V and Z is unlimited. Equal elements can appear in both visual states, ie none of the elements may be the same. Using the IR camera through the color twin system can be distinguished between details and individual elements. Without widening the information in the visual spectrum, separating the visibility in the two spectrums can separate one information from the other. By extending the V color layers with the same number of Z color layers, the possibility of separating whole areas of a cartographic document that contains elements of not only one information but the whole area with vegetation, water surfaces, heights, and built-up elements opens up.

The importance of cartographic information lies in the ability to prove real estate ownership, construction status, ownership of green areas, boundaries, sources of drinking water and copyright protection in all printing and storage processes of documents. Creating complex multilayer documents is a requirement and a set of jobs that gained extra degree of protection by using twin dyes. Modern technology and digital printing make it difficult to identify original copyright documents. Digital protection is achieved through the color twin system that remains in the channels written. The author's information can be placed in an extra space that is not visible to the naked eye. Hidden information does not interfere with the visual.

The map serves as a design element, on materials that are no longer a cartographic paper, but paper and textile. New technology can be used as a motivation for design. For this, colors had to overcome as twin dyes. Field plans are artisticly interesting because of the content of a large number of viewers, as these are not artwork reserved for art lovers. Motives are interesting because of roads, land owned by landowners, which is more interesting to people than viewing artwork while they do not expect something inside the map to hide. The expanded media is richer with duplicate images. Two images of V and NIR may have several interconnected links. Depending on the content they can be joined or separated. Stylish design with concealment elements inside the garment case serves as an exemplary release in the design sense of the artwork in an innovative way. Double image design using dual color infrared cartography is a compromise between the V and Z images. It depends on whether a higher degree of protection is required or, more importantly, that the V image remains unchanged.

5 CONCLUSION

This paper presents dye recipe for the infrared technology for the protection of graphic products. Twin color systems have been expanded to two spectral areas.

It was concluded that there was a need for security protection for products which previously had no security features through the new security dye system. Security in cartography is an innovation in graphics technology. For printing large prints and for test digital printing, new processes for creating multi-color twin dyes based on the InfrareDesign theory have been created. The extension of IRD theory is manifested in defining the process of making protective twin dyes of the same visual color tone and different responses in the infrared spectrum for spot and process dyes. In offset printing, spot dyes are mixed manually before printing, while in digital printing spot dyes are simulated with process colors. The first part of the experimental work defined the principle of twin dyes for offset printing. The new way of mixing offset dyes with twin dyes is the extension of the printing technology. The paper sets a system for creating twin dyes for digital printing through the new CMYKIRDT separation model. The model was applied in a trial press to achieve the same safety features as in big edition print. The Z values determined whether the reproduction would have a response to the NIR spectrum. The visibility of graphics in infrared printing is set for all Z twin pairs at Z = 25, and for V twin Z = 0. The experiments confirmed the hypothesis that mixing the twin dye gives equal solutions to the V and Z twin tones in experimental printing and offset printing of large edition prints. The paper deals with color mixing and recipe for offset and digital printing. The developed twin color system through infrared technology creates a unique protection method and opens up space for additional information in the expanded space. Two-spectrum twin dyes are tools for creating additional information within the graphics. By introducing color twin with the same response in visual and different infrared spectrum, new protection in the infrared information system was set up. For set dyes, the calculated spectrograms determine the degree of absorption of light in the infrared area. Based on the experiments and researches conducted, it is concluded that the two-spectrum dyes are a tool to create additional information within documents. Newly defined twin dyes enable the targeted shaping of security elements. Graphic elements are placed in visual and infrared spectrum without disturbing the look of the original and the graphic reproduction with spot and process colorants.

A specific area is the securing of plans and cartographic documents that have set color tones for the visual spectrum. The new method defines the design of infrared graphics in specific graphical preparation in layers. It ensures the protection of the phased process in the design and printing of maps and plans essential for use in tourism, construction, military actions, etc. By using dual infrared dye and visual properties, the authenticity of documents and printed information has been verified. It introduces and extends the Infraredesign theory to cartographic documents. Infrared cartography is an innovation that defines the protective printing of state documents with important cartographic information such as the position of the objects, the height of the terrain, the depth of the sea. Their protection is primarily used to prove originality and to protect the rights of the author. In this dissertation, the extension of the security printing theme to a new set of documents is given. Innovation and improvement of design methods through infrared technology has been achieved. With infrared graphics, the stability of the desired tone on all maps is ensured, for larger areas of colors such as water colors, forests, meadows. The new system provides an individualized level of involvement of the security infrared component within certain topographic information.

Infrared graphics in the cartographic system make a new area of protection for all owners in the process of document creation. Introduced are methods of breaking spot color, then methods of merging two images using $CMYKIR^{DT}$ separation depending on what kind of results are wanted and what kind of technology is at disposal. A twin-protected map can not be forged, ie its authenticity is determined by IR security printing. The new method ensures the protection of maps and plans at all stages of use.

The infrared graphics technology has a new role in color matching for large projects. Any deviation in the color tones of twin dyes $\Delta E > 3$ in the print results in the visibility of the Z graphics which need to be concealed. Infrared protection is retracted to all parts of the printing process and serves as a check for the correct color mixing.

Infrared cartography is an improvement in methods of design. Multiple layer planning is a new task. The designer of the future expands his skills in shaping double visual information. He learns about new technology that uses classic printing. Together with the graphic technologist he prepares protective graphics. Ideal solutions will have two separate visuals that may or may not have to be linked to the content. The picture in the V spectrum and the image in the Z spectrum are linked to the dyes in the press. The content is determined by agreement with the customer or by the designer himself. A visual and infrared state of the art is planned. Information in the infrared spectrum is in the background and can be seen if the observer knows what to look for. It does not disturb the first image visible to the naked eye. An additional image emphasizes the detail of the first visual image or sets up completely new information. The twin dye system creates a new design area for designers. Two visual information are separated only by double V and Z cameras. They operate in two spectral areas that are sufficiently distant from one another to see each image clearly. Two images together enable you to determine the originality of the designed graphic product. Any unauthorized duplication or copying will result in a dual IR design.

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7 BIOGRAPHY WITH PUBLISHED WORK

Maja Matas was born on May 1, 1986 in Osijek where she graduated from the Natural Science Mathematics Gymnasium. She completed graduate study in the field of Industrial Design in 2010 at the Faculty of Architecture - School of Design, University of Zagreb. In the same year she enrolled in the postgraduate study in Graphic Engineering and Design at the Faculty of Graphic Arts, University of Zagreb. She has experience working in a design studio and an advertising agency. The internationally renowned designer is currently working as the Head of Corporate Identity department in a corporation and is a frequent member of professional design juries. As a lecturer in the field of design, she teaches courses in the field of graphic design at the Academy of Arts, University of Osijek. Her area of scientific interest includes security print, protective dyes and design within the expanded visual reality, and she is the author of the following scientific papers:

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